Enabling Knowledge Communication between Companies

– the role of integration mechanisms in product development collaborations

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EFI THE ECONOMIC RESEARCH INSTITUTE

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Preface

This doctoral thesis was written at the Centre for Innovation and Operations Management at EFI, the Economic Research Institute at the Stockholm School of Economics.

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As usual, the author has been entirely free to conduct and present his research in his own ways as an expression of his own ideas.

Stockholm in November, 2008

Filip Wijkström	Christer Karlsson
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To my wife Ulrica

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A thesis project is like an expedition. It is challenging because the path is unknown, the workload is heavy and only you can get the job done. Still, most of all, it has been great fun, inspiring and I have learned a lot more than I ever could imagine.

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Stockholm in October, 2008

Mattias Axelson

Contents

1 Introduction

THIS IS A BOOK ABOUT HOW COMPANIES ORGANISE FOR ENABLING OF KNOWLEDGE COMMUNICATION IN PRODUCT DEVELOPMENT COLLABORATIONS. This is an important issue since many companies' product development increasingly takes place within networks of alliance partners, suppliers and consultants (Karlsson, 2003). Consequently, large shares of critical knowledge resources and major development activities are located outside companies. One major challenge facing product development in collaborations is the local and tacit nature of knowledge (Inkpen and Dinur, 1998; Simonin, 2004). It means a major complication regarding how to communicate knowledge with partner companies.

When I first began the journey with this thesis, I did not know this would be the issue addressed. However, it occurred to me that understanding one another's product technology and product development knowledge is one major challenge facing companies in product development collaborations. For example, several managers I met expressed frustration over not being able to make the partner understand e.g. their points of views regarding how to conduct product tests, how to evaluate product quality and how to organise documentation routines. It was often difficult e.g. to understand one another's product design ideas, system interface specifications and component material preferences. Hence, it was not sufficient and often not possible to realise intended knowledge transfer between one another. It became apparent that in order to realise product development in collaboration, it was necessary to communicate knowledge about both organisational processes and product technology between companies' R&D organisations. Consequently, it was a major issue to company managers how to enable knowledge communication.

Literature on product development supports this observation. For example, Dooley and O'Sullivan (2007) argued that one major challenge to distributed product development is to exchange knowledge between organisations. According to Tatikonda and Stock (2003), this kind of organisation creates new communication challenges compared to product development located within the company. How knowledge communication is realisable is important to learn since product development collaboration is a phenomenon increasing in magnitude (e.g. Hagedoorn and van Kranenburg, 2003).

Knowledge communication is used in this study as a term for how companies collaborating in product development share knowledge about product technology and development processes. The important role of communication for product development has been discussed by e.g. Tushman and Katz (1980) and Clark and Fujimoto (1991). It is for example emphasised that intensive and rich communication between functional units is important for effective product development (Brown and Eisenhardt, 1995).

The issue of how companies enable knowledge communication in product development collaboration has received little attention in existing research. Literature on knowledge transfer across organisational boundaries, however, provides us with some indications. It suggests that companies create organisational interfaces in order to transfer knowledge between organisations (e.g. Gupta and Govindarajan, 2000). For instance, companies move people, and create special boundary-spanning roles and co-ordination groups in order to enable knowledge transfer (e.g. Maidique and Hayes, 1984; Inkpen, 1996; Almeida et al., 2005). In the literature, 'integration mechanism' is a common term for these different types of organisational interfaces (e.g. Galbraith, 1973). Singh (2007) shows that the use of integration mechanisms enhances access to globally dispersed knowledge in research and development. One reason is that integration mechanisms, by creating conditions for interaction between people from different organisations, enable what here is called knowledge communication (e.g. Tushman and Katz, 1980; Sicotte and Langley, 2000).

The discussion here indicates two issues of importance, which are the points of departure for the present study. First, that enabling knowledge communication is an issue of strategic importance to many companies. Second, that it is an issue of relevance to the research field on the management of product development. Therefore, there is a need for a study of integration mechanisms' enabling of knowledge communication.

This chapter introduces the thesis, its background, central terms and relationship to existing research. In order to guide the reader, the following outline may be of some help.

- ➜ First, the discussion addresses industrial trends driving the increase of product development collaboration.
- ➜ Second, this part discusses knowledge communication in product development collaboration and develops a definition for this study.
- ➜ Third, this chapter introduces integration mechanisms as managerial tools enabling knowledge communication between companies.
- ➜ Fourth, it discusses how this study can add complementary knowledge.
- ➜ Finally, the purpose is presented, the unit of analysis is defined and the general outline of the book is introduced.

1.1 Industrial trends driving product development collaboration

Research clearly indicates that product development collaboration is increasingly becoming a central part of many companies' strategies (Dyer and Singh, 1998; Hagedoorn, 2002). The driver consists of competitive forces that make it necessary for the individual company to search for access to the best possible knowledge within its industrial network (Karlsson, 1992). According to literature, in order to gain competitive advantage, companies must continuously create, transfer and exploit knowledge that is globally distributed (Bartlett and Ghoshal, 1990; Doz et al., 2001).

Because of this development, large manufacturing companies, OEMs[1], are currently extending the geographical and organisational distribution of product development operations. One major implication of this development is, as Karlsson (2003) argued, that as much as 70–80% of R&D for OEM products takes place in the manufacturer's industrial network of partners, suppliers and consultants.

Consider, for example, the defence industry in Europe. Today, development of major defence systems mainly takes place within consortia networks and alliances. For example, a network of e.g. British, French, German and Swedish companies develops the Meteor missile. The trend is similar within the automotive industry. The new Volvo V70 and the new Ford Mondeo, for instance, may look different but they share much technology. They are the results of collaboration within the Ford group. In other industries, such as pharmaceuticals, major companies like AstraZeneca increasingly collaborate with biotech companies in order to enhance development speed and improve chances of launching major breakthrough drugs.

Certainly, product development between companies is not a new phenomenon. However, the increase is currently challenging the traditional view of product development as organised within the company's R&D organisation. Instead, a new image of distributed innovation networks emerges. The literature on innovation management has conceptualised this change under labels such as open innovation and industrial networks (Chesbrough, 2003; Karlsson, 2003). To many companies, distributed product development is a new situation, with new challenges and limited knowledge about how to manage operations across organisational boundaries. Knowledge concerning effective organising of product development within the individual company's R&D organisation provides insufficient guidance (Karlsson, 2003).

On a general level, competitive forces that make it necessary to reduce costs and shorten development time, and at the same time enhance innovativeness, drive the increase in product development collaboration (e.g. Shepherd and Ahmed, 2000). Improved productivity in competing companies' development processes drives the increase of cost pressure (Tessarolo, 2007). Companies rush to commercialise new products in order to stay ahead of competitors, although speed without organisational

1 OEM is an acronym for Original Equipment Manufacturer. Examples are manufacturers of trucks, aeroplanes and mobile telephones

and technical foundations will not lead to improved performance (Meyer and Utterback, 1995). Because of the time race, there is reduced time to technical obsolescence and product life cycles become shorter. At the same time, customers demand more technological content, variation and sophistication. One example is the increasingly advanced entertainment technology in modern cars. Therefore, in order to remain competitive, companies strive to enhance performance and improve design of new products (Shepherd and Ahmed, 2000). In order to manage these challenges, many companies engage in product development collaboration (Chen and Li, 1999).

One major reason underlying the increase in product development collaborations is the individual company's need to acquire and access knowledge resources from external actors (Grant and Baden-Fuller, 2004; Awazu, 2006). Several studies have viewed collaboration as a quest for resources (Eisenhardt and Schoonhoven, 1996; Gulati, 1999). According to research by e.g. von Hippel (1988), a company's potentially relevant sources for innovation are not only residing within its internal organisation. The reason is that collaboration with other companies increases exposure to new and varied sources of ideas, technology and experience that may contribute to enhance innovation potential (Dyer and Singh, 1998). Research shows that capacity to combine internal and external knowledge enhances companies' innovation potential (e.g. Powell et al., 1996). Therefore, one generic strategic motive for product development collaboration is learning external knowledge (Almeida, 2005).

Another important underlying reason for the increase of product development collaboration is the opportunity to share development costs (e.g. Doz and Hamel, 1998). Related to the cost reduction strategy is development of common product platforms. The ambition is to share components and production processes across several different models (Lundbäck and Karlsson, 2005). One advantage is that it enables companies to enhance economies of scale in product development (Karlsson, 2003).

This discussion points at a dilemma. Large manufacturing companies must simultaneously develop new products faster, which means less time for return on investment, and enhance product performance, which drives costs. This means that cost motives and innovation motives may be equally important reasons why a company chooses to engage in product development collaboration. Thus, as Hagedoorn (2002) argued, companies can have multiple motives to engage in product development collaborations.

Not only companies' needs drive the increase of product development collaboration. This development would not have been possible without the recent advancements in information technology. For example, Karlsson (2003) argued that development of information technology is a key enabler of product development between dispersed organisations. One major reason is that the traditional trade-off between richness and reach in information transfer has largely vanished. This means reaching great numbers of individuals with large quantities of the same data at almost no cost (Evans and Wurster, 1997). Of course, the costs for developing e.g. blueprints and implementing information systems may be high. However, the costs for reproducing such knowledge are close to zero. For instance, as an effect of this development, blueprints can more easily be shared and with hardly any time delay among the members of geographically dispersed product development teams.

The current development that has been described here points at the emergence of two parallel trends that enforce the increase in product development collaboration. First, we have the intention to collaborate driven by the rationale of sharing costs and enhancing innovativeness. Then we have the technological development that enhances opportunities to organise product development between organisations geographically dispersed. These trends are important contextual drivers of product development collaboration as an instrument for competitive advantage. The following section will turn to an operations perspective and discuss knowledge communication as a means for realising competitive product development between companies.

1.2 The role of knowledge communication in product development collaboration

Knowledge is widely recognised as a key to competitive advantage of companies (e.g. Winter, 1987; Kogut and Zander, 1992; Grant and Baden-Fuller, 1995). This view reflects the notion that the economic value of many companies lies more in knowledge resources than in tangible assets such as land and raw material (e.g. Quinn, 1992). For instance, according to Teece (1998) the capacity to transfer, integrate and exploit knowledge resources enhances competitive advantage.

Access to new and varied sources of ideas and knowledge is according to Dyer and Singh (1998) associated with increased innovation potential. It follows the line of thought from Schumpeter (1934) who argued that innovations are combinations of existing knowledge. Hence, access to external knowledge is likely to increase a company's chances of finding unique knowledge combinations. That is why, for instance, Knudsen (2007) argued that access to complementary knowledge enhances product development performance. In this study, the view is taken that knowledge communication contributes to combination of knowledge resources, and thereby knowledge creation in product development.

This perspective follows e.g. Clark and Fujimoto (1991), Brown and Eisenhardt (1995), and Sheremata (2000) who argue that communication is an important process for product development realisation. The reason is that complex problem-solving requires a free flow of ideas and knowledge in order to enable new combinations of knowledge to emerge (e.g. Sheremata, 2000). For instance, Magnusson (2000) refers to knowledge creation as a process of search and experimentation, which can be seen as a process of recombination. Obviously, it can be accomplished within the head of an individual, but on the organisational level, it requires communication of knowledge.

Following this literature, the perspective taken is to view knowledge communication between companies as important for realising product development in collaboration. Therefore, the following will elaborate how this study defines the term 'knowledge communication'.

1.2.1 What is knowledge communication?

The discussion here concerns the meaning of the term knowledge communication in the present study. First, the discussion addresses the major reasons for choosing this term – for an extended discussion see section 2.4.3. Second, the discussion focuses how this study defines the term knowledge communication.

To begin with, the term knowledge communication is seen as related, but not equivalent, to the more commonly used terms knowledge transfer and exchange (e.g. Kogut and Zander, 1992; Dyer and Nobeoka, 2000). There are two major reasons for the choice of knowledge communication instead of transfer or exchange. First, in my view the term knowledge transfer, as well as exchange, does not indicate clearly enough how knowledge, in particular tacit knowledge, is transferred or exchanged between companies (e.g. Simonin, 2004). Therefore, the term knowledge communication is a complement to these more traditional terms, since it focuses on the activities enabling transfer and exchange to take place. This perspective finds support in research by Murray and Peyrefitte (2007) who explored how different communication media facilitate knowledge transfer. Second, through the empirical studies it became apparent to me that the practical issues in product development collaboration are not transfer or exchange. Instead, the main concern was to accomplish communication between people regarding the product technology and the development process. Hence, knowledge communication is a more practically relevant term, whose use is justified in order to understand the product development collaborations studied. (Chapter 2.3.3.1 further develops the relevance of the term knowledge communication.) The following discussion develops this study's definition of the term knowledge communication.

The term knowledge communication largely builds on the concept of dialogue as a process for transferring knowledge between organisational levels (e.g. Hedlund, 1994). According to Hedlund (1994), the term 'dialogue' concerns distribution of knowledge between individuals and different organisational levels. According to this view, dialogue is a form of communication that enables actors in organisations to transfer both tacit and explicit knowledge. Explicit knowledge can directly be expressed through spoken or written words. Tacit knowledge is much more difficult to express. Nevertheless, the view here is that it is possible for the individual to communicate tacit knowledge for instance by using examples, metaphors and demonstrations, in combination with time for the receiver to reflect on the message (Nonaka and Takeuchi, 1995). Thereby, dialogue means interaction that enables sharing of both explicit and tacit knowledge between individuals and organisational levels. What is the reason for not using the term 'knowledge dialogue', instead of knowledge communication?

According to Encyclopaedia Britannica (1974), the term dialogue refers to conversation between two or more individuals. Conversation in turn refers to discussion between no more than a few individuals (Nationalencyklopedin, 1993). This definition makes the term dialogue insufficient for this study. The reason is that other forms of communication also need to be considered – such as e-mail, written documents and physical artefacts. These forms of communication also enable sharing of knowledge – in explicit form. They can also reach larger numbers of people than dialogue does. That is, dialogue is not the only relevant way to share knowledge in collaborations between companies. Indeed, explicit knowledge expressed in e.g. artefacts plays a central role in product development. Much dialogue in product development revolves around interpreting such knowledge. At the same time, in order to focus dialogues, explicit knowledge expressed in e.g. documents and artefacts plays an important role. It can also function as a support for dialogues, by expressing complementary knowledge. Thereby, the view taken here is that knowledge communication is a broader term including both dialogues and communication of e.g. documents and artefacts.

This study assumes that knowledge communication enables sharing of both tacit and explicit knowledge between individuals, organisational levels, and companies. The underlying view is that knowledge communication is a way for individuals in organisations to share and thereby make common what they know, to other individuals in their own organisation or in others.

It is important to clarify that this study sees the individual as the communicator of knowledge. The underlying reason is the notion of knowledge as inseparable from humans (Nonaka and Takeuchi, 1995). That is, even though knowledge is explicit, it requires human activity to express and to interpret the knowledge. This study also takes the perspective on knowledge communication as enabled, and at the same time constrained, by the specific organisational context (Spender, 1996). Hereby, organisational structures such as hierarchic positions, physical locations, and dominant management logics are factors potentially influencing the individual's knowledge communication.

Based on the above discussion, this study chooses the following definition of knowledge communication:

➜ Activity that people undertake in order to share knowledge resources such as product technology and development-process knowledge.

This definition expresses the view of knowledge communicated as a valuable resource to the companies participating in the collaboration. Following Barney (1991), the value of knowledge resources is due to their uniqueness, difficulty of imitation, and value to customers or partners. This study proclaims that communication of such knowledge resources can be motivated from two perspectives. First, if the company sees potential to achieve future value by sharing its knowledge with a partner company. Second, if the company sees potential to achieve future value through access to the partner's knowledge. Thus, knowledge communication does not concern just any knowledge, but knowledge of strategic value for the single company. Section 2.3.3.2 further elaborates the specific scope of knowledge communication addressed by this study – product technology on different system levels and development-process knowledge.

In brief, the kind of knowledge communication in focus for this study takes place between people belonging to different companies. It revolves around knowledge concerning product technology developed and the development knowledge used for accomplishing that task. It has the purpose of contributing to realisation of product development collaboration between companies.

The discussion here has concerned the choice of the term knowledge communication and its definition. It has been emphasised that it is a term complementing knowledge transfer and exchange. The distinction between knowledge communication and knowledge transfer/exchange is important to keep in mind. One reason is that much literature related to this study is within the field of knowledge transfer research. This becomes apparent in the following discussion on knowledge communication challenges.

1.2.2 Knowledge communication challenges

The previous discussion has emphasised that knowledge communication is of strategic importance to companies. This section addresses challenges to knowledge communication that make product development collaboration difficult and often costly.

The literature on knowledge transfer commonly argues that how easily knowledge can be transferred between organisations is influenced by its degree of tacitness, ambiguity about its use, and its contextual embeddedness (e.g. Kogut and Zander, 1992; Szulanski, 1996; Simonin, 1999; Birkinshaw et al., 2002). These aspects of knowledge are important reasons why it is difficult to communicate between organisations.

The strategic management literature regards this characteristic of knowledge as a source of competitive advantage, at the company level (e.g. Reed and DeFillipi, 1990). Kogut and Zander (1992) argue that one reason why companies exist is their superior capacity to create and transfer knowledge, compared to market relationships. One reason for this perspective is the view that companies are social communities where shared knowledge and language facilitate efficient knowledge transfer. Such knowledge is difficult to transfer and not easily imitated by competitors (Zander and Kogut, 1995). Consequently, for product development collaboration between companies, tacit knowledge is a potential source of disadvantage, since it constrains companies' potential to learn and create knowledge together (Simonin, 2004). Thus, in order to enable knowledge communication in such collaboration, it is necessary to handle the tacit, ambiguous and context-specific nature of knowledge.

Nahapiet and Ghoshal (1998) argue that the level of social capital, e.g. shared social codes and language, influences the capacity to exchange knowledge. These factors are likely to be lacking when companies establish new product development collaboration. Organisational differences due to different language, product and process philosophies are obstacles to understanding one another (Dougherty, 1992; March and Stock, 2006). This typically contributes to frustration and gives rise to conflicts between the collaborating companies. One implication is the difficulty of communicating knowledge (Tushman and Katz, 1980; van de Wijk et al., 2008). In addition, as for example De Meyer (1991) and Orlikowski (2002) argue, communication in distributed R&D organisations is a major challenge. Geographical separation is a challenge because it constrains opportunities for face-to-face interaction. Hence, knowledge communication in product development collaboration is a challenge because of the combination of organisational differences and geographical separation (Gieskes et al., 2002). So how are these challenges to knowledge communication managed by companies?

The following section will introduce integration mechanisms as managerial tools, which function as organisational interfaces, enabling knowledge communication between companies.

1.3 Integration mechanisms as organisational interfaces enabling knowledge communication

This study assumes that companies use organisational interfaces as managerial means for knowledge communication in collaborations (e.g. Gupta and Govindarajan, 2000). The literature discusses organisational interfaces under different labels.

According to Stock and Tatikonda (2004), it is necessary to meet communication requirements with inter-organisational interaction. Nonaka and Takeuchi (1995) use the term 'fields of interaction' to describe organisational means for tacit knowledge-sharing. According to von Krogh et al. (2000) and Nonaka et al. (2006), it is important to create the right context for interaction that can enable communication of knowledge, and thereby learning and knowledge creation. Hamel (1991) uses 'collaborative membrane' as a metaphor for the kind of organisational interface structure enabling organisations to collaborate on knowledge-intensive activities, such as product development. Classical organisation theory calls this kind of interface an 'integration mechanism' (e.g. Galbraith, 1973). This study chooses to use the term integration mechanism for the organisational interfaces studied. The reason is that this term points at the role of such interfaces – to function as managerial means for linking differentiated organisations.

The following defines the concept of integration mechanisms. It discusses different views on integration mechanisms and develops a definition.

1.3.1 What constitutes integration mechanisms?

In organisation theory, Galbraith (1973) is recognised for having developed a framework of different integration mechanisms. Following Galbraith (1973), this study addresses integration mechanisms that have the role of creating inter-organisational interaction. This kind of integration mechanisms can be used in order to link people and activities in otherwise differentiated organisations (e.g. Lawrence and Lorsch, 1967; Nadler and Tushman, 1987). Building on this research, the present study assumes that integration mechanisms create conditions for the kinds of contacts and interactions that facilitate knowledge communication.

The literature discusses a wide spectrum of different types of integration mechanisms, with relevance for the issue of how companies enable knowledge communication. For example, Allen (1977) and Tushman (1977) showed that gatekeepers, or boundary-spanners as Ancona and Caldwell (1992) call them, have an important role to play in facilitating communication between organisations. Leenders and Wierenga (2002) mentioned movement of people as a way to increase interaction between organisations. Twigg (2002) argued that joint product and process teams are useful in order to transfer product designers' tacit knowledge to those working with manufacturing.

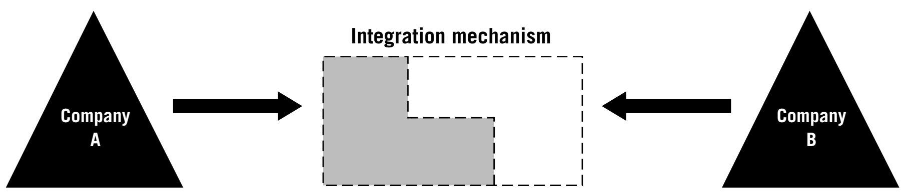

Figure 1: Illustration of INTEGRATION mechanisms as organisational interfaces

The figure here illustrates that integration mechanisms function as interfaces between companies. It proposes that integration mechanisms bring together and combine individuals and groups from collaborating companies.

This study takes the perspective that integration mechanisms consist of different organisational structures. The study addresses three different kinds of structures, elaborated in what follows.

The research by e.g. Galbraith focuses on integration mechanisms' formal structure. The formal structure of integration mechanisms concerns e.g. the official role of the integration mechanism, how people from different companies meet, who meets whom, and how many persons interact (e.g. Galbraith, 1973; Nadler and Tushman, 1987). One important aspect is that formal structures are tools that managers can design.

A complementary view is the concept of *"context"* (von Krogh et al., 2000). It refers to an arena for interaction, constituted by a combination of physical, virtual and mental spaces. It is a function for creation of knowledge through e.g. sharing of ideas and viewpoints on technology design (Nonaka et al. 2006).

The physical and virtual dimensions are related to the use, respectively, of e.g. co-located teams and information systems in order to handle geographical separation between organisations (e.g. Song et al., 2007). A term that captures both physical and virtual dimensions of integration mechanisms is 'location structure'. For instance, the constitution of one integration mechanism's location structure could be the team's office space. Hence, similarly to formal structures, managers can design the location structure of integration mechanisms.

In this study, mental spaces are referred to as cognitive structures. Examples of cognitive structures are perceptions of organisations' structures and activities, which according to e.g. Dougherty (1992) and Nahapiet and Ghoshal (1998) have a major impact on knowledge-sharing between organisations. Cognitive structures are difficult to design by managerial choice. The reason is that they are expressions of the experiences and organisational backgrounds of the people engaged in the integration mechanism. Nevertheless, this study assumes them to be one important dimension of integration mechanisms, with influence on knowledge communication.

In brief, building on Galbraith (1973) and von Krogh et al. (2000), integration mechanisms are here conceptualised as organisational interfaces constituted by formal, location and cognitive structures. The view here is that such integration mechanisms create interfaces for interaction between people, and thereby enable knowledge communication between companies.

A focus on integration mechanisms' structures is a limitation. This study does not include e.g. rewards, goals and plans. These examples of integration mechanisms have received attention from e.g. Galbraith (1973) and Griffin and Hauser (1996), and they are important means for accomplishing integration. They influence people's behaviour, such as motivation to collaborate across organisational boundaries. However, the choice to focus on integration mechanisms' structures is a practical limitation necessary in order to accomplish this study.

The discussion here has concerned how this study defines integration mechanisms. As previously mentioned, the study claims that integration mechanisms are managerial means enabling knowledge communication in product development collaboration. What, then, is known about the relationship between integration mechanisms and knowledge communication?

1.4 Integration mechanisms and knowledge communication

This section reviews existing literature in order to identify how the study can add complementary knowledge. The literature judged as related and relevant sheds light on integration mechanisms and knowledge communication. However, it is the content of the literature that is important, not that it necessarily uses exactly the same terms as this study. The specific kind of content sought concerns integration mechanism structures and communication of knowledge, between organisations.

The review of existing literature identifies three different lines of research that shed complementary light on this relationship – *the information-processing perspective*, *the global-local team perspective*, and *knowledge-transfer perspective*. These perspectives are the result of an effort by this study to categorise literature addressing integration mechanisms and knowledge communication. Hence, these three perspectives emerged through the mapping of literature.

The information-processing perspective focuses largely on the distribution capacity of different types of integration mechanisms' formal structures. The global-local perspective puts a focus on aspects of geographical separation's influence on communication. The knowledge-transfer literature is important because it focuses on both different types of integration mechanisms and aspects of knowledge flows between companies.

Much literature included in the review has an intra-organisational perspective, compared to this study, which has an inter-organisational perspective. This is a limitation in existing research, yet it contains important principles relevant for the study of integration mechanisms used between companies. For example, Galbraith (1973) gives attention to the capacity of different integration mechanisms for handling task complexity. One argument is that a liaison role can handle co-ordination between two organisations but, if complexity increases, a temporary team is suitable. These are principles expected to be relevant in collaborations between companies. Therefore, it is necessary also to consider the literature concerned with integration mechanisms within companies.

In what follows, literature is presented within the three lines of research identified. First, the information-processing perspective is reviewed, thereafter the global-local perspective, and finally relevant research on knowledge transfer. After the review, the discussion addresses how this study can complement existing research.

1.4.1 Information-processing perspective

The literature on integration mechanisms has to a large extent addressed different types of integration mechanisms and to some extent their information-processing capacity (e.g. Tushman, 1979; Daft and Lengel, 1986; Nadler and Tushman, 1987; Stock and Takikonda, 2004). The common view among these authors is that the level of task complexity which organisations face strongly influences the information-processing requirements on integration mechanisms (e.g. Nadler and Tushman, 1987; Sicotte and Langley, 2000). The principle is that the more complex and uncertain a task, the more communication is needed (e.g. Tushman, 1979; Nadler and Tushman, 1987).

As mentioned in section 1.3.1, the literature discusses several different types of integration mechanisms. Section 2.2.1 presents a more extended review of different types of integration mechanisms. For the discussion here, it can be mentioned that the literature identifies a spectrum of integration mechanisms. It ranges from managers who meet occasionally, and single persons temporarily transferred to work in a partner organisation, to large co-ordination groups created between organisations (Nadler and Tushman, 1987; Griffin and Hauser, 1996).

The information-processing research largely builds on communication theory (e.g. Daft and Lengel, 1984) and focuses on the capacity of different communication channels to transmit messages. There are major differences in information-processing capacity between the different types of integration mechanisms. According to Nadler and Tushman (1987), hierarchic integration mechanisms, between managers, have the lowest capacity, while e.g. teams that are more permanent have high capacity.

The integration mechanisms enabling high information-processing capacity contain e.g. larger numbers of people than those with low capacity. The reason is, according to this literature, that the handling of increasing information processing requires integration mechanisms enabling direct contacts between organisations – e.g. direct collaboration between several team members (Katz and Tushman, 1981). This is a principal insight expected to be relevant for how knowledge is communicated – at least explicit knowledge. Another important aspect of integration mechanisms discussed in the literature is its decision-making authority. According to Griffin and Hauser (1996), the capacity to make decisions is one critical integration-mechanism quality. In addition, the intensity of work interaction is regarded as important for the role and functionality of integration mechanisms (Nadler and Tushman, 1987).

Hence, the information-processing perspective gives important indications on the role of formal structures of integration mechanisms for knowledge communication. For instance, it points at the importance of the number of people engaged in cross-border interaction for communication. However, its focus is information and not knowledge. One major limitation of the information-processing perspective is that it ignores how differences in interpretation, due to different organisational contexts, influence communication (Tuomi, 1999). Related to that, it does not discuss aspects of communicating tacit knowledge. Hence, the information-processing perspective does not explain different integration mechanisms' enabling the communication of knowledge.

The reason for this limitation is that the literature on information-processing capacity largely has a bandwidth perspective – the more bandwidth, e.g. face-to-face contacts, the higher the information-processing capacity. As Carlile (2004) argued, it assumes that a shared lexicon is enough for enabling the sharing of knowledge. This is a reasonable assumption for routine communication where the collaborating parties share common knowledge and contextual understanding. However, it ignores challenges to knowledge communication, such as difference in tacit knowledge (Simonin, 2004). Furthermore, even though the literature on integration mechanisms recognises the role of physical barriers for information processing (Griffin and Hauser, 1996), it is little concerned with the implications of geographical distribution of activities (e.g. De Meyer, 1991). Hence, it does not explain how different types of integration mechanisms handle challenges to knowledge communication between different locations.

1.4.2 Global-local team perspective

Reflecting globalisation of companies' activities there is growing literature concerned with distributed product development operations (e.g. De Meyer, 1991; Orlikowski, 2002; Richtnér and Rognes, 2008). This line of research is related to studies on integration mechanisms and information processing. However, it is primarily concerned with the geographical aspects of product development operations. Of interest here is the literature addressing communication challenges in distributed product development teams (e.g. McDonough III et al., 2001; Subramaniam, 2006; Song et al., 2007).

One of the first authors to address the issue of global product development from an operations perspective was De Meyer (1991). The research showed that communication in global R&D is a major challenge to accomplish, since it constrains opportunities for face-to-face interaction. In recent years, two perspectives have come to dominate the literature on global development teams – those who argue it is possible to conduct effective global development and those who argue it is not. For example, McDonough III et al. (2001) see potential with distributed product development teams, but the empirical evidence, they claim, is limited. With limited empirical evidence, there is more rhetoric than reality behind the view that distributed product development is effective (Berggren, 2004). On the other hand, this does not necessarily mean that distributed development is inefficient or ineffective.

However, the support is strong in the literature for the view that distributed product development teams face major communication challenges (e.g. Richtnér and Rognes, 2008). For example, different time zones, travelling distances, organisational differences, and lack of trustful personal contacts constrain communication between team members located in different organisations (e.g. Dubrovski et al., 1991; Jarvenpaa, 1998). Lack of face-to-face interaction constrains the social messages communicated between people. This does not only mean that content may be lost in the distributed teams' communication; it also brings about more frustration and misunderstanding compared to face-to-face communication (Warkentin et al., 1997). In order to handle these effects, Song et al. (2007) argue that a combination of co-location and sharing of information systems is useful in order to enhance communication between globally distributed organisations. Using co-location early in the collaboration can create informal relationships and mutual understanding, which enable more virtual collaboration in later phases.

The research on distributed development teams complements the literature on information-processing capacity by emphasising the role of geographical distribution in integration mechanisms' communication. It provides explanations for why knowledge communication may be difficult in product development collaboration between geographically dispersed companies. However, it does not explain how integration mechanisms enable knowledge communication between dispersed companies.

1.4.3 Knowledge-transfer perspective

The research on inter-organisational knowledge transfer and exchange is related to the literature on distributed product development, and it partly builds on the literature discussing integration mechanisms and information processing. Nevertheless, it provides some complementary views of relevance for the issue studied. Therefore, the following will review research on knowledge transfer related to this study's interest in relationships between integration mechanisms and knowledge communication.

In the literature on knowledge transfer, several authors address integration mechanisms, similar to those discussed by the information-processing research (e.g. Inkpen, 1996; Gupta, and Govindarajan, 2000). Inkpen and Dinur (1998), for example, identify visits to the partner's organisation, frequent meetings, and exchange of employees as means enabling knowledge transfer. Similarly, e.g. Almeida et al. (2005) recognise movement of individuals between organisations as a way to enhance knowledge transfer across organisational boundaries. Job rotation, for example, stimulates the development of personal relationships enhancing informal integration of knowledge between organisations (Maidique and Hayes, 1984). Transferred individuals also develop skills to learn from different organisational functions and adapt to different situations, which enhances their co-ordinative capability. Nonaka et al. (2006) discuss the organisational context created between organisations and knowledge activists, i.e. boundary-spanners, as important tools for knowledge-sharing between organisations. Lindkvist (2001) uses the concept 'knowledge vehicles' to describe means for transferring knowledge between organisational units. Artefacts and documents are knowledge vehicles used for transfer of explicit knowledge. Transfer of tacit knowledge requires interaction between people – e.g. moving people in order to enable them to work side by side. In a case study, Orlikowski (2002) found that interaction face-to-face between individuals contributed to development of the capacity to distribute knowledge across organisational boundaries. Another important contribution is that of Hansen and Løvås (2004), who found empirical evidence for the important role of informal relationships in enabling transfer of knowledge between organisational units within one company.

Existing research suggests that several types of integration mechanisms are used in order to enable knowledge transfer. However, the bulk of this research focuses on knowledge transfer within companies (e.g. Hansen and Løvås, 2004). The inter-firm perspective has received considerably less attention, although there are a few important contributions (e.g. Inkpen, 1996; Simonin, 2004; Easterby-Smith et al., 2008). Simonin (2004), for instance, showed how knowledge ambiguity makes transfer difficult to accomplish between companies. Inkpen and Tsang (2005) argued that social capital aspects, such as strong personal ties, facilitate knowledge transfer in alliances. Easterby-Smith et al. (2008), based on reviews of existing research, recognise the importance of organisational context and social ties for knowledge transfer between geographically dispersed organisations. Still, it remains unclear how integration mechanisms enable knowledge communication between companies.

Furthermore, the literature reviewed here focuses on transfer and not the communication between actors that enables transfer. Even though the term 'communication' is sometimes used (e.g. Zander and Kogut, 1995; Inpen and Dinur, 1998) it is usually not defined how the term differs from transfer or exchange. Two notable exceptions are by Bresman et al. (1999) and Murray and Peyrefitte (2007), who recognise communication as a means for knowledge transfer. However, these studies do not explain how knowledge communication is achieved. Thus, this supports this study's choice to focus on knowledge communication, but it does not explain the issue of integration mechanisms' role for enabling of knowledge communication. In addition, much research on technology transfer and exchange uses surveys or conceptual reasoning – which make it difficult to uncover the factors relevant for explaining the functioning of integration mechanisms (Hansen and Løvås, 2004; Inkpen and Tsang, 2005). The knowledge-transfer literature also focuses mainly on product technology and shows little interest in product development knowledge. This seems to be a limitation since much of the knowledge content communicated in the cases studied concerns organisational processes for accomplishing collaboration. Thus, the scope of the transfer literature does not specifically address the knowledge communication practice found in product development collaboration that has been studied.

This review of knowledge-transfer research shows that little empirical research exists regarding the relationship between integration mechanisms and knowledge communication, in product development collaboration between companies. Other limitations were found in the review of the information-processing and the global-local perspectives. Based on the review here of the three different perspectives regarded as both related and relevant to the issue of interest, the following sections discuss how this study can complement existing research.

1.4.4 Complementing research on integration mechanisms and knowledge communication

The previous sections identified that there is a considerable literature on integration mechanisms, information processing, communication and knowledge transfer between organisations. Still, research is limited regarding integration mechanisms' enabling of knowledge communication between companies.

As noted in the review, existing research largely focuses on integration mechanisms used within companies (e.g. Nadler and Tushman, 1987; Griffin and Hauser, 1996). Consequently, there is limited knowledge regarding the use of integration mechanisms between companies in product development collaborations. As mentioned previously in this chapter, the lack of e.g. shared relationships, language and tacit knowledge makes knowledge communication between companies more difficult. Therefore, it is possible that the types of integration mechanisms used in collaboration between companies are somewhat different. This study can therefore complement existing literature by identifying types of integration mechanisms used in order to enable knowledge communication in product development collaboration between companies.

Several integration mechanism factors may influence communication of knowledge between companies. The literature has identified e.g. geographical separation, informal relationships and face-to-face interaction (De Meyer, 1991; Hansen and Løvås, 2004; Nonaka et al., 2006). Factors such as uncertainty can influence the functioning of integration mechanisms (e.g. Galbraith, 1973; Tushman, 1979). Others have addressed the importance of e.g. visits to the partner organisation for the transfer of knowledge in alliances (e.g. Inkpen and Dinur, 1998). Several authors (Simonin, 2004; Carlile, 2004) have also discussed sharing of knowledge between organisations as influenced by differences of interpretation in the different contexts. Hence, we know what may be important hindering and enabling factors of knowledge communication.

However, existing research has not specifically explained the relationship between integration mechanisms' knowledge communication between companies. Hence, academic knowledge is limited regarding integration mechanisms' enabling of knowledge communication, in product development collaborations between companies.

This study sets out to add complementary knowledge to the existing research. Now let us turn to the purpose of the study, which will specify the knowledge this study will generate.

1.5 Purpose

The point of departure for this study is the notion that product development collaboration is a phenomenon growing in strategic importance to large manufacturing companies. Activities that used to be integrated within the single company are now often globally distributed in the company's industrial network (Karlsson, 2003). This development brings new managerial challenges, compared to situations with product development co-located within the single company.

The issue of interest in this study is knowledge communication between collaborating companies. It takes the perspective on integration mechanisms as managerial means enabling knowledge communication. The review of existing research shows there is a need for more knowledge about integration mechanisms' enabling of knowledge communication.

Therefore, the specific purpose of the present study is to add complementary knowledge to research and practice by exploring and explaining:

How and why different types of integration mechanisms enable knowledge communication in product development collaborations between companies.

In order to accomplish the purpose, this study has the following research aims:

1. Explore integration mechanisms of different types that influence knowledge communication in product development collaborations between companies.
2. Analyse how identified types of integration mechanisms influence knowledge communication in product development collaborations between companies.
3. Explain why identified types of integration mechanisms influence knowledge communication the way they do in product development collaborations between companies.
4. Explore and analyse factors moderating identified types of integration mechanisms' influence on knowledge communication in product development collaborations between companies.

This study defines the units of analysis as integration mechanisms used as organisational interfaces between companies in product development collaborations. It means that the study treats organisational dimensions of product development collaborations, such as internal R&D departments and management functions, as the environment of integration mechanisms.

It is also important to mention here that, even though knowledge communication takes place between companies, this study takes the perspective of the single company. This choice comes from the notion that the individual company is the key actor in the kind of collaborations studied. It is thus interesting to investigate the individual company's activities in the collaboration and its perception of effects. However, as a complement, the partner company in the studied collaborations has been included in the study in order to validate data. Chapter 3, on method, elaborates this and other methodological choices.

1.6 The structural outline of the thesis

The structure of a book is a map of its content. The structural outline constitutes the architecture of the thoughts that the author wishes to share with the reader. This book uses a structure typical for how an academic thesis is designed. There are obviously individual variations but, in general, a thesis begins with a problem that is suitable for research, a purpose, theoretical perspectives, method, empirical data, analysis, and conclusions. This thesis is no exception from that tradition, which I believe contributes to making the presentation transparent. Nine different chapters are the major building blocks. The following figure presents the major relationships between these chapters.

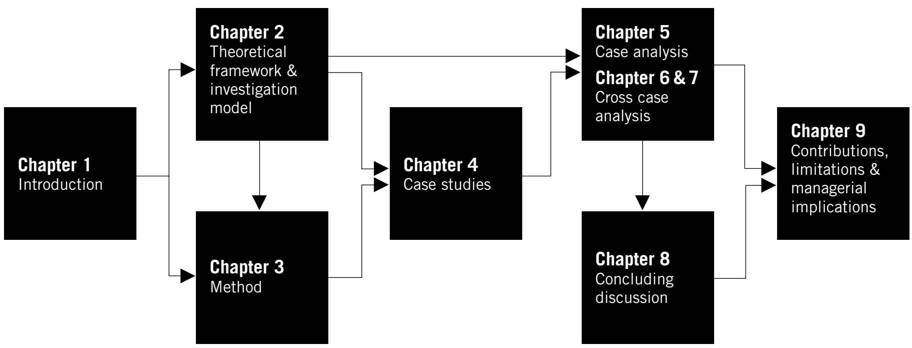

Figure 2: Outline of thesis

This introductory chapter addresses the issue of how companies enable knowledge communication in product development collaborations. It reviews existing literature and identifies how this thesis can add knowledge. The purpose is presented, research aims are outlined and the unit of analysis is defined. In Chapter 2, the focus is on development of the theoretical framework and the investigation model, which makes the study operational and supports the analysis of empirical data. Chapter 3, on method, is concerned with how the study is accomplished – for example, with selection of cases, analysis of data and generalisation from the results. Chapter 4 presents the empirical results from the three case studies. In Chapter 5, the different cases are analysed. This means that the chapter identifies integration mechanisms and analyses their knowledge communication capacity. The sixth chapter analyses how and explains why identified types of integration mechanisms influence knowledge communication. Chapter 7 compares the different cases in a cross-case analysis focusing upon moderators of integration mechanisms' influence on knowledge communication in product development collaborations. Chapter 8 discusses the results and develops a model that integrates results concerning how and why integration mechanisms enable knowledge communication between companies. The final Chapter 9 presents contributions to academic knowledge, limitations of the present study, and discussion of what managers can learn from this study.

2 Theoretical framework and investigation model

This chapter develops the study's theoretical framework and investigation model. It builds on existing knowledge that provides perspectives useful for the present study. Thereby, it provides the point of departure for the empirical investigation and the analysis.

This chapter develops the theoretical framework and the investigation model used for accomplishing this study. It uses theories from different fields in order to address the issue studied, e.g. product development literature, alliance research, communication theory and knowledge philosophy. The aim is to construct a framework that provides complementary perspectives on integration mechanisms' enabling of knowledge communication between companies.

The literature used has both an inter-organisational and an intra-organisational perspective. The reason for also using intra-organisational research is that it provides principles useful in order to understand integration mechanisms used in collaborations between companies.

Building on the theoretical framework, the final part of this chapter develops the investigation model in order to make the study operational. It constructs factors and the relationships that this study, based on the research aims defined in section 1.5, investigates and analyses in the following chapters.

This chapter has the following structure.

➜ First, it discusses important organisational factors in the product development collaboration's organisation. The investigation model addresses these factors as potential moderators of integration mechanisms' influence on knowledge communication.

➜ Second, integration mechanisms' structures are conceptualised, from the perspective of their role for knowledge communication.

➜ The third part of the chapter combines communication theory and literature on knowledge. It develops this study's perspectives on knowledge communication.

➜ In the final section the investigation model, which makes this study operational, is developed.

2.1 Organisational factors shaping product development collaboration

Why do companies engage in collaboration on product development? What is the impact of different forms of collaboration? What is the role of the product technology in focus of development collaborations?

These questions concern the background motives for integration mechanisms' existence, the kind of structure they operate in, and the tasks they handle. This study views these issues as potential moderators of integration mechanisms' influence on knowledge communication. In order to construct a basis for investigating the moderating role of the organisational factors, the following will discuss:

- ➜ Strategic motives of companies engaging in product development collaboration.
- ➜ Forms of collaboration that companies commonly use in order to enable product development together.
- ➜ Product technology's influence on development collaboration between companies.

2.1.1 Strategic motives for product development collaboration

The previous section 1.1 mentioned costs and innovation motives as major reasons why companies choose to engage in product development collaboration. The underlying reason is change in competitive forces, which drives companies to engage in collaboration with external partners for development of new products (Karlsson, 2003). This section will further elaborate on strategic motives as factors shaping product development collaboration.

Following Wernerfelt (1984), Winter (1987) and Grant (1996) it can be argued that one important source of competitive advantage is the company's internal knowledge resources. Of principal importance is Barney's (1986) argument: sources of sustainable advantage are combinations of resources, not individual resources. Building a competitive position means creating or acquiring resources that are unique, valuable, difficult to imitate and sustainable (Barney, 1991). According to Ahuja (2000) the resource-based rationale influences both the choice to collaborate and the individual company's attractiveness as a partner. For example, according to Stuart (2000), collaboration is a potentially valuable source of resources, status and recognition, and thereby competitive position.

One major motive for collaboration is to access a partner's knowledge, in order to enhance building of new competence (e.g. Hamel et al., 1989). Inkpen (2000) argues that it is unusual that learning is the main reason for collaboration, but it is often a prerequisite in order to enable other objectives. For example, companies' strategic learning intention is driven by ambitions to e.g. exploit partner knowledge, enable combination of companies' different knowledge, or develop skills in a new area of operations (e.g. Singh and Perlmutter, 2001; Kale and Singh, 2007). This can enable a company to build competence in a new area much faster than internal development would allow (Doz and Hamel, 1997). Hence, learning e.g. a partner's technology is a strategic issue because it contributes to strengthening the individual company's knowledge assets (e.g. Amit and Schoemaker, 1993).

The combination of internal and external knowledge resources can also enhance innovation potential in the development of new products (Dyer and Singh, 1998). Powell et al. (1996) shows that the locus of radical innovation is the network of partners and not the single company. This view relates to Schumpeter (1934) who argued that innovations are combinations of existing knowledge. From that perspective, one important reason why companies engage in collaborations for development of complex products is a competition-driven search for new and/or complementary knowledge.

According to Hennart and Zeng (2005), a primary drive for collaboration is to access complementary external knowledge in order to allow the internal organisation to specialise on what it does best. This view follows the argument that the company should focus on its core competence in order to build sustainable competitive advantage (Prahalad and Hamel. 1990). Through collaboration, a company can gain access to knowledge it does not have and cannot develop internally without significant costs. Other resource motives driving efforts to engage in collaboration are to access financial support, physical facilities and equipment.

Underlying the specialisation argument is the cost logic that drives companies to combine knowledge resources in order to accomplish something none of them can achieve alone (e.g. Chen and Li, 1999). One example is large manufacturing companies. It is currently common that OEM companies specialise in developing integrated product functions, and outsource vertical product technologies such as break systems (Karlsson and Sköld, 2007). A clear division of work between the companies characterizes such collaboration. Nevertheless, it is necessary for the companies to understand interfaces between each other's work packages. The reason is, as Persson (2004) showed, that integration of product modules is rather complex. Thus, product development collaboration based on specialisation creates a need for communicating, between the companies, critical knowledge about interfaces. For instance, Takeishi (2002) claims that efficient outsourcing of product development demands some overlapping architectural knowledge between an OEM and a supplier.

Another example is horizontal collaboration between two OEM companies that wish to develop a new technology or product but cannot afford to do it themselves (e.g. Doz and Hamel, 1998). By collaborating, they can share development costs and thereby explore new technology that they could not afford alone. Through collaboration, they create potential to achieve scale advantages in development and production of new products (Karlsson, 2003). These cost motives drive, for instance, many large manufacturing companies to collaborate on product platform development

(Lundbäck and Karlsson, 2005). This means that a new product technology is developed for both collaborating parties' markets, but with possible variations in e.g. design in order to retain brand distinction. Therefore, companies need to develop shared product knowledge in order to realise development of a joint product platform (Sköld and Karlsson, 2007). Hence, there is also a strong learning aspect in order to enable cost advantages through collaboration.

Summary of strategic motives:

➜ To enable learning of new technology, including skills from the partner company.
➜ To enhance innovation potential through new and creative combinations of internal and external knowledge.
➜ To share development costs, in order to develop products no one company can afford alone.

The discussion here has concerned strategic motives for collaboration and its implications for relationships between companies. The choice to specialise or to work integrated on product development obviously can be expected to have implications for the functioning of integration mechanisms and knowledge communication. This study investigates strategic motives' potential role as moderator of integration mechanisms' influence on knowledge communication.

Having discussed motives and why companies choose to collaborate on product development, the following section will focus on different forms of collaborations and the major reasons for choosing them.

2.1.2 Forms of product development collaboration

The previous section discussed important reasons why companies collaborate. The focus here is on different forms of collaboration that companies can choose among in order to develop new products together. The form of collaboration creates the organisational structures within which integration mechanisms are used.

To begin with, this study's view of collaboration is: "*any voluntarily initiated cooperative agreement between firms that involves exchange, sharing, or co-development, and it can include contributions by partners of capital, technology, or firm-specific assets*" (Gulati and Singh, 1998). Thus, in a formal sense, collaboration is an agreement between independent companies who have decided to share resources or in other ways to support one another. This general definition explains what characterises collaboration between companies, but ignores the fact that there are several different forms of collaboration.

Collaborations can differ both in legal arrangements, such as different joint ventures, and in type of operational level collaboration (Harrigan, 1988; Zollo et al., 2002). Lorange and Roos (1992) and more recently Todeva and Knocke (2005) have developed categorisation of different forms of collaboration. The categorisations of collaboration forms developed in the literature range from informal projects to equity-based ventures with varying degrees of vertical and horizontal integration. Following Lorange and Roos (1992), it is reasonable to differentiate collaboration forms into three groups:

- ➜ Informal cooperative venture, which is a market-based collaboration form without much integration of resources and activities.
- ➜ Formal cooperative venture, which is a contract-based collaboration form that may contain some integration of resources and activities.
- ➜ Joint ownership, which is a kind of collaboration taking place in a jointly owned legal organisation with management control over integrated resources and activities.

Based on existing research it is reasonable to believe that different formal types of collaboration are a factor with impact on integration mechanisms' influence on knowledge communication. Mowery et al. (1996) found that the form of collaboration has implications for knowledge communication. Equity joint ventures are likely to encompass rich knowledge transfer – which suggests high knowledge communication capacity. In contrast, contractual agreements have low knowledge transfer capacity. Hence, this suggests that collaboration form influences knowledge communication between companies. Therefore, this study investigates collaboration forms with potential moderating effects on integration mechanisms' knowledge communication.

Summary of collaboration forms:

- ➜ Collaboration refers to an agreement between independent companies, who have decided to e.g. share resources and work together.
- ➜ There is a spectrum of collaboration forms, from informal to highly integrated equity-based partnerships.

2.1.3 The role of product technology

The establishment of collaboration between companies can reflect a company's attempt to deal with resource interdependence and uncertainty (e.g. Pfeffer and Salancik, 1978). Thus, the individual company's motives for selecting a particular form for collaboration could reflect its resource requirements and the uncertainty associated with developing a new product. The discussion in the following will focus on the role of product technology in development collaborations between companies. It is important to this study because it concerns the content in focus of the collaborations studied.

There is a rich variation of product technology development typologies – e.g.

radical/incremental (Ettlie et al., 1984), exploration and exploitation (March 1991), product/process (Utterback and Abernathy 1975). All these typologies have in common that they try to distinguish between development along an established path and development that takes an unconventional route. New technology development that challenges established knowledge frames in search of qualitatively new configurations may lead to discontinuous change of dominant architectural design (Tushman and Anderson, 1986). In contrast, new technology development within a dominant architecture means incremental change. In reality, however, it may not always be easy to distinguish between exploitation/radical and exploration/incremental new technology. For instance, parts of the product technology could be new while the other parts remain largely unchanged. Hence, many product development projects fall somewhere in between the polar type categories.

Henderson and Clark (1990) are of some help for this discussion. They argue that radical innovation and incremental innovation are extreme points. In order to move beyond the dichotomies they offer a more nuanced framework that revolves around change in two dimensions – within subsystems, and linkages between systems and components. Radical product technology refers to new knowledge that challenges and destroys established technologies by offering new architectural and component solutions – i.e. creates a situation of creative destruction. The characteristics of incremental product technology development are changes within established configurations on both architectural and component levels. Architectural product technology means that the relationships between different components in a system are changed, while the components remain largely unchanged. Modular product technology development refers to change of subsystem architecture, while the relationships between different components remain largely unchanged.

Tushman and O'Reilly (1999) recognise that the ideal organisational structure depends on the kind of product developed. As Henderson and Clark (1990) imply, development of new architecture faces greater uncertainty than incremental development. The main reason is the limited knowledge existing regarding relationships between components. One implication is that companies which set out to develop a new architecture together need to choose an integration mechanism enabling close collaboration (Stock and Tatikonda, 2004). The situation is likely to be similar for modular and radical product technology development. In contrast, incremental product technology implies that the architecture is known, as well as much of the underlying components. This makes it possible to organise product development around differentiated work-tasks, which require little integration (Chesbrough and Kusunoki, 2001).

The discussion here has addressed the relationship between product technology and collaboration structures between companies. Based on this discussion, the study investigates whether and how different kinds of product technology moderate integration mechanisms' influence on knowledge communication.

This subchapter can be summarised:

- ➜ Product technology developed can be categorised after its degree of newness on architectural and component levels.
- ➜ The kind of product technology developed influences the distribution of product development work between companies.

2.2 Integration mechanisms' structures

The following discussion will focus on mechanisms that companies can use in order to accomplish integration. It will address characteristics of integration mechanisms of importance for knowledge communication in product development collaborations between companies. First, however, as a point of departure, the discussion elaborates on the relationship between integration and differentiation.

According to Lawrence and Lorsch (1967) differentiation is a state of segmentation of the organisation into subsystems with the purpose of enabling division of tasks. They developed three principal dimensions for differentiation – the sales subsystem, the production subsystem and the R&D subsystem. Galbraith (2002) developed complementary dimensions for differentiation – geography, customers, processes, products and functional areas. The kind of differentiation used depends on the scope of activities and the resources applied. Differentiation is necessary for accomplishing specialisation, such as product design.

However, effective organisations are characterised by also accomplishing integration (Lawrence and Lorsch, 1967). They defined integration as "*the process of achieving unity of efforts among the various subsystems in the accomplishment of the organization's task*". That is, in order to function effectively a differentiated organisation needs integration mechanisms that can handle the division of work tasks. In product development, differentiated organisations, for example, need to be able to share knowledge in order to handle complex problems, which requires integration (Sheremata, 2000). The point of departure here is the view of integration mechanisms as means for accomplishing something that differentiated organisations cannot achieve alone (Galbraith, 1973). Building on that perspective, in the present study integration mechanisms are means for enabling knowledge communication in product development collaborations between companies.

Section 1.3 defined integration mechanism structures as formal, location and cognitive structures. The discussion here will elaborate on integration mechanisms' different structural characteristics. It will thereby construct a theoretical basis for studying integration mechanisms and their influence on knowledge communication.

The first section addresses integration mechanisms' formal structures, such as different types of teams for linking operations between companies. The second section discusses integration mechanisms' location structures, for instance aspects of co-location. Finally, the third section focuses on cognitive structures in integration mechanisms.

2.2.1 Integration mechanisms' formal structures

The choice to address formal structures of integration mechanism builds on the assumption that managers directly control certain aspects of integration mechanisms. They can, for instance, decide the kind of work to be managed within integration mechanisms. The formal structures of integration mechanisms are largely discussed in literature developing different types of integration mechanisms (e.g. Galbraith, 1973). Therefore, this section builds on literature discussing different types of integration mechanisms.

The discussion here largely follows Galbraith (1973). The main reason is the strong conceptualisation of different types of integration mechanisms. The major complement to Galbraith used here is the work of Nadler and Tushman (1987). They specifically address the information-processing capacity of different integration mechanisms – which this study regards as relevant for addressing the issue of knowledge communication. In addition, this section borrows from research that has developed similar types of integration mechanisms and discussed their use in e.g. relationships between functional units (e.g. Griffin and Hauser, 1996).

The table introduces different types of integration mechanisms.

Types of integration mechanisms
• Hierarchic role
• Liaison roles/boundary-spanners
• Personnel movement
• Cross-units group
• Integrator role/department
• Managerial linking role

Table 1: List of integration mechanisms
The table is built on categories developed by Galbraith (1973); Nadler and Tushman (1987); Griffin and Hauser (1996).

The integration mechanisms in the table represent different strategic and operational integration structures and they have different communication capacity. The review of existing research on integration mechanisms and knowledge communication in Chapter 1.4 indicated that there is limited knowledge about which types of integration mechanisms are used in product development collaboration. Therefore, integration mechanisms identified in this study will be compared with these different categories in order to investigate similarities and differences.

A *hierarchic role* is a form of managerial integration mechanism adequate in collaborations facing relatively low degrees of environmental complexity and work-related interdependence (Galbraith, 1973). Managerial integration implies direct work contact between managers in order to facilitate integration between two units. One managerial role is to communicate between the individuals or the units. Since the manager filters information, that person can exercise control over the volume and content of knowledge transferred between different hierarchic levels (Nadler and Tushman, 1987). In complex environments with ambiguous information – e.g. in research and development – the hierarchic integration mechanism faces the risk of information overload (e.g. Galbraith, 1973). Thereby, managerial hierarchy is not likely to be an integration mechanism suitable for collaboration with ambitions to communicate substantial amounts of complex knowledge.

Liaison roles are useful when communication requirements are relatively low but the required amount of contact is considerable in order to co-ordinate the work in two units. Another term for a liaison role is that of a 'boundary-spanner' or 'gatekeeper'. A liaison role is a formal linkage that bypasses vertical communication channels. It is often a position without formal decision-making authority and it is typically a part-time assignment. There are different liaison roles, however. It typically means that a single person co-ordinates work performed in two different functional units, serving as a carrier of information and contacts between organisations. For example, such a person can have an ambassadorial role representing a department in another organisational unit. In other situations, it may be appropriate to have one liaison person in each unit – i.e. two liaison individuals (Galbraith, 1973; Nadler and Tushman, 1987; Ancona and Caldwell, 1992).

Personnel movement has been recognised for enhancing transfer of knowledge and learning between organisations (e.g. Nonaka and Takeuchi, 1995; Inkpen and Dinur, 1998; Lindkvist, 2001). People who move between companies or organisational functions bring knowledge to a new group that reduces the risk of misunderstandings. The reason is that by working within different organisations they are able to understand, and thereby create linkages between, knowledge in the different contexts (Inkpen and Dinur, 1998). In that sense, they are effective tools for transferring knowledge. However, personnel movement may not be efficient for communication between organisations over long periods. The reason is that there is a risk that people who spend a very long period in another organisation lose some of the contacts and incentives enhancing communication (Allen, 1977).

A *cross-unit group* can be useful in situations requiring more communication than can be handled by a liaison role. Compared to a liaison role, a cross-unit group has work contacts involving more people from the collaborating organisations. Therefore, they are effective in order to facilitate direct contact between representatives of different organisational units. The cross-unit role shares characteristics of a task force. It is often an *ad hoc* constellation set up to deal with upcoming issues. A typical cross-unit group meets regularly to accomplish a particular task and it exists only as long as a problem exists; thereafter it is disbanded (Galbraith, 1973; Nadler and Tushman, 1987).

A more permanent integrating mechanism may be necessary if the communication requirements are highly complex. It can be categorised as an *integrator role* or *department* for integration (Nadler and Tushman, 1987). It is useful when there are complex inter-organisational issues requiring substantial management attention. The major task is to continuously co-ordinate work and manage the joint decision-making process between organisations. This kind of role is a tool bringing senior management's points of view to the co-ordination between e.g. functional units. The idea is to have a real-time top management influence on co-ordination of functional units' work-tasks – i.e. the integrator role is to represent the interests of top management. However, an integrator role does not often have the authority to execute decisions. This means that formal decision-making authority remains within e.g. functional units (Galbraith, 1973; Nadler and Tushman, 1987; Griffin and Hauser, 1996).

A *managerial linking* role is useful when it makes sense to add decision-making authority to the integration mechanism. This means that the integrator shares characteristics with an integrator role, but with more power. Such a role is common in situations where considerable communication and co-ordination by mutual adjustment are required. For example, a managerial linking role may have the responsibility of integrating functional units with different goals and loyalties. It is also a useful role in situations characterised by high uncertainty, e.g. product development projects. Such a person may e.g. hold the position of project manager for large product development projects. Decision-making authority cuts across the activities of the different functional departments' activities – but it does not include the formal authority over departments' employees. This means that in order to execute power, the linking manager may need a combination of formal decision-making authority, budget control and negotiation skills. In addition, a good deal of trust in the manager is likely to be necessary, in order to make it function effectively as an integration mechanism (Galbraith, 1973; Nadler and Tushman, 1987).

There is also extensive literature on management of product development projects that can shed complementary light on the types of integration mechanisms discussed here. This literature has largely revolved around different team concepts. One popular concept is the cross-functional team, which implies that R&D, production and marketing work together during development projects (e.g. Clark and Fujimoto, 1991). Wheelwright and Clark (1992/95) discuss other concepts related to the scope for this thesis. They categorise development team structures according to project leader roles and to the commitment of those working in the project. They construct four types of product development organisations – the functional team, the lightweight team, the heavyweight project, and the autonomous project. The following summarises these team structures' main characteristics:

➜ In a mature business, companies typically use functional teams, which often focus on detailed issues within their functional specialty.

➜ A committee of persons from different functional areas constitutes lightweight teams. This kind of team has little formal decision-making authority. Instead, line managers make the major decisions.

- ➜ Heavyweight projects work with total solutions – e.g. development of a new product. However, the project largely accomplishes its work-tasks within functional units.
- ➜ Autonomous teams are heavyweight project organisations with the members having full-time assignments to the project. This kind of team is often co-located and self-contained.

Summary of integration mechanisms' formal structures:

- ➜ There is a substantial variation in integration mechanism types – from single personal boundary-spanners to integrator departments. They have different roles and capacity to accomplish integration between organisations.
- ➜ Integration mechanisms' formal structures specifically addressed by this study are decision-making authority, the number of people engaged, and the level of work integration.

This section has focused on different types of integration mechanisms and their formal structures. One factor related to the formal structures is integration mechanisms' location structure. It is of interest because the collaborations studied take place between companies separated by considerable geographical distance. Therefore, the next section discusses integration mechanisms' location structures.

2.2.2 Integration mechanisms' location structures

Companies increasingly face unbundling of the relationship between location, resources and activities (Persaud, 2005). The increase of product development collaboration is part of this phenomenon. Therefore, one aspect of importance to the present study is that companies deciding to collaborate often are geographically dispersed (Barczak and McDonough, 2003). As mentioned in Chapter 1.2.2, geographical separation is one factor inhibiting knowledge communication between companies (De Meyer, 1991). Hence, one role of integration mechanisms is to handle implications of geographical separation between collaborating companies. This section first discusses aspects of distributed location in order to outline the challenges to knowledge communication, and thereafter focuses on the role of integration mechanisms' location structures.

Research shows that product development within one organisation can simultaneously take place at several locations (e.g. Bartlett and Ghoshal, 1990). In the literature, in particular two aspects of distributed location appear to influence product development – distance and time zone difference. Research by Lindkvist (2001) shows that geographical distance between members of product development organisations has the consequence that there is a lack of contacts between different locations. One implication is limited knowledge about people working with similar tasks and lack of knowledge about relevant activities in other parts of the organisation. Early in collaboration, companies with limited or no experience of collaborating with one another face a situation with very few personal contacts. Lack of personal contacts hinders communication between people in the distributed organisations (Hansen and Løvås, 2004). Difference of time zones between geographically distributed organisations is also an aspect making communication difficult (Boutellier, et al., 1998). The reason is that people at different locations only have a few hours per day when they can communicate with one another. This requires more planning in order to synchronise communication, and it increases time lags in response to e.g. e-mails.

One major issue for managing distributed product development is thus to create location structures in integration mechanisms enabling knowledge communication. The literature on product development identifies two principal kinds of location structures – co-location and distributed location (McDonough III, et al., 2001; Richtnér and Rognes, 2008). Both kinds of structures are integrative responses to geographically separated product development operations. The discussion here will first address aspects of co-location and thereafter distributed location.

Co-location has received considerable attention for its influence on communication patterns. Allen (1977) showed, for instance, that a distance of less than 30 meters between people drastically increases their communication. One important aspect of co-location is office physical structure. For example, the building, the furniture and the equipment are important structures (e.g. Löwstedt, 1995). The reason is that the combination of these and other physical structures constitutes the environment for social interaction, and thereby development of informal communication channels (Hatch, 1997). Research by Leenders and Wierenga (2002) found that marketing and R&D work were more integrated if they were co-located. Westling (2002) shows that informal meetings in e.g. hallways served as means for addressing complex issues during product development projects. These meetings enabled more exploratory conversations than formal meetings. Building on Allen (1977), one interesting implication is that the chances for informal communication in product development organisations are largely influenced by the kind of co-located structure used. For instance, the location of the coffee machine influences the frequency of spontaneous interaction patterns within the organisation. When two functional units share the same coffee machine, this may be a factor contributing to enhanced cross-functional knowledge communication.

The choice of co-location has direct implications for the kind of collaboration that will emerge between companies. Research on cross-functional collaboration has clearly indicated that physical co-location enhances interaction intensity and mutual understanding (Kahn and McDonough, 1997). According to Moenaert and Caeldries (1996), compared to distributed location the quantity of communication was unchanged by co-location. However, co-location enhances the quality of communication. The reason is, as argued by e.g. Daft and Lengel (1984), that co-location enables face-to-face communication.

Although physical co-location has clear advantages for product development, it is not always necessary or even possible to accomplish between companies. As indicated by McDonough III et al. (2001), companies also use distributed teams in product development. One important reason is companies' use of common information systems in order to support communication during product development (e.g. Nittmar, 2000). One effect of common information systems is capacity to facilitate qualitative interaction within distributed teams (Zammuto, 2006). It enables communication of large quantities of explicit knowledge, such as blueprints. However, information systems cannot fully replace the advantages of physical co-location. The major reason is, as Magnusson (2004) argues, that knowledge used for product development is tacit, which is difficult to communicate across distances (De Meyer, 1991). One underlying explanation is that, because of geographical separation, there is little development of interpersonal relationships, which generally are central for knowledge communication between organisations (e.g. Richtnér and Rognes, 2008). The implication is that distributed location structures may be useful when knowledge relevant to communicate is largely explicit, but insufficient when tacit knowledge is important to communicate.

However, research by Orlikowski (2002) indicates that the company can overcome collaborative obstacles to distributed product development, if the members of the organisation develop shared tacit knowledge. Song et al. (2007) argue that by working co-located early in collaboration, people develop shared understanding. One effect is enhanced potential for communication in a distributed organisation during later collaboration phases. The reason is that existence of personal relationships and shared tacit knowledge enables better interpretation of subtitle messages between people in the distributed organisation.

This section has addressed integration mechanisms' location structures. In this study, location structures concern how integration mechanisms create linkages between geographically separated companies. It addresses two principal types of location structures – co-location and distributed location.

Summary of location structures' main characteristics:

➜ Co-location refers to the fact that people work in the same physical area, e.g. office floor or industrial plant. The physical distance between co-located people influences their opportunities for frequent and informal interaction.

➜ Collaborating with people located at different sites creates a distributed location structure. They can e.g. be connected through an information system or by travelling in order to create opportunities for interaction.

2.2.3 Integration mechanisms' cognitive structures

This section discusses the role of cognitive structures in integration mechanisms. First, it discusses how this study views cognitive structures; secondly, it addresses major characteristics of importance for collaborations; and finally it examines how cognitive structures can be changed.

There are different and complementary views on cognitive structures in the literature. Prahalad and Bettis (1986) argued that cognitive structures are conceptions of e.g. the organisation's technology resources, product development function and managerial tools. Argyris and Schön (1978) used the following explanation of what they call organisational maps: "*They describe actual patterns of activity, and they are guides to future actions*". These maps include e.g. description of work processes, the organisation's formal chart, and communication patterns. In essence, they argue, an organisation can be seen as a cognitive enterprise.

This study refers to cognitive structure as a collective conception of the organisation and its environment (Hellgren and Löwstedt, 1997). It provides shared meaning and understanding between the organisation's members (Löwstedt, 1989; Nahapiet and Ghoshal, 1998). In integration mechanisms, cognitive structures from different companies meet through the individuals participating in the integrative work. Therefore, cognitive structure is a factor expected to influence knowledge communication between companies.

Cognitive structures have some characteristics of major importance for collaboration between companies. The cognitive structures within an organisation function as an interpretative filter that is common among its members (Prahalad and Bettis, 1986). In an organisation, the cognitive structures also guide the members' collective actions and language. Hence, in collaboration between companies, the difference in cognitive structures shape how people from the companies understand one another. The following discusses the implications of these characteristics of cognitive structures.

First, regarding the role as interpretative filter, Carlile (2004) argued that differences in interpretation frameworks are boundaries constraining communication between organisations. Dougherty (1992) explained that one important reason why different cognitive structures are barriers to effective collaboration is that organisations not only know different things, they also know things differently. Thereby, companies that collaborate may easily encounter situations where people from the different organisations perceive situations and e.g. technology rather differently.

Second, as Daft and Weick (1984) argued, assumptions about the environment and the internal organisation's intrusiveness influence patterns in how a company acts. Prahalad and Bettis (1986) had a similar discussion and argued that what they call dominating logics guide decision-making in the company. The role of cognitive structures does not only influence decision-making, it broadly influences the organisation's patterns of activities. This means that a company expresses its cognitive structures through patterns of actions among its members, such as common ways of communicating between colleagues (Taylor and Osland, 2005). For instance, imagine typical communication patterns between managers and employees. In some organisations, the communication is informal, e.g. the managers walk around in the office and "small-talk" with people. In other organisations, managers may only communicate at formal meetings and through documents. These differences are expressions of different ways to think about e.g. status, leadership and sources of knowledge. If two companies representing two different communication styles collaborate, it is likely that people working in integration mechanisms will find it difficult to understand the partner's way of communicating.

Third, the organisation's cognitive structures can also be expressed through language used by its members. For example, Griffin and Hauser (1996) mentioned differences in language between development departments and marketing departments as expressions of different work-tasks. The effect of these differences was different terminology, which inhibited cross-functional collaboration. Lindkvist (2001) found that both different national language and organisational terminologies were barriers to efficient communication of knowledge between organisational units. Thus, difference in language is an interpretative barrier between organisations (Brown and Eisenhardt, 1995; Bjurström, 2007). Conversely, as Kogut and Zander (1992) recognised, a common language is central for sharing knowledge in organisations. Hence, it is reasonable to expect that difference in language has major implications for knowledge communication between companies.

The discussion in this section has so far discussed the functioning cognitive structures, and it has made clear that difference in cognitive strictures may be a major obstacle to collaboration. The following will discuss what theories have to say regarding how companies may handle differences in cognitive structures.

To begin with, Hedberg (1981) argued that cognitive structures are difficult to change. The reason is that they represent e.g. core values and beliefs that the organisation at large shares (Lyles and Schwenks, 1992). The implication is that people may come and go but underlying values, norms and behaviours are likely to remain stable. However, this does not mean that cognitive structures are static. Instead, cognitive structures can be seen as evolving through social construction of shared understanding (Dougherty, 1992). It is a sense-making process, through which the members of the organisation gradually renegotiate their collective notion of the world, as it comes across new experiences.

The ability to manage change of cognitive structures obviously has major implications for enabling collaboration between companies. According to March and Stock (2006), companies need to develop a shared understanding in order to take advantage of each other's knowledge. This implies that in order to enable communication of complex and organisation-specific knowledge, collaborating companies need to reduce the difference between their cognitive structures. How fast the organisation manages to reorient depends on the strength of resisting cognitive structures (Åhlström, 1995).

In order to reduce cognitive differences, people from collaborating companies need to develop what Dougherty et al. (2000) call shared sense-making of e.g. roles, rules and routines. This requires what Argyris and Schön (1978) called double-loop learning. They argue that: "*Double-loop learning occurs when error is detected and corrected in ways that involve the modification of an organization's underlying norms, policies and objectives.*" Löwstedt (1989) argued that that through actions and discussions people influence one another and thereby set in motion a change of collective conceptions. This implies that overcoming cognitive barriers in product development collaboration requires that people from collaborating companies change their existing ways of thinking and acting. This can mean either that they develop shared perspectives or that they enhance the understanding for one another's perspectives (Boland and Tenkasi, 1995). When it is not enough to reconsider the existing cognitive structure, it may also be necessary to replace it with a new one (Södertröm, 2004). In product development collaboration, this may e.g. concern challenging the companies' established perceptions of product quality and functionality, and together creating a common view. Hence, whether and how differences in cognitive structures are reduced in integration mechanisms can be expected to have major implications for knowledge communication in collaboration between companies.

Summary of cognitive structures' major characteristics:

➜ This study operationalises cognitive structures as collective conceptions of collaboration structures, product technology, and processes.

➜ Cognitive structures in organisations are here seen as interpretative filters, and they are expressed through actions and language.

➜ The present study is interested in cognitive structures within integration mechanisms used in product development collaborations. The point of departure is that people from different companies may not share the same cognitive structures. Differences and similarities in cognitive structures are expected to have an impact on how and why integration mechanisms influence knowledge communication.

2.3 Communication of knowledge

The previous sections discussed integration mechanisms and the characteristics of their different structures. This sub-chapter focuses on the effect of interest in this study – knowledge communication between companies.

Chapter 1 presented this study's definition of knowledge communication. The following will elaborate the discussion on knowledge communication in order to develop a theoretical basis for the study of knowledge communication.

The following structure is used. First, the discussion addresses aspects of communication. Thereafter, it addresses the term 'knowledge' and perspectives of knowledge dimensions. Finally, it elaborates views on knowledge communication in product development between companies.

2.3.1 Aspects of communication

To begin with, the term communication comes from the Latin word *communicatio* meaning mutual exchange. The verb form is *communico*, which means to share, to make common (Nationalencyklopedin, 1993). According to Encyclopaedia Britannica (1974), communication is exchange between individuals through a common system of symbols. It includes use of verbal and written expressions as well as physical gestures. Communication can be extremely complex with many actors and subtle messages. It is an activity that, in sequences, forms a process through which the involved actors ideally reach a shared understanding for the meaning of the content communicated (Harris and Nelson, 2008).

The starting point for the discussion here is a basic conceptualisation of communication. Thereafter, the discussion addresses communication intensity and richness, which this study uses as indicators of knowledge communication.

2.3.1.1 A model of communication

Communication is a complex activity, involving several different aspects. Therefore, in order to present the different aspects and their relationships, the choice here is to begin with a holistic view of the communication process.

A classical illustration of communication is the S-M-C-R model – i.e. source, message, channel and receiver (Rogers and Agarwala-Rogers, 1976). Another is the Shannon and Weaver model of communication (1949). This model is a valuable starting point for the discussion of knowledge communication, because it provides a comprehensive view on aspects of communication. Therefore, the following presents this principal communication model.

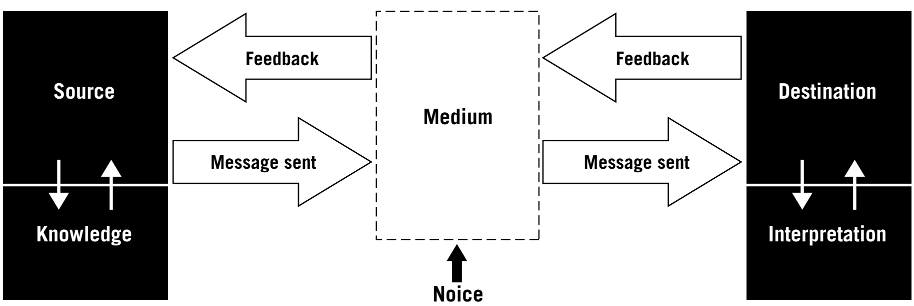

Figure 3: Communication model (after Shannon and Weaver, 1949)

A *source* can be an individual or a group of individuals working together. The source is the originator of the message. The source's *knowledge* influences the construction of messages. In this study, knowledge is the content of messages communicated. The *message sent* is a combination of symbols with certain meaning. The message is created through encoding, which is a translation of the source's knowledge. A *medium or* *channel* is the means used for transferring the message to the receiver. Media can be categorised as different types of mass media and interpersonal channels.

Communication can be moderated by several different types of *noise* – for instance, sounds, distractions, and the configuration of communication media, as well as more subtle factors such as the sender and receiver's attitudes toward one another. The receiver is the *destination* of the message. In order to make sense of the message it must be interpreted. Interpretation of a message depends on to what extent the source and the receiver share the same language and understanding of e.g. symbols. Communication may have effects on the receiver – for instance a change in behaviour. There are three main categories of change that communication may influence: the receiver's knowledge, attitude, and behaviour. *Feedback* is the receiver's response to the source's message. It can be positive or negative, and it can influence the relationship between the source and the receiver. In order to respond, the receiver needs to use a medium, which is not necessarily the same as that used by the sender. Feedback is a necessary aspect for two-way exchange and thereby the dynamics of the communication (Shannon and Weaver, 1949; Rogers and Agarwala-Rogers, 1976).

However, this classical communication model can be criticised because it does not take into account the issue of communicating tacit knowledge. It does not address, for instance, the role of experience and organisational context for formulation and interpretation of messages. Hence, it needs to be complemented with other theories, which this study discusses in the following sections. With this in mind, this model is still useful for conceptualising important aspects of integration mechanisms' influence on knowledge communication.

- ➜ First, in this study the senders (source) and receivers (destination) of communication are working in integration mechanisms.
- ➜ Second, in the present study, the content addressed in the sender's messages is knowledge. The content of communication is discussed further in 2.4.3.2.
- ➜ Third, the medium used is of relevance for the capacity to communicate intended messages – e.g. face-to-face or electronic means of communication. The capacity of different media will be discussed in 2.4.1.3.
- ➜ Fourth, it can be expected that knowledge communication between people in integration mechanisms is moderated by noise, such as irrelevant information, imprecise messages, and interruptions.
- ➜ Fifth, the receiver's interpretation of the message is influenced by his/her existing knowledge and cognitive structures, as well as by personal relationships with the sender.
- ➜ Sixth, the receiver answers the sender with a new message, which reflects the receiver's interpretation of the first message. The speed of feedback has implications for the intensity of communication; this is discussed further in section 2.4.1.2.

Since Shannon and Weaver in 1949 first published their communication model, the field of communication research has developed complementary theories. One important development concerns the role of nonverbal communication such as handshakes, facial expressions and people's artefacts. Of interest for this study is also the nonverbal communication through the location structure – e.g. the size of office rooms (which indicate power and status), the furniture in the office and the office's architecture. The nonverbal communication aspects are largely context-dependent. Together they influence the verbal communication between people, i.e. the content, the process and interpretation (Harris and Nelson, 2008).

Yet this basic conceptualisation of communication provides a framework useful for analysing communication. Having discussed communication from a holistic perspective, the following two sections will focus on two aspects of communication – intensity and richness.

2.3.1.2 Communication intensity

Communication intensity is one factor discussed in the literature as having important implications for product development (e.g. Clark and Fujimoto, 1991). The reason is that it influences the capacity to work integrated. For example, integrated product development between companies or functional units requires intensive communication. In contrast, less intensive communication is required in sequential work relationships (ibid.). A similar pattern is expected in collaboration between companies.

The communication pattern in the organisation strongly influences intensity. The important role of communication patterns has received substantial interest among authors (e.g. Allen, 1977; Hansen, 2002). First, the number of people connected is a factor influencing communication intensity between organisations. A large number of people with direct linkages is obviously likely to enable more intensive communication than if only one individual functions as boundary-spanner between organisations (Hansen and Løvås, 2005). Second, people's and organisations' relative network position has a major impact on their communication patterns. The principal relationship is that the more central a network position, i.e. the larger the number of direct relationships, the more intensive the communication achieved (Rogers, 1995). One implication is that communication becomes more intensive within organisations than between different organisations (Rogers and Agarwala-Rogers, 1976). This is one major reason why different kinds of organisational interfaces, i.e. integration mechanisms, are used for facilitating knowledge communication across functional and company boundaries.

Network position refers not only to a nodal position in relation to other actors, but also to aspects such as hierarchic position and status. For instance, research by Allen (1977) suggests that people are more likely to communicate with colleagues having equal social status. This pattern is not only apparent within organisations. According to Rogers (1995), people's informal networks are largely homophilous, meaning that people largely talk to persons similar to themselves. One possible implication is that knowledge communication between organisations largely takes place between people in equal hierarchic positions. This can have a potentially limiting effect on access to new knowledge from outside the network clique, i.e. what Rogers and Agarwala-Roger (1976) call an interlocking network. Research by Hansen (1999) shows that "weak ties" contain low-intensive, but important, communication on knowledge, which gives new impulses to product development. Strong ties used for problem-solving, on the other hand, contain communication with much redundant knowledge. Thus, variations in knowledge communication intensity in product development play different and complementary roles.

Communication intensity can also be explained, as indicated by the discussions in 2.2.1, by the organisation's location structure. Allen (1977) found that a distance of more than some 30 meters drastically reduces the communication intensity between people on an office floor. Separation on different floors in a building has the same constraining effect. According to e.g. De Meyer (1991), geographical distribution reduces communication between people in R&D organisations. It makes it more difficult for people to interact, especially face-to-face. In addition, it is both costly and potentially exhausting to travel between different locations.

The discussion here indicates potentially large variations in communication intensity between organisations. There is obviously a strong subjective and relative element in the appreciation of intensity. Hence, it is rather difficult to define what constitutes intensive communication. Yet in order to make comparison in this study possible, it is necessary to use a definition of communication intensity. In the literature, there are a few different attempts to create scales in order to measure communication intensity within and between organisations. For instance, Gupta and Govindarajan (2000), Hansen and Løvås (2004) use a seven-degree scale that spans from daily to several months. Allen (1977) used a communication intensity scale with four intervals: daily, twice a week, weekly, and less often. This study pragmatically builds on Allen (1977) and develops a scale with three levels of intensity: high (daily), moderate (weekly), and low (less than weekly).

Summary of communication intensity:

➜ Relative network position and the number of contacts between organisations influence communication intensity.

➜ Intensive communication is essential for problem-solving, while low-intensive communication with peripheral actors is a potential source of new knowledge.

➜ Intensity is here defined as high (daily), moderate (weekly), and low (less than weekly).

2.3.1.3 Communication richness

Media richness is a school of thought within the field of communication research, which emphasises richness as a measure of communication capacity. According to this theory, richness in communication has important implications for an organisation's problem-solving capacity (e.g. Daft and Lengel, 1984). Tatikonda and Stock (2003) suggest that the choice of communication media is highly influential for the knowledge communicated between organisations. Organisations facing highly uncertain and complex situations such as those characterising many product development collaborations need high communication richness. Conversely, problems with low complexity and uncertainty require little communication richness (Daft and Lengel, 1986).

According to literature, the richness in communication depends on the medium's ability to transfer multiple languages, the pace of feedback, language variation and individualisation of messages (Daft and Lengel, 1984). The combination of these factors creates conditions for dynamic communication, with more or less opportunity to make corrections and add additional information in order to make sense of the received message. Rogers and Agarwala-Rogers (1976) call communication with direct feedback 'synchronous', and 'asynchronous' if there are time delays. Face-to-face communication is therefore synchronous and written communication may be asynchronous (Collins, 2003). However, different forms of electronic communication may enhance feedback in written communication (Nittmar, 2000). The reason is the capacity of almost real-time communication of messages – such as e-mail.

Rapid feedback enables several iterations between actors (Dennis and Kinney, 1998). In that sense, richness is a factor related to communication intensity. Multiple languages refer to possible combinations of verbal and physical languages, e.g. verbal communication supported by gestures and visualisation that can be used in order to transfer a message. In written communication, e.g. computer-aided communication, the use of multiple languages is limited, which means lower richness (Daft and Wiginton, 1979). Different languages can complement one another since they have different capacity to carry different types of messages. For example, verbal language lacks the precision of computer code, but contains more nuances. Individualisation of messages refers to the capacity of the medium to provide opportunities to e.g. ask questions and thereby receive answers to specific questions.

The richness in different forms of communication is summarised in the following table:

Communication medium	**Richness level**
Face-to-face	High
Video conference Telephone	Moderate
Written documents	
Numeric documents E-mail	Low

Table 2: Forms of communication and media richness (after Daft and Lengel, 1986; Rognes, 1999)

Face-to-face communication is the medium with the highest capacity for richness, which makes it useful in highly complex situations, requiring communication of tacit knowledge (Murray and Peyrefitte, 2007). In stable situations, face-to-face communication is partly replaceable with other means of communication such as telephone and e-mail (e.g. Tushman, 1978; Galbraith, 2000). Media such as telephone and video conferencing have moderate richness capacity, while e.g. e-mail has low capacity (Rognes, 1999).

In the literature, the social environment, for example colleagues' attitudes and behaviour, influence the media choice (Fulk and Boyd, 1991). If, for example, there is a positive attitude toward the use of e-mail, it can be expected to positively influence individuals' use of that media and vice versa. According to Harris and Nelson (2008), people's willingness to share knowledge openly influences e.g. speed of feedback in communication. This means that a combination of attitudes toward different media and perceptions of the situation influence the communication richness realised in collaborations.

Furthermore, the media richness theory provides one explanation of why co-location of people enhances the quality of communication (Moenaert and Caeldries, 1996). Meaningful communication also requires that the receiver is capable of understanding the communicated message. For instance, shared language and knowledge symmetry between sender and receiver influence the effectiveness of communication. In addition, personal affection and trust are factors influencing the communication, both within and between organisations (Johnson and Chang, 2000).

The media richness theory can also shed important light on communication across organisational distance. It is well known that as a response to distance, people and organisations use different information systems (Trevino et al., 1987). For instance, large organisations use information systems such as intranets in order to communicate with their employees (Harris and Nelson, 2008). As pointed out by Moenaert et al. (2000) the deployment of information systems creates an infrastructure that enables low communication costs and enhances transparency between dispersed organisational units. The low-cost communication and high transparency potential have obviously important implications for product development collaborations. Amami and Beghini (2000) suggest that the use of information technology in product development expands the capacity to communicate large volumes of data between organisational units. For instance, advanced CAD systems make it possible to work in parallel on the same blueprint while being located in different parts of the world. Nittmar (2000) showed that intensity in communication was enhanced between companies when a new information system was implemented. One shortcoming, however, is the limited communication richness achieved in information systems.

Summary of communication richness:

➜ Media richness concerns the capacity of different means of communication to enable speed of feedback, multiple languages, language variation, and personalisation of messages.

➜ Media richness capacity ranges from high (face-to-face communication), moderate (e.g. telephone), to low (e-mail).

2.3.2 Definition of knowledge and its dimensions

Since this study is concerned with knowledge communication, it is of course important that the theoretical framework include a discussion of the term knowledge. Therefore, the discussion here outlines different dimensions of knowledge. First, however, this section presents the study's definition of the term 'knowledge'.

A common definition of knowledge is "*justified true belief*" (e.g. von Krogh et al., 2000) – which originates from Plato. According to this definition, in order to know something, it has to be true, believed to be true and justified as true. This definition has been criticised because it is not very practical. First, in order to have knowledge, it must be true. Second, it also has to be believed in order to exist in people's consciousness. However, what is believed to be true is not necessarily true, if there is a chance that the belief is mistaken (Nonaka and Takeuchi, 1995). So how can we be sure our beliefs are not mistaken? Third, the idea of justification concerns ensuring that what is believed to be true is based on legitimate grounds (Tell, 1997). The problem is how we can know for sure that justification has reached a point which justifies the claim that what is believed to be true also is true. Possibly we can never know for sure that something really is true. From that perspective, the traditional definition of knowledge is difficult to use.

Instead, a more pragmatic view is of knowledge as a process of continuous "*justifying personal belief toward the "truth"*" (Nonaka and Takeuchi, 1995, p 58). From that perspective, knowledge is a resource constantly changing through reflection and interaction with e.g. theories, values and practical experiences. The implication is that much knowledge existing today is likely to be different tomorrow.

In order to develop a conceptualisation of knowledge useful for this study, the discussion here addresses different dimensions of knowledge. First, it focuses on three different categories of knowledge. Thereafter, it discusses the explicit and tacit nature of knowledge. In the third part, it elaborates on the explicit and tacit nature of the knowledge categories. Finally, the discussion addresses the issue of individual and organisational knowledge.

2.3.2.1 Categories of knowledge

In product development, companies use different knowledge in order to generate concepts, create design and validate performance. Some knowledge comes from research in e.g. physics, and other knowledge comes from experience of similar development projects. A useful point of departure for the discussion of knowledge here is thus to outline different categories of knowledge. The following builds on Aristotle's conceptualisation of different knowledge categories – *episteme*, *techne* and *phronesis* (e.g. Flyvbjerg, 2001).

Episteme is scientific knowledge that explains causal relationships and eternal principles, i.e. knowing how and why. In this thesis, this kind of knowledge is referred to as theoretical – for example, the physical laws of gravity. *Techne* refers to knowledge that is for practical use, e.g. know-how for solving a particular problem. Thus, *techne* can be understood as the skills used for conducting e.g. tests of prototypes during a development process. *Phronesis* is also practical knowledge, but concerns the underlying values guiding human action. There is no modern term that really translates the meaning of *phronesis* (Flyvbjerg, 2001). However, according to Dunne (1993) *phronesis* is knowledge for action, based on experiences. It is knowledge that influences how skills are used. In this study it refers to knowledge influencing how the individual chooses to act e.g. in order to solve engineering problems together with colleagues during product development collaboration.

2.3.2.2 Explicit and tacit knowledge

A classical dichotomy in the literature about the nature of knowledge is between explicit and tacit knowledge (e.g. Nonaka and Takeuchi, 1995). Johannessen (1999) refers to explicit knowledge as articulated in e.g. documents. He refers to tacit knowledge, or what Polanyi (1966) calls tacit knowing, as embedded in practice and difficult or even impossible to describe with words. Of interest for this study is explicit knowledge such as blueprints, and tacit knowledge such as the skills used for creating the blueprints.

The relationship and difference between the two knowledge types, explicit and tacit, has been in focus for extensive debate. Cook and Brown (1999) argued that explicit and tacit knowledge are two distinct types of knowledge. From that point of view, one type of knowledge is not convertible to another. According to another view, explicit and tacit knowledge are not mutually exclusive categories (Polanyi, 1966). Tsoukas (1996) argued that tacit and explicit knowledge are inseparably related. According to them, explicit knowledge is based on tacit components. Tacit knowledge cannot be articulated, but it is manifested in what we do and what we say (Tsoukas, 2005). Nonaka and Takeuchi (1995) argued that knowledge can be converted both ways – from tacit to explicit and from explicit to tacit.

This study takes the perspective that there is no clear distinction between explicit and tacit knowledge. Similar to Nonaka and Takeuchi (1995), the view here is that tacit knowledge can be articulated and thereby converted into explicit form and explicit knowledge can be converted into tacit knowledge. This means that what is tacit and what is explicit knowledge can change over time and vary between different individuals and contexts (e.g. Richtnér, 2004).

2.3.2.3 The explicit and tacit nature of different knowledge categories

The discussion of knowledge has so far pointed at different knowledge categories and the explicit and tacit nature of knowledge. The question asked here is: how are explicit and tacit types of knowledge related to the three knowledge categories?

Theoretical knowledge consists of e.g. scientific results that can be largely verbalised and expressed in written documents. Hence, theoretical knowledge is explicit (Flyvbjerg, 2001). However, following Spender (1996), the individual's tacit knowledge as well as the research community's values and norms influence interpretation of such knowledge. That is, although theoretical knowledge revolves around its explicit form, interpretation is largely inseparable from tacit dimensions.

A skill refers to knowing how to perform certain actions, which takes practice to develop (Göranzon, 1995). Skills are partly possible to codify in e.g. process descriptions, but the skilled performance is based on tacit knowledge (Polanyi, 1958; Dunne, 1993). For instance, a chef can write a recipe, but this does not mean that a reader can replicate the originator's dish. There may be years of experience that have generated skills which enable the chef to e.g. create certain flavours.

The concept of *phronesis* refers to knowledge used for making judgements about e.g. how to act in a given situation. It is embedded in the values guiding activities, i.e. the use of skills. This kind of knowledge is tacit in a more profound way than skills. Yet individuals with similar backgrounds – e.g. profession or experience from the same organisational context (Flyvbjerg, 2001) – can largely have it in common.

The knowledge communication of interest in this study takes place between companies – the knowledge content is both individual and embedded in the organisations. It is therefore important to complement the discussion so far with views on the distinction between individual and organisational knowledge.

2.3.2.4 Individual and organisational knowledge

A central theme in the debate on knowledge is whether there exists any knowledge outside the individual – i.e. to what extent it is meaningful to think of organisational knowledge.

Some researchers argue that knowledge can only exist within individuals (e.g. Simon, 1991). According to this view, organisations cannot learn. The contrasting point of view is that organisational knowledge does exist in the form of e.g. routines, strategies and technology (Levitt and March, 1988).

A moderating view is that knowledge exists on both the individual and the organisational level (Spender 1996; Tsoukas, 1996). Ekstedt (1999) has expressed a similar view and argues that knowledge is embedded in organisations, individuals, and documents, as well as artefacts. Spender (1996) argued that the individual's knowledge is dependent on its social context. At the same time, activities within a social context reflect individuals' knowledge. Therefore, the organisation's capacity to take efficient action is largely influenced by to what extent the individuals share the same social knowledge (e.g. Tsoukas and Vladimirou, 2001). Hence, there is an important overlap between individual knowledge and organisational knowledge.

It is possible to relate individual and organisational knowledge to both the explicit and tacit dimensions. As Spender (1996) and Richtnér (2004) argued, explicit and tacit knowledge can exist on both the individual and the organisational levels. Explicit knowledge exists in a tangible sense in e.g. documents and artefacts on both levels. Tacit knowledge exists within individuals in the form of e.g. skills (Polanyi, 1958). On organisational levels, tacit knowledge refers to e.g. collaborative values, norms and activities that several persons share. The tacit nature of much organisational knowledge makes it sticky and hence difficult to localise and transfer to external actors (e.g. Szulanski, 1996).

The aspects of knowledge mentioned here have important implications for how companies communicate knowledge in product development collaborations. Building on this section, in the following the term 'knowledge communication' is further elaborated.

2.3.3 Knowledge communication in product development collaboration

This section further elaborates how the study addresses knowledge communication in product development collaboration. The point of departure is the discussion and definition of knowledge communication in section 1.2. Based on that and this chapter's discussions of communication and knowledge, the following focuses on aspects of knowledge communication in order to make this study operational.

First, the treatment elaborates the differences between the term knowledge communication and the more traditional terms transfer and exchange. Second, it addresses the practical relevance of the term knowledge communication. Third, it discusses the scope of knowledge communication in product development collaboration. Fourth, it refers back to the discussion of knowledge types in 2.4.2, and discusses aspects of communicating explicit and tacit knowledge.

2.3.3.1 The relevance of the term knowledge communication

The discussion here develops the relevance of the term knowledge communication for the present study. The relevance is justified for two major reasons: the shortcomings of existing terminology, and this term's application in practice.

In the literature, the term knowledge transfer is commonly used to describe how knowledge is distributed within and between organisations (e.g. Kogut and Zander, 1992; Szulanski, 1996; Almeida, 2005). The term knowledge transfer implies that knowledge flows one way – e.g. from one project to another (Lindkvist, 2001), from product development to manufacturing (Twigg, 2002), from one company to a competitor (Zander, 1991), between collaborating companies (Simonin, 2004). A term related to transfer is knowledge exchange. For instance, Dyer and Nobeoka (2000), Praise and Henderson (2001), and Praise and Casher (2003) use the term technology exchange to describe reciprocal knowledge-sharing. Compared to transfer, knowledge exchange emphasises reciprocity, which makes it more relevant to product development collaboration. The reason is that product development requires knowledge not only to change location, but also to undergo several iterations across organisational boundaries in order to solve common problems (Sheremata, 2000). The difference between these two terms is the direction of knowledge flows, and it is an important distinction. Although much literature on knowledge transfer would argue that the term includes exchange (e.g. Inkpen and Dinur, 1998), the precision in terminology is questionable in those cases.

Regardless of this difference, the terms knowledge transfer and exchange have in common that they do not focus on the activities enabling knowledge distribution within and between organisations. As Carlile (2004) argued, these terms focus on the phenomena, not the process in practice. For instance, both knowledge transfer and exchange imply that the knowledge sent is the knowledge received. The literature recognises that this is often difficult to ensure (e.g. Simonin, 1999). One important reason is that interpretation of knowledge is context-dependent (Spender, 1996). That is, it is not necessary or even likely that the receiver makes the same interpretation as the sender. This is not even certain concerning explicit knowledge such as artefacts. For example, a written document is explicit knowledge reflecting underlying tacit elements (Tsoukas, 1996). The receiver's interpretation of the document, and how it responds to the sender, is influenced by his/her tacit knowledge, which is largely context-dependent. The implication is that the sender and the receiver of a document may make rather different interpretations. This is problematic in product development work where the receiver is supposed to build on e.g. the blueprint from a partner company. This implies that in order to transfer product knowledge of any magnitude for productive use, it is necessary that both the sender and the receiver share important contextual knowledge (Boisot, 1998). However, the terms knowledge transfer and exchange do not explain how the transfer/exchange is accomplished. Therefore, another term is required in order to address the issue of distributing knowledge between companies in practice.

Initially, this study did not intend to use the term knowledge communication. However, it was realised during the case studies that, on the operational level in collaborations, engineers and project leaders tried to communicate knowledge to colleagues in the partner company. This communication concerned a range of issues regarding product technology and the development process. For example, the companies discussed interpretation of new blueprints, accomplishment of integration between subsystems, and application of different software tools. Hence, communication revolved around knowledge residing within the companies and of practical relevance for the collaborations. Therefore, the term knowledge communication appeared relevant.

As mentioned in section 1.2, the term knowledge communication builds on Hedlund (1994), who used the term dialogue in order to explain transfer of knowledge. When the term knowledge communication was first introduced, the idea of using it found support in the product development literature, which emphasised the important role of communication in product development within companies (e.g. Brown and Eisenhardt, 1995). Among others, Leonard-Barton and Sinha (1993) also inspired this choice. They found that successful transfer of development results from a laboratory to a factory required mutual adaptation between development of the new technology and the production system. A high level of interaction made it possible, for instance, to fine-tune the production process to the requirements of the new technology and vice versa. This study assumes that communication of knowledge is of major importance in such mutual adoption, and thereby for transfer of knowledge. As mentioned in section 1.2.1, this is similar to the approach of Murray and Peyrefitte (2007) who studied how communication through different media facilitates transfer of different types of knowledge.

By choosing the term knowledge communication, this study focuses on the kind of activity that makes it possible for collaborating companies to share what they know during development of new products. Thereby, this study aims to complement the more commonly used terms transfer and exchange with one that is closer to practical action. Because, the main difference between the term knowledge communication and the related terms transfer and exchange is that the former is a kind of activity enabling the latter to take place.

Having discussed the theoretical and practical relevance of the term knowledge communication, the following addresses knowledge content communicated in product development collaboration.

2.3.3.2 The scope of knowledge communication in product development collaboration

This study assumes that knowledge communication in product development collaboration largely concerns the product's technology content and the process for accomplishing the development (see section 1.2.1). This section further elaborates the different kinds of knowledge communicated in product development collaboration between companies. It begins with the perspective of the industrial technology system as constituted by two types of technologies: horizontal technologies and vertical technologies (Karlsson, 2003).

Horizontal technologies refer to product functions – e.g. safety, comfort and climate, i.e. the product's functionality. Underlying such technologies is knowledge about integration of specialised technologies, as well as design and concept development, concerning the integrated product. The companies developing and manufacturing horizontal technologies are referred to as OEMs. Vertical technologies refer to specialised areas of knowledge such as airbags, brakes and engine parts. Companies developing and manufacturing vertical technologies are system and component suppliers (Karlsson, 2003). As indicated in section 2.1.2, it is expected that these technology dimensions have implications for knowledge communication between companies.

Building on this distinction between horizontal and vertical technologies, the study makes assumptions about implications for knowledge communication. First, it assumes that collaboration on development of horizontal technologies concerns issues such as the principles for design of the entire product. Hence, the content of knowledge communication is very advanced and largely related to what Prahalad and Hamel (1991) call the company's core competence. Second, knowledge communication in collaboration on vertical technology is expected to revolve around interpretation of technology specifications, interfaces between different subsystems, and specific technology solutions' performance. Thus, the knowledge communication's breadth and depth may be more limited than is the case with collaboration on horizontal technologies (Grunwald and Kieser, 2007).

Concerning both horizontal and vertical technologies, knowledge communication is also expected to deal with aspects of organising the development process. The reason is that companies have their own ways of e.g. running tests and distributing information, which may be more or less incompatible with those of a partner company (Dougerthy, 1992; van Echtelt, 2008). Research by Kale and Singh (2007) demonstrates learning how to manage processes in the collaboration is critical for performance. Common process knowledge concerns e.g. manuals, routines and tools for e.g. co-ordinating product design processes. Hence, such process knowledge is of importance to product development collaboration, and this study expects it be an important content of knowledge communication.

Based on the discussion above, this study defines the scope of the knowledge communication investigated. It can be summarised as:

➜ Product technology knowledge, which includes different systems levels – product system, subsystems, components and interfaces between different systems.

➜ Development process knowledge, which concerns organisational aspects – e.g. when to run tests, how to evaluate designs, and when to start planning for production.

The discussion here has revolved around the different kinds of content in scope for knowledge communication. Two important dimensions of such knowledge are the explicit and tacit forms. Thus, for this study it is necessary to address aspects of communicating explicit and tacit knowledge.

2.3.3.3 Communication of explicit and tacit knowledge

This study, as mentioned in section 2.4.2.2, sees knowledge as consisting of two different types, explicit and tacit (e.g. Nonaka and Takeuchi, 1995). The focus of this section is on principal aspects concerning communication of these two types of knowledge between companies.

Notwithstanding the common challenges of interpretation, explicit knowledge is often technically relatively unproblematic to communicate, because it is e.g. expressed verbally, in artefacts or in text (e.g. Kogut and Zander, 1992). For instance, blueprints, computer code and manuals are packages of explicit knowledge. Indeed, a book contains knowledge made explicit by the author. The nature of much explicit knowledge makes it easy to distribute through e.g. the use of information systems. One implication of distributing explicit knowledge in digital form is the capacity to reach many persons with large volumes (Evans and Wurster, 1997).

As noted in 2.4.1.1, a crucial issue in communication is to what extent the receiver understands the message from the sender. Language clearly plays a fundamental role for the interpretation of explicit knowledge. On the most basic level, a lexicon can define the meaning of terms, and thereby enable communication of knowledge. The information-processing approach builds on this view of interpretation complexity (Galbraith, 1973; Nadler and Tushman, 1987). However, words describing knowledge developed in different contexts may not be translated through a common lexicon. There may be semantic variations, which give different meaning to the terms used. Hence, the receiver may interpret the knowledge communicated rather differently. Different interpretations of meaning can be translated e.g. through negotiations on a common definition (Carlile, 2004).

However, much tacit knowledge is not easy to convert into explicit forms and is thereby more difficult to communicate (e.g. Zander and Kogut, 1995). This does not mean communication of tacit knowledge is impossible (Ambrosini and Bowman, 2001). Carlile (2004) argued that the greater the difference in e.g. product knowledge between two organisations, the more effort is required for knowledge-sharing. One way to enable communication of tacit knowledge is dialogue with time for reflection (Hedlund, 1994). According to this view, communication face-to-face enables people to share their thoughts with peers, and through "collective reflection" their different tacit elements can be shared (Nonaka and Takeuchi, 1995). Hedlund (1994) illustrated this with the example of teachers using dialogue in order to help students articulate what they know, but cannot easily express.

Concerning tacit knowledge, such as many skills, communication through dialogue and reflection is not enough to make it common (Spender, 1996). For instance, professional knowledge is largely only expressed in action (Schön, 1983). Such knowledge is largely tacit because, whether it concerns individuals or organisations, its constitution is experience of practice. One illustrative example is the Toyota production system. Lean production is a concept well known, yet it is not likely that any other company has managed full replication of Toyota's production capability.

Following Nonaka and Takeuchi (1995), it is reasonable to believe that communication activities may need observation and imitation as complements. For instance, a company that wishes to learn how to integrate a new technology in one of its products can send people to a partner company in order to observe how integration is accomplished. They can thereafter bring that knowledge back to their home organisation in order to imitate the partner's practices. This is not the same as copying, but rather what von Krogh et al. (2000) call re-creating knowledge in a new environment. This combination of observation, imitation and dialogue is the classical principle used by masters' training apprentices. Thus, communication of tacit knowledge may require a process of dialogues in combination with time for reflection and shared practice.

In brief, communication of explicit knowledge is often relatively easy to accomplish technically. However, interpretations of explicit knowledge may require communication of tacit knowledge elements. Hence, although explicit and tacit knowledge may be analytically separable, in practice they are largely inseparable.

Summary on communication of explicit and tacit knowledge:

➜ Explicit knowledge can be communicated through e.g. documents and artefacts.

➜ Tacit knowledge can sometimes be made explicit through creation of common semantic understanding of words and thereby communicated in e.g. documents.

➜ Tacit knowledge, which is very context-specific, can be communicated through face-to-face dialogues in combination with time for reflection – complementary observation and imitation of action may be required.

Now the building blocks of the investigation model are in place. The following sub-chapter will build on the discussions so far in order to construct this study's investigation model.

2.4 Investigation model

The investigation model presented here builds on the theoretical discussions in this chapter. It is a conceptualisation of factors and relationships regarded as important to address in order to enable the realisation of the study's purpose.

The purpose of this study contains several aspects, which means it is necessary to realise the study through a sequence of analyses. The study addresses four research aims in order to accomplish the purpose (see section 1.5):

1. Explore integration mechanisms of different types that influence knowledge communication in product development collaborations between companies.
2. Analyse how identified types of integration mechanisms influence knowledge communication in product development collaborations between companies.
3. Explain why identified types of integration mechanisms influence knowledge communication the way they do in product development collaborations between companies.
4. Explore and analyse factors moderating identified types of integration mechanisms' influence on knowledge communication in product development collaborations between companies.

The investigation model is developed in order to make these research aims operational.

This section first introduces the investigation model and briefly describes its major content and relationships. Thereafter, it elaborates its different parts, presents operationalisation of its different factors, and describes where in the analysis the different parts are addressed.

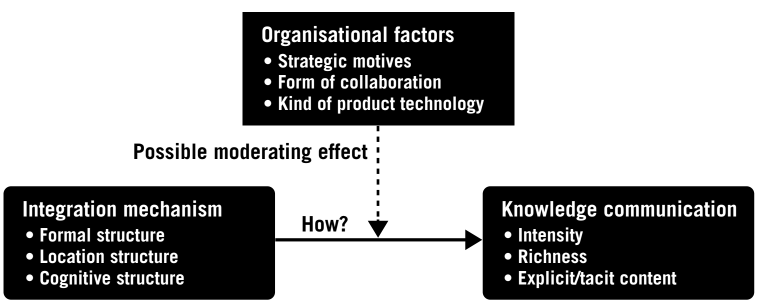

Figure 4: Investigation model

The investigation model is an overarching conceptualisation of the expected relationships between factors with potential to influence knowledge communication between companies. This study presumes that different structures constitute (1) integration mechanisms. Through these structures, integration mechanisms influence

(2) knowledge communication. The influence on knowledge communication is conceptualised as intensity, richness and content. Hence, this model focuses on a causal relationship – integration mechanisms' influence on knowledge communication[2]. This model also addresses factors in collaborations' organisational context that possibly (3) moderate the influence of integration mechanisms on knowledge communication.

The following elaborates the investigation model's different parts.

1) This study sees integration mechanisms as organisational interfaces, which are tools enabling knowledge communication. It assumes there are different types of integration mechanisms. In Chapter 5, in order to accomplish the first research aim, this study identifies different types of integration mechanisms. It is assumed that integration mechanisms are different because they have different structural characteristics. This study analyses how and why different types of integration mechanisms influence knowledge communication by investigating the role of (a) formal structure, (b) location structure and (c) cognitive structure. These structures are addressed in Chapters 5 and 6. Analysing these structures is important for accomplishing the second and third research aims.
    a) Formal structure of an integration mechanism concern e.g. the decision-making authority, the number of people involved, and their work integration. They are created by management decision – and have the purpose of enabling integration of activities between dispersed organisations (here companies). One such activity is knowledge communication.
    b) Location structure is conceptualised as co-located and distributed. Co-location means sharing of office space between the members of integration mechanisms. Distributed location means geographical separation of the integration mechanism's members, i.e. location of people in their different home organisations.
    c) Cognitive structure is term for collective conceptions of the collaboration structure, its product technology, and processes. They are expressed in the language used and the actions undertaken by the people from different companies. It is assumed here that an integration mechanism's cognitive structure cannot be created by managerial choice, because it reflects e.g. the organisational background of people involved. However, this study takes the view that integration mechanisms can change the initial cognitive structures over time.

2 The focus on integration mechanisms' influence on knowledge communication does not mean that this study assumes a static relationship between structure and process (or single activity). Hence, this study assumes that integration mechanisms and knowledge communication influence each other, over time. In focus of the present study, however, is the principal relationship between structures of integration mechanisms and knowledge communication – assuming a causal relationship. Underlying this choice is the assumption that integration mechanisms' structures are tools which managers largely can design in order to accomplish a certain effect, i.e. knowledge communication.

2) In this study, the intensity, richness and explicit and tacit types of knowledge content indicate knowledge communication influenced by integration mechanisms. Addressing these indicators is important for realising the second and third research aims – which is accomplished in Chapters 5 and 6.
   a) Intensity is defined as how often communication takes place. High intensity is to be understood as daily communication, moderate as weekly, and low intensity as less than weekly.
   b) Different communication media influence richness. Face-to-face communication indicates high richness, telephone and video conferences indicate moderate richness, and media such as e-mail indicate low richness.
   c) In this study, the knowledge in focus is product technology and development process knowledge. Product technology refers to the product system level, subsystem level, and interfaces between systems. Development process knowledge refers to skills, and routines used for realising development, e.g. how to run tests and validate product design. However, these areas in focus for knowledge communication do not indicate the quality of knowledge communication. Therefore, there is a need for another indicator. Both product technology and process knowledge contain explicit and tacit types of knowledge. Hence, the content communicated is in the form of explicit and tacit knowledge. This study takes the perspective that explicit and tacit knowledge are two qualities of knowledge communication. Therefore, this study defines indications of knowledge communication content as explicit and tacit knowledge.
      - Communication of explicit knowledge is indicated by sharing of documents and artefacts between companies. Explicit knowledge communication is observable in real time as it takes place, as well as retrospectively. For instance, the engineer receives or received a document with blueprint.
      - Communication of tacit knowledge is more difficult to indicate. The reason is that how it is communicated is difficult to observe and the effect on the receiver may be difficult to judge. The choice here is to operationalise communication of tacit knowledge as indicated by the combination of dialogues on knowledge such as product technology and development process, followed by perceived change towards more mutual understanding of the knowledge in focus.

3) The organisational factors investigated were discussed in section 2.1. They concern motives for engaging in collaboration, different forms of collaboration, and the kind of product technology developed. The study addresses whether and how each of these factors moderates integration mechanisms' influence on knowledge communication. It is presumed that the moderating effect may be positive or negative. That is, positive moderating effect refers to enhanced knowledge communication and negative refers to constrained. The study addresses the role of moderating factors in Chapter 7, and thereby the fourth research aim is accomplished.

This chapter has developed the theoretical framework and investigation model for this study. The next chapter, method, will describe the process of going from concepts to empirical investigation and analysis. It also discusses the research environment that has influenced this study and the issue of generalisation from the results.

3 Method

This chapter discusses the realisation of this study. The motives and considerations guiding selection of cases will be described as well as how the empirical investigation and the analysis were accomplished. Finally, it is discussed how the results from this study can be interpreted.

This chapter concerns how this study was conducted. It thereby takes the step from theory to the implementation of the research endeavour. In focus for the discussion are the principles regarding how the research purpose is made operational and is accomplished. Therefore, the following pages will discuss central issues that have influenced this study and how different sequences in the research process have been accomplished.

The chapter is organised in the following way:

1. The research tradition that has been the home for this study is introduced.
2. It is described how the study was made operational.
3. The process of entering the empirical field is discussed.
4. The process of collecting data is described.
5. It is discussed how the analysis of the different cases was conducted.
6. The process of cross-case analysis is described.
7. The final section focuses on how the results can be interpreted.

3.1 Research tradition

The research environment is the context that is likely to have the greatest influence on choices made during a research process. It is thus important to mention the major characteristics of the academic environment where this study has been accomplished.

The academic home for this thesis has been the Centre for Innovation and Operations Management at the Stockholm School of Economics. The group of researchers I belong to at SSE has a history of longitudinal in-depth case studies and clinical studies. The research tradition is characterised by issue-based research, primarily focusing on management issues in innovation and operations management (e.g. Åhlström, 1997; Rognes, 1999; Nittmar, 2000; Lindkvist, 2001; Richtnér, 2004; Söderström, 2004; Linnarsson, 2005; Nordin, 2005; Sköld, 2007). A large share of the research is carried out in close collaboration with companies – e.g. through direct participation in or through close observation of change processes. This means that the research projects aim both to develop academic knowledge and knowledge for managerial practise (Van de Ven, 2007). The main research interests concern changes within global OEM companies' operations – e.g. product platform strategies, efficiency strategies for product development, and implementation of production systems.

This research environment has both influenced and supported the methodological choices made for this study. As will be described in detail in the following sections, a case study methodology is used to accomplish the purpose of this study. The different case studies have been accomplished in close collaboration with companies. They have been characterised by what Earl (2006) describes as a sequence of exploration, examination of data, and validation.

3.2 Operationalisation of the study

How did the purpose of this study become operational? In the following two sections, the process of making the study operational will be discussed. The first part concerns the selection of methodological approach. The second part will describe how the cases were selected and what the motives were for choosing them.

3.2.1 Selection of a longitudinal multi-case approach

The investigation model presented in Chapter 2 proposes that the use of integration mechanisms and their capacity for communication is a result of several strategic, technological and organisational factors. In order to explore and explain underlying factors influencing integration mechanisms and their knowledge communication, it is necessary to access in-depth data. The aim is to open up the "black box" in the causal relationships – i.e. here between between integration mechanisms and knowledge communication (Van De Ven and Huber, 1990).

As discussed in the introduction, Chapter 1, we know little about different types of integration mechanisms used and their influence on knowledge communication in product development collaborations. It would therefore be interesting to study different cases in order to explore whether there are considerable differences between integration mechanisms and why and how they influence knowledge communication. This view is based on Glaser and Strauss (1967) who argue that maximising differences increases the chances of collecting varied data within categories.

However, there are both advantages and disadvantages with studying several cases. Voss et al. (2002) recognise that there is a trade-off between efficiency and richness of data when selecting the number of cases. It is difficult to determine the exact number of cases that constitutes the optimal trade-off between breadth and depth. That depends on the individual study. A motive for single case studies is that they enable the research to access in-depth data about a unique empirical event (Yin, 1994). However, limiting the scope to one case implies the risk of observer bias. Multiple cases may be helpful in order to balance against observer bias by providing data from several similar situations. Thereby, multiple cases give results that are more robust and increase the potential for generalising (Voss et al., 2002). For the purpose of this study, three different case studies were conducted. It might have been possible to conduct more cases. However, as will be explained in the next section, the three cases complemented each other. In addition, given the trade-off between conducting in-depth case studies and covering a larger number of cases, three complementary cases were considered to be enough.

Another important issue is whether a case study should cover a short period, be longitudinal, or be retrospective. For this study, the choice was to conduct longitudinal case studies but also to use retrospective data as complements. The reason for a longitudinal approach is that such case studies give the researcher an opportunity to develop in-depth knowledge on the case and to capture some dynamics of organisational change (e.g. Schein, 1987). Longitudinal case studies also give the researcher the opportunity to access rich data from several organisational levels and perspectives as well as to observe organisational development over time (Leonard-Barton, 1990; Van De Ven and Huber, 1990). It may for example be possible to observe changes in actors' roles, processes and attitudes (Pettigrew, 1990). Hence a longitudinal case study approach is valuable when trying to identify causal relationships in phenomena where the underlying factors and their relationships are largely unknown (Voss et al., 2002). Thus, it is considered a useful approach in order to uncover the relationship between integration mechanisms and knowledge communication in product development collaboration.

As mentioned, a longitudinal multi-case approach does not exclude retrospective data gathering. In fact, it may be useful to look back on events that happened during a longitudinal study, ask complementary questions, and e.g. read documents from that time. In this study, retrospective data gathering was used in order to investigate what happened before the case study began. In addition, after the longitudinal phase had ended it was valuable to complement data by asking new questions. For one case study, the retrospective approach became more substantial than first expected. The reason was that the studied collaboration was cancelled when the study had lasted only a few months.

3.2.2 Selection of cases

The selection of cases first concerns defining the population – i.e. the group of organisations – from which the samples are to be drawn (Eisenhardt, 1989). Selection of a population reduces variation of potential cases by clarifying the domain of the findings. This also defines the limits for generalising results from the study. The population investigated in this study is large manufacturing companies engaged in product development collaboration.

The first step in the search for cases was to define the general population of companies. In this study, the criteria for the population are:

➜ OEM companies developing new products in collaboration with another manufacturing company of fairly equal size – OEM or major subsystem supplier. The reason is to focus on collaborations of significant size and thus major organisational and product complexity.
➜ The central aim with the collaborations should be development of new high-technology products. The product should be either a complete product system or a major subsystem. Hence, knowledge complexity plays a major role in the collaboration between the companies. Thereby, organisational differences can be expected to be major challenges to the collaboration.
➜ The collaborating companies should be geographically separated – between an OEM in Sweden and a large company located in another country. The reason is to address the challenges associated with product development between dispersed companies.

Taken together the population is representative for a limited number of the contemporary larger industrial companies in Sweden. From this population the next step was to define a sample.

Theoretical sampling of cases is important in order to select cases that share certain characteristics. Yin (1994) argues that by using theoretical sampling it is possible to make theoretical generalisations based on the case studies. In contrast, if the cases have been randomly selected there is limited potential for generalising results (Eisenhardt, 1989). The reason is that it is difficult to compare the results between the studied cases. Therefore, the cases being selected should be expected to give either similar results, or contrary results but for predictable reasons (Voss et al., 2002). If there is little difference between the cases and they give similar results, it can be anticipated that the findings are true for other similar cases. Studying cases with expected differences in results for predictable reasons makes it possible to generalise to a broader population. This is not to say that the results necessarily are true for all possible cases in the population, but it enhances the robustness of results.

This study set out to identify different product development collaborations with contrasting characteristics. At that time, it was assumed that the level of knowledge exchange would be the factor to determine difference between cases. This choice was inspired by research by Mowery et al. (1996) who claimed that different kinds of collaboration can be expected to have different levels of knowledge transfer. It was motivated by the aim to investigate how companies managed to realise knowledge exchange in collaborations.

Hence, during the process of defining selecting cases, the term knowledge exchange was used instead of knowledge communication. The latter's relevance was not identified before the winter of 2005/2006, after approximately two years of case studies. This change in terminology reflects the insight that knowledge communication was the practical concern and was the means for accomplishing exchange. The change in terminology does not change the relevance of the cases, since communication simply replaced exchange when it was realised to be a better term. The case studies had also investigated communication patterns and content before it was decided that knowledge communication would be the key term. The reason was that this study anticipated, e.g. based on Allen (1977), that communication was an important aspect in order to understand knowledge exchange. In the following paragraphs, it is described how this study selected cases.

The selection of cases began by contacting four OEM companies located in Sweden, within the defined population. The names of the companies are made anonymous due to secrecy agreements that were necessary in order to enable the companies' participation in the study. In two of these companies, I contacted people I knew from previous work. That meant I immediately got access to persons working with tasks related to the research issue. The third company that was contacted was positive at first, but due to work overload it was decided not to continue discussions about a case study. Regarding the fourth company I met a representative for the company by chance and asked for a point of contact. After a few phone calls, I got in touch with a representative for the company's senior management who became interested in the research project I suggested.

The three companies that were willing to participate in a case study agreed to start with a pilot study. The case companies are here called Red Systems, Blue Systems, and Green Systems. The purpose of the pilot studies was to further develop the research issue and to identify potential cases. Therefore, during the spring of 2003 the pilot study was conducted at the three companies. It was at that stage possible to identify differences in collaborations' knowledge exchange – they were the same as for knowledge communication. Following the pilot studies, there were additional discussions concerning alternative cases in the companies, since all the companies had a couple or more collaborations of potential interest to the present study.

As it turned out, variation in knowledge exchange (later knowledge communication) was found in product development collaborations with different kinds of product technology being developed. These kinds of collaboration could be related to the innovation typology developed by Henderson and Clark (1990). Red Systems had a collaboration concerned with development of new architectural product technology, where knowledge communication played a major role in the daily operations. Green Systems was engaged in one modular product technology (subsystem) collaboration with a supplier, where a major concern was to enhance knowledge communication with a supplier. Blue Systems had a collaboration focused on incremental product development, based on an existing architecture. The companies in this collaboration shared rather little knowledge. Hence, this study set out to study three product development collaborations that developed different kinds of product technology, because they indicated differences in knowledge (exchange) communication.

Having identified case studies, the next step was to enter the field and start the empirical investigation.

3.3 Entering the field

Entering the field meant a choice of perspective on the cases. Three alternatives were identified – to address the collaborations from both companies' perspectives, from one company's perspective, or from within the collaboration organisation. The choice was to use a mix of these perspectives in order to obtain as nuanced data as possible, but to lean more towards the second alternative. This meant that the cases were studied mainly from one of the participating companies' perspective. Hence, the case studies focused on three case companies, Red Systems, Blue Systems and Green Systems, as to their experiences of collaboration and motives for participating. However, the partner companies' perspectives were also included in the case studies in order to validate data. The within-collaboration perspective was included since a large share of the data was collected from people engaged in the everyday operations in integration mechanisms.

There were three reasons for this choice. First, it was easier to gain access to people in the companies willing to participate in the case studies. The three companies mentioned supported this study because they expected to gain knowledge that could help them to improve their management of collaborations. Second, the geographical distribution of collaborating companies between several countries made it difficult to conduct longitudinal studies at all companies' sites. Third, the single company is the major actor in collaborations. It was thus regarded as interesting to focus on its experiences and capacity to influence its collaborations. In particular, it was expected to gain more practically relevant results through this approach.

Hence, it was decided that the main perspectives on the product development collaborations would be the Swedish-based OEM companies. In order to handle the risk of leaning too much on one side's perspectives, the partner companies were included in the empirical data gathering and their sites were visited during the case studies. Thereby, experiences of difficulties in understanding each other as expressed by one company could be validated with the other party in the collaboration. This issue is further discussed in the section concerning data collection.

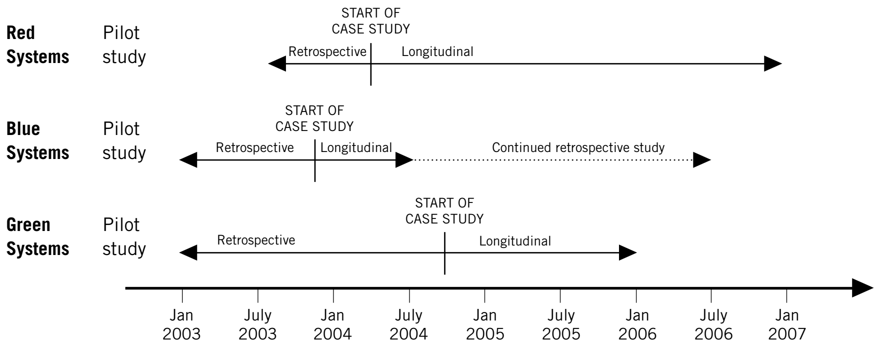

Figure 5 : Illustration of the time for the different case studies

After the pilot studies there was a period focused on the development of the study's theoretical framework. The first case study to begin was the Seeker, which was started up in December 2003. The Explorer case study at Red Systems began in May 2004 and the Mover case study at Green Systems began in August 2004. As illustrated in Figure 5, the Mover case study lasted approximately one year, and the Explorer and the Seeker case studies lasted about three years. However, the longitudinal part of the Seeker case study was only half a year. In June 2004, the collaboration was cancelled and the study continued with a retrospective approach – looking back to the beginning of the Seeker collaboration in January 2003 to the finalising in June 2004. The largely retrospective approach meant that the data obtained often had fewer nuances than in the longitudinal case studies. Also in the other case studies retrospective data were used, both interviews and documents. However, most of the data were collected during the time the cases were followed. The result is that the data from those case studies are more detailed concerning e.g. what topics were discussed during meetings. Including the pilot study and following interviews and dialogues, the case studies lasted for two and a half years. If additional workshops and follow-up interviews are to be included, the total time for empirical investigation was close to four years.

From the outset of this study, the ambition was to engage case companies in the research project. How this was accomplished will be described in the next section. However, it can be mentioned here that the motive for choosing close collaboration was to enable access to data through e.g. interviews over a long period. From the first contacts until the finalising of the case studies, almost four years passed. This would hardly have been possible unless the research issue was of general interest to the case companies. Since the case companies became interested in the research project, they offered substantial time for interviews and workshops. The obvious benefit with this approach is that it provided access to rich data and enabled me to become familiar with problems and perspectives important for understanding the cases.

The potential downside of a close relationship between a company and the researcher is a development of bias for the studied cases – e.g. the researcher overemphasising the importance of certain issues and adapting the respondents' views. It is therefore essential that both the researcher and his/her colleagues are aware of potential biases and critically consider how close relations with case companies may influence the individual research project. For this study, a thesis committee and colleagues have contributed comments on both design and interpretation of empirical results, which should reduce the risk for biases. Also the conceptual investigation model focused the empirical investigation on factors that were identified as theoretically interesting for the research purpose – which also contributes to the validity of the research. The investigation model at the beginning largely contained the factors included in the final version presented in Chapter 2. However, the relationships between them changed over time as new insights emerged concerning the possible causal connections. This did not influence the collection of data.

In all three case companies, senior management supported the case study. Without management support, it is difficult to see how access to people and data would have encountered so little friction. People who were asked to contribute with e.g. interviews expressed that, in their view, the top management's support meant that they could speak freely. There was, for instance, an openness and willingness to share both strategies and critique about managers and partner companies.

In order to support the case studies, a point of contact was established within each company. This person had senior management acceptance for supporting the case study. The point of contact acted as a door opener by spreading information to potential respondents whom I was going to contact and explaining why their participation in the study was important. On several occasions, the points of contact booked interviews with people in their own as well as in the partner company. As time passed, a personal network of respondents was established within each company. The networks consisted of key respondents, such as project leaders, who were valuable to have frequent contact with in order to follow developments over time.

Having established contacts, the next phase was to collect data. This process will be the topic of the following section.

3.4 Collection of data

Collection of data is the process of empirical investigation. It concerns a broad range of issues such as planning, choices of data sources and data gathering techniques. This section describes the process. The case study protocol that was used for the data gathering is presented in Appendix 1.

Theoretical categories were used in order to structure the data collection. Eisenhardt (1989) argues that using theoretical categories helps the researcher to achieve more focused empirical investigation, by specifying the kind of data to gather. The idea in this study was to focus the empirical work on those theoretical issues expected to be important to address in order to accomplish the purpose of the thesis. Based on the theoretical categories, a case study protocol was developed and used during the data gathering. According to Yin (1994), a well-designed research protocol enhances the reliability and validity of the case study's data. In this study, the case study protocol was to plan questions which should be asked and to determine which data gathering tools should be used for each aspect being investigated (see Appendix 1).

The same issues were addressed in all three cases – even though there was continuous modification of the case study protocol, which meant that more specific questions were asked. Over time, there was also some variation between the different cases concerning detailed issues, e.g. regarding particular work patterns in the collaboration. Both Glaser and Strauss (1967) and Voss et al. (2002) argue that a researcher should use the knowledge about concepts that emerge during a study in order to ask more well-informed questions. This interactive approach is important in order to move beyond what can be discovered by a snapshot survey. In this research project, the collection of data and analysis was an iterative process, where the focus of data collection was adjusted as the analysis gave new insights and raised new questions. For instance, as it was recognised that communication of knowledge was important in the collaborations, more questions concerned e.g. how people communicated, on what issues and when they communicated.

All interviews were based on the case study protocol in order to ask the same types of questions to all respondents (see Appendix 1). However, as some respondents participated in several interviews, variations of the original protocol were developed in order to address current and more specific questions related to those individuals' experiences. The majority of interviews was face-to-face and lasted approximately two hours. Respondents working abroad were largely interviewed by telephone. However, with key respondents a face-to-face interview was set up when they visited their offices in Sweden. In addition, people at the partner company were interviewed face-to-face during plant visits. The frequency of interviews with a few key respondents, largely project leaders and middle managers, was approximately every second to third month. At the end of each interview, the respondent was asked to comment on how he/she expected things to develop until the next interview. In the next interview, the respondent was asked to review the development since the last time. If something happened that was of particular interest for the study, interviews were arranged in order to cover the development more frequently than every third month.

Triangulation of data is useful for validation of case studies. This means using different sources of information in order to gather validate data on the aspects being investigated (Yin, 1994). An advantage with case studies is that they enable the researcher to access data from different levels and perspectives on the phenomena of interest. The following table presents the major sources of data used in the different cases.

Data gathering method	**Explorer case** Between Red Systems and Yellow Partner	**Seeker case** Between Blue Systems, Black Partner and White Partner	**Mover case** Between Green Systems and Far Partner
Interviews	Senior management: 2 (tot. 3 interviews) Middle management 7 (tot. 11 interviews) Project leaders 2 (tot. 9 interviews) Engineers 8 (tot. 10 interviews)	Senior management: 3 (tot. 3 interviews) Middle management 7 (tot. 12 interviews) Customer management 5 (tot. 7 interviews) Project leaders (incl. deputies) 6 (tot. 10 interviews) Engineers 2 (tot. 2 interviews)	Senior management: 5 (tot. 6 interviews) Middle management 7 (tot. 8 interviews) Project leaders 2 (tot. 7 interviews) Engineers 5 (tot. 9 interviews)
Documents	Contract Plans – development phases Organisational charts Work breakdown structure	Contracts Plans – development phases Organisational charts Work breakdown structure	Contracts Plans – development phases Organisational charts
Data feedback workshops	November 2004 May 2005 January 2006 November 2006	August 2005 April 2006 June 2006 March 2007	March 2005 May 2005 October 2005 December 2005

Table 3: Data sources used for the cases studies

Interviews were conducted with people on different organisational levels. The persons interviewed are divided into four categories: (1) persons involved with the senior management of the company, e.g. senior vice president for product development; (2) middle management related to the studied collaborations operations; (3) individuals assigned as project leaders that work with the management of the collaborations' everyday operations; (4) engineers assigned to work with the everyday technology development in the project. In addition, for the Seeker collaboration interviews were conducted with managers in the customers' organisation. The reason was that they played a rather active role during the collaboration between the companies. Interviewing people on different organisational levels was one way of obtaining triangulations. In order to complement the interviews with the Swedish OEM companies, I visited the partner companies for interviews with persons working in the collaboration project with the Swedish OEMs.

Documents were used in order to access complementary data, such as contracts, organisational charts and plans. These data gave access to formal statements concerning the relationship between companies. Contracts, for instance, were sources that expressed original intentions with the collaboration and the companies' roles. Hence they were valuable complements to respondents' views. Plans were, for example, illustrative for the commitment by the companies. All collaborations studied were expected to last five years or more, so the studied periods only capture a small part of the product development process. By and large, the documents studied provided contextual and background data, but gave little insight concerning integration mechanisms and knowledge communication.

Data feedback workshops played a vital role in the study. This was a way to receive comments on tentative results, to test ideas and conclusions, and to access complementary information (Earl, 2006). For the case companies, the workshops were used to access findings and conclusions. In each case study a sequence of data feedback workshops was arranged. In the first workshop, data were presented to a group of employees from the case company. The participants were all respondents. The data were presented in power point. The data content was ordered in major categories and subcategories. Following the first workshop, additional interview were made and documents gathered. The second was a later version of the first workshop – with some modifications from the first and new data. Thereafter, the data were analysed. The third workshop gave a presentation and discussion of the analysis. Building on the feedback from the third workshop, a final analysis was made. In a fourth workshop, the final analysis was presented to the case company together with conclusions and implications. In addition to the workshop, the final analysis was presented to senior managers in the companies, which generated discussions that contributed to the work with finalising the study.

Using different sources of data gave complementary views on the studied aspects. It could have been expected that there would be conflicting evidence from the multiple sources – not least from respondents in different companies. However, there were few disagreements on major aspects such as difficulties in accomplishing enough communication. By presenting the data for representatives from the involved companies it was possible to verify observations and to verify whether both sides agreed – which they did. This lack of conflicting evidence should not be interpreted to mean there were clear answers to questions from the beginning. It took several interviews and workshops in order to create a solid image of the situation in the different cases.

The companies' different perspectives meant that they partly searched for different explanations of situations. That is, although they could agree on e.g. having communication difficulties, the reasons could be different. For example, people from one company could say that the partner was somewhat arrogant, while the partner could say 'we have more experience and they do not understand how to deal with this situation'. This could be taken to show e.g. that different industrial experiences made it difficult to agree on what constituted the best solution. When findings like these were presented to groups of people from the different companies, it often led to discussions between the participants. During those discussions they typically agreed on their different interpretations and shared views regarding the situation, e.g. too little of communication on knowledge. Hence, such differences in the data do not provide conflicting evidence concerning what actually happened, only that it had different meaning for the companies.

This section has presented how the data were collected during the case studies. However, collecting data was only the first step in the study. The next section will discuss how the empirical findings were processed in the analysis.

3.5 Case analysis

This section will describe how the cases were analysed. It will first present how the analysis was conducted. Thereafter the analysis within each of the cases is specifically described.

There are different ways to analyse qualitative data. The approach used here builds on Glaser and Strauss's (1967) constant comparative method. In short, the idea is to have a continuous interactive process between data and theory. Data are gathered and coded, categories are developed, and then new data are added and gradually the categories are nuanced. Meredith (1998) argued that this kind of case study approach enables the researcher to enhance in-depth understanding of the studied phenomena. For this study, the aim of this iterative approach was to develop enough understanding of the studied cases to explain how integration mechanisms influenced knowledge communication. The following paragraph describes how the analysis process for this thesis project was conducted.

The first step in the analysis process was coding of the collected data as suggested by e.g. Voss et al. (2002). The data from interviews were coded on the same day or within a couple of days after the interview had taken place. The coded data were compared within each case study and empirical categories were developed. This was a continuous process but not as frequent as coding of interview results. The identified categories were gathered in a table. Based on this empirical categorisation a first draft of the case descriptions was written. Writing up the cases enhanced the understanding of the empirical material. It was also valuable in order to identify where further data gathering was necessary. It is of course difficult to determine when enough data have been gathered – but the pragmatic approach used was to stop collecting data when additional data did not have any particular impact on the different categories identified. For example, when the additional data only confirmed what was already known regarding the structure of an integration mechanism, any additional interviews were seen as unnecessary at that time. Later on, in the follow-up interviews, any change in the integration mechanism and its functioning was searched for.

Having developed the case descriptions to a level where additional data would make little difference to the content of the case, the following step was to analyse the patterns within each case (Eisenhardt, 1989). In this analysis, the investigation model was used in order to structure the data. The analysis was conducted through iterations between power point structures, with e.g. integration mechanism categories' characteristics, and development of written analysis. These two approaches supported one another. Power point was useful in order to create structures in the data and to identify e.g. key characteristics. Writing texts was useful because it nuances the thoughts developed through the initial structuring.

The analysis has four different steps, in order to accomplish the research aims defined in section 1.5. The first and second steps concern the analysis within the cases studied, which accomplished the first research aim and, partly, the second aim. The third step accomplished the second and third aims. The fourth step was conducted to realise the fourth research aim. The third and fourth steps were cross-case analyses, which are presented in the section after this.

These four steps, in practice, were not sequential but overlapping. The process from the initial analysis to the final version presented in this book lasted more than two years. It was characterised by both intensive periods and intervals of relatively little focus on the analysis. The intensive periods were important in order to push the analysis forward. The slack intervals were valuable for getting distance from the analysis and thereby enabling new approaches with some perspective on the previous period. The four steps presented here should be seen as an attempt to describe a rather complex, iterative and not always very structured process.

The first step, presented in Chapter 5, identified integration mechanisms within each case that influenced knowledge communication. The case analysis found eleven different types of integration mechanisms. In this phase of the analysis, different theoretical perspectives were used – largely theories of organisation and product development management – in order to address the characteristics of integration mechanisms.

The second step's first part was to analyse how each of the different types of integration mechanisms influenced knowledge communication. Thereby, the second research aim was partly accomplished – it was fully accomplished with the cross-case analysis, which is discussed in the following section. The results of this analysis are presented in Chapter 5. This part of the analysis focused on the knowledge communication indicators: intensity, richness, and explicit and tacit knowledge. The observed effects were related to the factors constituting integration mechanisms, in order to seek causal relationships between integration mechanisms and knowledge communication. Interpretations of how integration mechanisms influence knowledge communication emerged through the combination of empirical observations and theoretical reasoning. For example, it was observed in one of the integration mechanisms that people experienced that they received too little knowledge from the partner company. The analysis of knowledge communication indicated moderate intensity, low richness and mostly explicit knowledge shared. These effects, through support from theory, could be explained by e.g. the distributed location structure that made it difficult to achieve the knowledge communication necessary.

One central aspect of the integration mechanisms' analysis was to interpret data concerning the knowledge communicated. It was easy to observe indicators concerning communication of explicit knowledge, e.g. in the form of documents. For instance, in some integration mechanisms, people communicated blueprint approximately every week. However, as pointed out by Koners and Goffin (2007), operationalising tacit knowledge is difficult.

Chapter 2.4 presented how this study operationalise communication of tacit knowledge. The following extends that discussion. The approach in the present study is to look at the communication actions and experienced changes in understanding of the partner's knowledge. Von Krogh et al. (2000) argue that tacit knowledge can be made common through discussion where people share thoughts. As mentioned in the discussion on knowledge communication in Chapter 1, Hedlund (1994) used the term 'dialogue' with time for reflection to share tacit knowledge. In the studied cases it was investigated how people interacted, under what forms they communicated, and what knowledge was being discussed. For example, in one integration mechanism people from the collaborating companies used brainstorming in order to create a shared image of the product they were about to develop. The knowledge communication concerned how the development could be accomplished and how the technology could be designed. This knowledge was largely tacitly embedded within e.g. individuals' collective experiences. In the beginning of the collaboration, it was therefore not easy to understand one another. However, through e.g. brainstorming they were able to express ideas that they later discussed, analysed, and tested in models and even prototypes. This meant that there was time for reflection, new dialogues and additional reflection. It can be anticipated that such a process enables communication of tacit knowledge. The effect can be observed when people from different companies express that they have increased their shared understanding of e.g. the product design or the meanings of technical terms. That is, when people experienced greater understanding of a partner's knowledge, it was interpreted as an indication of communication of tacit knowledge.

3.6 Cross-case analysis

The previous section described the analysis of each of three cases. This section will deal with the cross-case analysis. The cross-case analysis was conducted in order to explore patterns across the cases studied. This means that it focused on continuing to accomplish the second and third research aims as well as the fourth.

The third step built on the analysis of the single integration mechanism's influence on knowledge communication. Hence, it focused on patterns concerning how and why integration mechanisms influence knowledge communication. The fourth step addressed organisational factors that were expected to have a potential moderating role in integration mechanisms' communication capacity. The cross-case analysis was important for developing propositions of causal relationships (Voss et al., 2002). It thereby aimed to accomplish the second, third and fourth research aims defined in order to accomplish the study's purpose.

This first cross-case analysis was accomplished by creating a table in which the main results from the analysis of individual integration mechanisms and knowledge communication were listed (see section 6.1). In the next step, the data in the table were compared in order to search for patterns that could explain how integration mechanisms influence knowledge communication. The observed patterns were compared with existing theories in areas such as organisational and communication research, so as to construct explanations grounded in both observation and existing knowledge. Through this process, it became possible to identify three factors (see Chapter 6) that can explain how integration mechanisms influence knowledge communication between companies. This was, however, not a straightforward process. The initial cross-case analysis was modified several times as new insights emerged concerning how and why integration mechanisms influence knowledge communication. The results of the third step in the analysis are propositions concerning the causal relationships between integration mechanisms and knowledge-communication effects.

The fourth step in the analysis process was to search for patterns across the three cases with focus on organisational factors that potentially moderate integration mechanisms' influence on knowledge communication. There are several techniques that can be used for analysing data across cases (Eisenhardt, 1989). The technique here was to use theoretical categories from the empirical investigation and compare them across the cases in order to search for patterns. Therefore, for each case a table was created with data for each of the theoretical categories. The process of identifying patterns across the cases was an iterative process – which meant revisiting both cases and theory and making several reinterpretations of patterns. Theories from different fields were used in order to develop explanations for the observed patterns. The final part of the cross-case analysis was to write up the text included in Chapter 7. It generates propositions concerning factors moderating integration mechanisms' influence on knowledge communication.

3.7 Generalising from the study

How can it be determined whether the results from case studies are generalisable? Generalization of a study concerns to what extent the results can be used to predict results in similar cases. This section will discuss how the findings from this study can be interpreted – how valid they are for explaining and predicting other similar cases.

One advantage with case studies is that they are useful for developing novel theory through in-depth investigation of constructs explaining a phenomenon. This is possible since case studies enable the researcher to get a detailed understanding of the empirical data (Eisenhardt, 1989). Such rich, well-grounded results are possible to use for development of hypotheses. The generalisability of a case study's results can be determined by testing the hypothesis on a larger population. This will give a statistical generalization. However, the generalisation from a qualitative in-depth case study is also possible without a statistical survey. Instead, theoretical generalization can be used – which means that the results are generalized against theory and previous research.

In order to build a ground for theoretical generalisation, it necessary to design case studies so that they are likely to generate results which plausibly have explanatory value beyond the particular case or cases (Yin, 1994). In this study, this was accomplished by using complementary cases – different levels of knowledge communication – and by relating results to existing theory. In order to make cases comparable, the same theoretical factors were studied in all three cases (see Appendix 1). This makes it possible to compare what is similar and what is different between the cases, as well as to develop plausible explanations for what the differences may depend on (e.g. Meredith, 1998). Thus, the complementary cases enable replication of results between the cases. This strengthens the reasons to believe that the results are valid beyond the single cases.

The results from the analysis are also compared with existing theories in order to enhance generalisability (Eisenhardt, 1989). This means that if theories can support the findings, it is more likely that the results are valid for other situations than the studied ones alone. The implication is, for example, that explanations for how identified integration mechanisms, such as co-located teams, influence knowledge communication are likely to be relevant to similar integration mechanisms used in other contexts. This is not to say that the findings in this study are true for all similar situations. Nevertheless, it is reasonable to believe that the results concerning integration mechanisms' influence on knowledge communication are valid for other situations than those investigated by this study.

4 The product development collaborations studied

This chapter describes the product development collaborations studied. It will introduce the background to the three collaborations, the form of collaboration that took place and how it was managed. The case descriptions will focus in particular on integration mechanisms and knowledge communication between the collaborating companies.

This chapter will present and describe the three case studies conducted for this thesis. The cases studied are product development collaborations between companies. The cases largely build on the perspective of one of the companies in the studied collaborations, which is further elaborated in section 3.3. In focus for the cases presented is how integration mechanisms influence knowledge communication.

The companies whose collaborations are studied are large OEMs located in Sweden. Their partner companies are located in other countries. Two of the Swedish companies are active within the defence industry and one operates on a market with business customers. The companies' names in this presentation are fictitious in order to ensure the anonymity of the companies being studied. The companies participating in the study requested anonymity and it was regulated in secrecy agreements. It has the advantage of enabling one to make detailed descriptions without having to consider whether, for example, the data contain details that may have an impact on the image of the individual company. One of the defence companies is called Red Systems, the other Blue Systems and the third company Green Systems.

- ➜ The first section of the chapter will present Red Systems' collaboration with Yellow Partner on development of product technology. The product is called the Explorer since the aim was to take a technology leap, to generate a new type of product architecture.
- ➜ The second case study describes Blue Systems' international collaboration. The aim of the collaboration was to develop a product, which here is named the Seeker. The Seeker was planned to become the next generation product within one of Blue Systems' major business areas, i.e. largely incremental change compared to previous products. For the other companies involved in this collaboration, the Seeker was a completely new product category.

➜ The third section presents the empirical findings from the case study on Green Systems' collaboration with Far Partner on the development of the Mover – a new subsystem of strategic importance for both companies. That is, in focus for the Mover collaboration was development of a product module. It was planned to be used in one type of OEM product and drastically improve its functioning.

The following table introduces the studied cases. It presents the main characteristics of the collaborations. The perspective taken is that these are factors constituting important conditions for integration mechanisms and knowledge communication.

Case characteristics	**Explorer case** Between Red Systems and Yellow Partner	**Seeker case** Between Blue Systems, Black Partner and White Partner	**Mover case** Between Green Systems and Far Partner
Collaboration background	Located in different European countries Distance approx. 2000 kilometres Same time zone Same industry Competitors on other products Limited previous collaboration Different national cultures Similar technology level Similar quality & cost values Different work processes Different technical terms Different national languages	Located in different European countries Distance approx. 200 and 700 kilometres Same time zone Related industrial backgrounds Not competitors No previous collaboration Related national cultures Asymmetric technology levels Different product quality & cost values Different work processes Different national languages	Located on different continents Approx. 20h travelling Six hours time difference Same industry – but different positions (OEM and supplier) Not competitors Major previous collaboration Different national cultures Complementing technology, asymmetric levels on key areas Different product quality & cost values Different work processes Different national languages
Strategic motives for the collaboration	The companies aimed to take a technology leap The task was to develop a new product architecture Both companies wished to take a leading position on the changing market Shared view on the relationship as a strategic partnership	No shared strategic motives Blue Systems aimed to meet customer expectations and remain in business Blue Systems wished to develop a new product generation Black Partner and White Partner wished to fill their order books & enhance competence	Both companies wished to take a technology leap The collaboration was seen as a way to realise first mover advantage Green Systems wished to reduce dependence on suppliers Far Partner needed to share R&D costs
Form of collaboration	Contractual agreement – vertical relationship Autonomous project structure – independent and co-located Each company owned its contributions – intellectual property Different levels of openness	Joint venture (phase 1) Shared project structure Contractual agreement Each company owned its contributions – intellectual property Different levels of openness	Contractual agreement Operator project structure – where the supplier has lead Shared ownership of intellectual property

Table 4: Introduction of the case studies

The outline of the case presentations is the following. Each case presentation begins with a short introduction of the companies, the collaboration's background, the strategic motives as well as the form of collaboration used. The development of collaboration is presented, and finally there is a detailed description of integration mechanisms and knowledge communication.

4.1 The Explorer case: product development between Red Systems and Yellow Partner

This case describes the management of the Explorer collaboration – with a focus on integration mechanisms between Red Systems and Yellow Partner – and how they influence knowledge communication. This case study includes both companies' perspectives, even though it is conducted with mainly a Red System focus.

In 2003, the defence company Yellow Partner, located in a major European country, invited Red Systems in Sweden to participate in development of a new product technology. The first contact was by people on middle management level from Yellow Partner. They contacted colleagues at Red Systems whom they knew from previous projects, and asked whether they could investigate whether Red Systems would be interested in collaborating on the proposed project. Red Systems found the proposal interesting since this was an opportunity for the company, both to develop new technology in strategic areas and to develop strategic industrial relations. In total more than 2 billion SEK were planned to be invested. The major costs, as is often the case in the defence industry, were paid by government procurement agencies.

The proposed collaboration aimed to take a technology leap, in order to test new technology for the first time and thereby build a knowledge base for future development projects. In focus for the proposed collaboration was therefore development of new product architecture as well as some subsystem applications. This included both physical structures and functional structures – and the interfaces between different subsystems.

The case study focused on the collaboration's conceptual design phase, which began in September 2004 and lasted until autumn 2005. In this phase, the overall architectural design was developed and selected. Work in the collaboration focused on the reduction of technical uncertainties and the establishment of the collaboration's organisation. Several companies joined the collaboration in the subsequent development phase. In the conceptual design phase, Red Systems collaborated only with Yellow Partner. The focus here is thus on the collaboration between those two companies. The case revolves around the organisation used in order to enable the collaboration, with focus on knowledge communication.

This case description has the following outline. The first section presents the background to the project. Next, the focus turns to the strategic motives driving the collaboration. Thereafter, the presentation focuses on the form of collaboration. Subsequently, the description concerns the development of integration mechanisms, after which there will be a focus on specific integration mechanisms and knowledge communication.

4.1.1 Collaboration background

Red Systems is a defence company located in Sweden, and the city is here called Home Town. The company has a background as manufacturer of complex OEM products for military forces. During most of the last century, Red Systems has focused on the domestic market and a few export markets. The customer played a very active role during the process of developing new products. As is often the case in the defence industry, the customer financed product development from the start, because companies are not able to take risks developing for an uncertain politicised market. Through the close collaboration with its national customer, today Red Systems is one of a handful of OEM companies in its industry.

Together with Red Systems and a couple of other companies, Yellow Partner is one of the leading providers of advanced military products in its area of operations. The two companies are competitors on the world market with their existing products. This, however, was not seen as an inhibitor to collaboration, since none of the companies would receive such a development contract alone from their national governments.

The companies' industrial and strategic backgrounds are similar in many important respects. Red Systems and Yellow Partner are two European OEM companies of fairly equal size. They operate in the same market segment, with a couple of thousand employees, and have a few billion SEK of revenue per year. Both companies are part of larger industry groups, in which they are very central parts, not least for the brands. Both companies have influential R&D departments, which are internationally well known for their capacity to develop state-of-the-art products. To both companies, product development collaboration is a relatively new phenomenon. The studied Explorer collaboration is one of their first major international development ventures.

After initial contacts during the summer of 2003 to start the collaboration, discussions continued on a middle management level with representatives from Red Systems' project management and managers on a similar level at Yellow Partner. It was not until late 2003 that the CEOs from Red Systems and Yellow Partner had their first contact regarding the Explorer. However, they had previously met and discussed a possible collaboration between the companies.

After the collaboration began, most contacts between the companies continued to take place on the operational level – the top management met approximately once a year. However, their support for the collaboration was made clear through discussions within the two companies.

The CEOs from Red Systems and Yellow Partner announced in 2004 that the Explorer project was seen as the first part of long-term collaboration between the two companies. The reason is that both companies considered the collaboration as a way to build a competitive position that would enable more collaboration on forthcoming products. After a year of negotiations about division of work, the two companies began the Explorer collaboration in September 2004.

4.1.2 Strategic motives for the collaboration

When Yellow Partner invited Red Systems to participate in the development, it was seen within Red Systems as an opportunity to really enter the new market segment and to build new technological competences in several areas. This included e.g. technology in the systems' advanced communication system and knowledge concerning its performance capacity. The collaboration was also considered an opportunity to build a new competence platform for future international deals and orders from the domestic customers. This platform was expected to emerge through the joint development of the Explorer's architecture. To Yellow Partner the strategic view was similar. The following elaborates the strategic perspectives.

The companies' market was going through a period of change. The change was characterised by consolidation, fierce competition and limited demand for the new generation of traditional products. There was a political process both in its domestic market and abroad to realise greater European collaboration. The process was driven by a shrinking market where no one government customer alone can afford to develop and purchase a new product generation. Instead, European collaboration was seen as a necessary development by both industry and governments in order to achieve economies of scale and to meet the competitive challenge from American defence companies.

In order to adapt to the changing market, Red Systems' strategic ambition was to achieve a central position in an emerging market segment and for expected consolidation in the industry. The new market segment emerged as result of a technology shift. The technology shift meant that forthcoming products would have rather different architecture compared to the existing ones. Underlying this development was both technology development, such as more powerful computers, and change in customer preferences. Facing this situation, with the ambition to remain a major player in its industry, Red Systems perceived it necessary to establish international collaborations. Yellow Partner's situation was similar and it was clear that collaboration was a necessary strategic move.

From a strategic point of view, Red Systems had the ambition to develop leading competences in a number of areas of technology related to the new market segment. In addition, the company was seeking to remain, and develop its competence as, an OEM, i.e. its system integration capability. To Red Systems this means that the company needed to be able to manage the parallel roles of being OEM and subsystem provider across different collaborations in its industrial network.

Employees and managers alike at Red Systems felt that starting the Explorer project was a significant step in the company's development towards the vision of future products. This vision was commonly shared by people in the company. It was widely regarded as the next step for the company. On a personal level to many, it was an opportunity to work with state-of-the-art technology.

To both companies the Explorer collaboration was seen as a way to leverage competences from different companies in order to take a technology leap which none of the companies could have accomplished alone with available resources. In addition to developing expertise in a new emerging technology area, Red Systems also wished to develop its competence in efficient development. The ambition therefore was to develop efficiency skills by adapting so-called commercial, off-the-shelf technology (COTS) and other military off-the-shelf technology (MOTS) for the Explorer applications. That kind of technology, having already been developed, was expected to cost less, but also to require a great deal of experimentation in order to create solutions meeting customer requirements. This philosophy may be illustrated with a quotation from one of the engineers engaged in the collaboration:

> "It is an experimental process where, for instance, MOTS and COTS technology is tested, reconstructed and tested again."

Both companies had the ambition to develop collaboration skills in order to adapt to the internationalisation of their market. Coming from a tradition of managing a vertically integrated industry structure, both companies had the need to develop new methods and competences in order to be able to manage future international product development collaboration.

Previously, the industry had struggled with international collaboration, with accelerating costs, quality problems and time delays of several years. A "vision" incorporated into the project was to demonstrate that it is possible to develop this type of product efficiently in international collaboration. The view at Red Systems at the outset of the project, therefore, was that close, integrated collaboration would force both companies to develop their collaborative skills.

4.1.3 Form of Collaboration

Formally, Yellow Partner was the main contractor and Red Systems was one of six subcontractors in the Explorer project. With its share of the total project being 25 percent, Red Systems was the only company that collaborated in the first phase, focusing on defining overall product architecture. The formal structure is illustrated by the following figure.

Figure 6: Work share in the explorer collaboration's design phase

The formal structure suggests that Yellow Partner dominated the collaboration. Internally, however, Red Systems considered its role as being that of a partner, a view also shared by Yellow Partner.

Among managers from Red Systems' R&D department, the conceptual design was seen as a major opportunity in order to become a "partner" in the development of the Explorer. One manager at Red Systems' R&D department describes this view:

> "You have to be onboard early in the development process in order to influence the design. This is important in order to keep the system perspective and the system integrator role, which is important for integrating weapon systems in the future."

In the early negotiations, Yellow Partner was reluctant to allow Red Systems to participate in the early concept development. They wanted to have control over the initial phase in order to be able to define the product architecture. However, Red Systems was determined to be engaged from the very beginning. One major reason was that active participation harmonised with Red Systems' strategy to optimise learning from the Explorer development. Yellow Partner agreed to give Red Systems an active and influential role, after a period of hard negotiations. The reason for this deal was that the two companies had worked together on previous minor projects. Based on that experience, Yellow Partner expected that Red Systems would contribute to the general architectural design. In addition, Yellow Partner needed someone to share the costs.

Contractually, the companies in the project were jointly responsible. This meant that even though Yellow Partner was the prime contractor, the other companies that would participate shared responsibility for completing the project. This is described by one of the Explorer's project leaders, who said that:

> "If one company causes a delay, all the others are responsible for solving it. So we are bound together – it is not possible to say that this is not our fault."

The companies developed an intellectual property right (IPR) framework for the collaboration in order to enhance integrated work between the companies. The IPR framework consists of four levels. It ranges from the first level with open information that both companies can use to the fourth level with information that the partner can see but cannot use.

This section has outlined the general aspects of the collaboration between Red Systems and Yellow Partner. The following will address more in detail how conditions for collaboration were constructed through division of work between the companies.

4.1.3.1 Division of work

The working relationship in the collaboration was regulated by a work breakdown structure (WBS). The WBS defined each company's work package. In total, nine major work packages were defined. During the collaboration phase with conceptual architectural design, the companies collaborated on all but one, which Yellow Partner was responsible for alone. Each work package was loosely defined when the conceptual design phase began, but it became clearer as the project proceeded. The work was divided up and decision-making authority was defined on a general project level.

The architectural design work was located in a joint organisation at Yellow Partner's plant, in the European city which here is called Metropolis. According to the project plan, the work on the joint organisation should focus on project management and technical integration. The joint work was divided between nine different work teams – one for each work package. Red Systems was represented in eight of these teams.

It was seen as necessary to work in an integrated way in order to construct a detailed design of the Explorer where all the systems function together. One of the engineers working with the joint development illustrates one important motive for the choice to work closely together.

> "By working together a shared world view will be developed." "It is important that we can understand one another, in order to enable development of such a complex product between our companies."

The underlying idea was simply that if the design work were performed within each company, there would be substantial problems with integrating the whole system. Experience from other similar projects was that lack of close collaboration in the design phase generates problems with integration of subsystems, driving up costs and causing delays for the whole development. Therefore, the shared work packages were expected to enable development of a shared knowledge platform, which was expected to make the development work more efficient.

In parallel with the joint organisation, in-depth technology development of subsystems would take place within the companies' home organisations. Thereby, the joint organisation had the roles of designing the product architecture and co-ordinating the two companies' in-depth technology development. For Red Systems, this meant that engineers worked in their home organisation – some full-time, others part-time – on detailed technology development for the Explorer. The design engineers working together with Yellow Partner directed the work content. During the studied phase, this co-ordination role was largely limited to initiating work in the home organisations.

The basic division of work – as negotiated at the start of the project – did not change during the phase under study. However, the details of the division and the interfaces between different work packages were gradually defined more clearly. The design of interfaces was complicated since it had to consider both the products' physical design and the functional architecture. It was therefore one of the major issues discussed by the project leaders.

Being the prime contractor, the Yellow Partner project manager ultimately had the right to make decisions about the project. This solution was chosen in order to avoid endless discussions that would hinder the progress of the collaboration project, which was the companies' experience from other collaborative ventures. The formal power over the collaboration, however, was not being used in the daily work; instead, as will be described later, decisions were mostly made in consensus between the project leaders. There was a project board with senior managers from Yellow Partner and Red Systems, who had the task of resolving conflicts that could not be handled "inside" the project. The aim was that this function should not be used on a regular basis – and during the conceptual design phase being studied, it was never used.

This section has presented the form of collaboration used between Red Systems and Yellow Partner. In particular, it has described the division of work in the collaboration. The following will focus on the development of integration mechanisms, which functioned as interfaces between two companies.

4.1.4 Development of integration mechanisms

The collaboration's organisation was established in September 2004, as the forum for direct contact between Red Systems and Yellow Partner. It was constituted by some twenty engineers, during the studied period. The joint organisation was co-located in one open office space at one of Yellow Partner's plants. The joint office space was expected to function as a mechanism for everyday interaction between two companies. The following will describe the main development of the collaboration between the two companies in the Explorer collaboration.

Red Systems had six employees working approximately every second week in the joint organisation. It was seen as vital that the persons working in the project were open-minded and interested in getting to know the partner company. Both companies had "hand-picked" people for assignment to the Explorer project.

In addition, two persons travelled frequently on an ad hoc basis. They were called down to Metropolis when their expertise was needed. Together with their colleagues from Yellow Partner, approximately 20 individuals used to work in the joint development organisation – but the exact number was constantly changing, depending on e.g. the kind of tasks addressed during a certain week. Each team was responsible for one major work package. One major task was to develop the technical specifications within each work package. Another major task was to develop technical solutions for integration of the technology developed within the different work packages. They were also distributing work-tasks to the home organisations dealing with in-depth technology development. For Red Systems, some 20 persons in Home Town worked with technology development for the Explorer, and this team was expected to expand as the collaboration entered forthcoming development phases.

In order to accomplish integration between the companies, it was seen as important that employees experienced the collaboration as valuable. In practical terms it was seen as necessary to have highly motivated employees willing to tackle challenges in an international collaboration. It was also necessary that key individuals from Red Systems were willing to move abroad to work. It was felt that a strategy process within Red Systems involving a large number of employees contributed to developing a sense of doing something important in the collaboration. The strategy processes had focused on Red Systems' long-term development of new technological competence. This meant that the proposal to join the Explorer collaboration was developed in order to fit these strategic aims. There was thus a well-known and accepted strategic rationale for involvement in the Explorer collaboration. People working with the development of the Explorer experienced that the strategic motives made sense and made them feel motivated to accomplish the collaboration.

4.1.4.1 Establishing the integrated work

During the first two months, those working with the Explorer development experienced the collaboration as quite intensive. It meant several joint work activities, such as workshops and attention to a broad range of technological and administrative issues. Thereafter, intensity slowed down for a couple of months, before gathering new momentum in January 2005. Relatively intensive collaboration continued until the autumn of 2005. The following describes the general development during the studied phase.

The joint work started with meetings between the engineers from the two companies. During the first two months a number of brainstorming sessions were used that dealt with the major issue: "*How do we design the Explorer?*" The approach to this question was open discussion. One of the project managers describes this attitude in the following quotation:

> "We have an open attitude to the system design. The idea is to define general architectural principles first."

The ideas about how to design the Explorer were generated on whiteboards and large papers. It was regarded as important to establish a number of basic principles for the architecture of the Explorer. The aim was to define basic technical principles, on a high system level, in order to avoid lock-in solutions. One such principle is using a modular product architecture that enables continuous updates of the subsystem without changing the vehicle's general architectural design.

After approximately one month of joint work, there was a pause due to a call for tender from Yellow Partner's customer. This interrupted the work in the teams at a stage where technical work had just begun. The tender was part of the process to reach an agreement for the project in early 2005. The tender process required a detailed definition and cost estimate of work packages, which turned the focus away from joint technical work. During the late autumn and early winter, the intensity of joint work was low with only a few meetings per month. The work on developing alternative designs, however, remained intensive with daily discussions between engineers from the two companies. After a few months of joint work, two alternative designs were presented. During the late winter and early spring, the main focus of the project leaders' collaboration was to reach an agreement for the development phase. However, from January 2005 the technical work continued with daily meetings and discussions around the shared tables, during the weeks of working together. During this period the team members from Red Systems and Yellow Partner worked together approximately every second week. In between the periods in Metropolis, the Red System team worked back in Home Town with the project.

One important milestone in the early phase was the signing of the contract for the collaboration between Red Systems and Yellow Partner in early April 2005. By that time, two alternative designs had been evaluated and one of them was selected as the main alternative for the following development. A concern, at that time, was the political uncertainty on whether the Swedish government would support the Explorer development. It was important that it would be expected, since Red Systems' share of the development costs would be financed by the Swedish defence budget. Those working with the Explorer development noticed the political uncertainty, but they did not describe it as a major concern. Instead, they were preoccupied with the daily challenges of creating a functioning development organisation.

4.1.4.2 Encountering differencies between the companies

One of the daily issues that both managers and engineers faced was misunderstandings because of differences in the companies' terminology. The members of Red Systems' team experienced early in the collaboration that there were differences in how the two companies interpreted the meaning of technical terms and concepts. For example, there were differences between the companies' notions of technical systems definitions, how they defined interfaces between systems, and what they called different activities during the development process. For example, the interpretation of the term 'PER'

(Product Design Review) was different. For Red Systems a PER was associated with certain documents that should be included in the review and a certain level of project progress. Yellow Partner associated the term with a different content and time in the project. In another example, Yellow Partner used the term 'computer modelling' for the computer tool handling technical specifications, while Red Systems used the term 'database' for the same thing.

One senior engineer explained the difference in interpretation and use of technical terms in the following way:

> "There are deep differences in the companies' conceptions of words, which are related to their history."

The industry in which the companies operate has largely been "national". This means that there are few "international" standards e.g. concerning definitions. One of the project managers said:

> "Defence companies had not told other companies how they solve technical problems. Keeping this secret has been a goal itself. The implication is that there is a journey to make before we talk the same language."

Typically, at meetings during the first months of collaboration, engineers from the two companies were talking about the same document but had a different understanding of its content. Both engineers and project leaders experienced that these misunderstandings slowed down the joint work. It also contributed to causing frustration among those working in the joint organisation. Therefore, in order to create a mutual understanding of the technology being discussed, meetings held during the first six months often began with a discussion on a basic level in order to define the main terms. Having agreed on how the terms should be interpreted, the work could continue with the focus on how the technology should be developed.

In order to improve the joint understanding of, for instance, technical terms, a work process began which aimed at the development of vocabulary for the project. The process began in May 2005 and was expected to last throughout the project as new terms emerged. The process was characterised by continuous discussions on how different terms should be interpreted. It was also a formal process, in the sense that there was documentation of terms when there was consensus on their meaning. The development of the vocabulary was described as an iterative process with reviews and continuous updates. Gradually, the development of a common vocabulary was experienced as contributing to development of increased common understanding among people from the two companies.

Having frequent meetings was seen as central for developing a shared language and for handling differences in perspectives on e.g. the work process. Meetings with 2–3 persons were regarded as more effective for progress than larger meetings. One of Red Systems' engineers working in the joint team together with Yellow Partner illustrated this in the following quotation.

> "Sitting down together has been important in learning to understand one another."

It was appreciated that working together gradually contributed to an increased level of mutual understanding. As understanding increased, the work process became easier. However, the misunderstandings remained an issue even after almost a year of collaboration. It was felt that the improvement in understanding of each other's company was associated with the development of personal relationships between individuals from the two companies. Having worked together for some nine months, one of the members of Yellow Partner's team said:

> "We are now becoming better at understanding each other regarding technology – we are creating a platform for understanding."

As mutual understanding emerged, the persons from Red Systems and Yellow Partner working together became more skilled at identifying when they did not understand each other. One of the members of the Red Systems team expressed this experience in the following way.

> "We are now better at identifying, in meetings or other situations, when we do not understand each other."

Representatives from Yellow Partner shared this view. The fact that individuals had a positive attitude toward differences in, for example, communication style and language was regarded as essential to tackling differences. Both engineers and project leaders experienced that this enhanced the development of mutual understanding. This development contributed to create a platform for sharing knowledge during the collaboration. The reason was that people working with colleagues from the other company learned to handle behaviour that they did not understand at the outset of the collaboration. It was experienced that people began to develop a common view of the Explorer technology and development process.

However, the difficulties of understanding one another did not just vanish. It was experienced that it took time to reduce differences, and was expected to be a process during the whole development period. One of the project leaders said:

> "It is often really difficult to understand one another's points of views. For instance, when we argue that according to our experience certain integration of computers is impossible they do not agree. They think they know what to do and so they just think we are wrong. This reflects our different experiences and they are difficult to share."

The same manager continued:

> "Working side by side every day is the key to handling these misunderstandings. If we had worked within our home organisations and only met every month or so, we would not have been able to solve these problems. Problems are solved through endless meetings where the same issues are discussed over and over again."

Both managers agreed that working side by side in the joint office and on the same work packages were important factors in order to enable communication. This was important not only to solve problems together, but in order to avoid duplication of work between the companies.

This section has described how integration mechanisms emerged in the Explorer collaboration. The following section focuses on the characteristics of integration mechanisms and their influence on knowledge communication.

4.1.5 Different integration mechanisms' influence on knowledge communication

Two project leaders – one from each company – managed the collaboration's organisation. The development of the Explorer's architecture and subsystem definition was conducted within the team with employees from the two companies. In the following, it is described how project management and the joint team functioned as the Explorer collaboration's integration mechanisms for knowledge communication.

4.1.5.1 Project management

The overall operational management of the project was delegated to two project leaders – the project leader from Yellow Partner and the deputy project leader from Red Systems. The deputy project leader was also the manager for Red Systems' share of the project. The main role assigned to the project leaders was to lead the development of the Explorer development, which included co-ordination of the work contributions performed with each company. Substantial authority to make decisions was delegated to the project leader level with regard to technology and organisational issues. However, authority over budgeting and financial control was kept within the two companies. Within Red Systems it was the programme management at Red Systems in Home Town that was formally responsible for the collaboration project.

In a formal sense, the project leaders had different roles. The project leader from Yellow Partner had overall responsibility and the authority to make decisions for the project. However, the project leaders' relationship was characterised by close informal collaboration and decision-making based on consensus. That meant that all major decisions concerning technology choices were made together, normally after extensive dialogue with employees from both companies. Concerning major issues, the project leaders usually found solutions during their informal discussions. One of the project leaders made the following comment:

> "It is during our informal meetings, alone in his or my office, that we find solutions to problems."

Both project leaders described how this informal collaboration was enabled by working closely together. Having their offices next to each other there were plenty of brief, informal discussions and opportunities to address up-coming issues immediately and to discuss e.g. distribution of work-tasks and responsibility between the companies. This close collaboration contributed to development of an informal relationship, and of what was described as an open dialogue. They relate that both technology content and development process issues were discussed, practically every day. For example, technology discussions concerned everything from details concerning cable installation that the engineers could not agree on, to major issues such as design of interfaces between the subsystems developed by the companies. The major focus, however, during their discussions, concerned the development process – for example, how the companies' different approaches to software development could be combined, how the shared information system should be designed and used, or where tests of the product should take place.

Being able to have daily discussions was experienced as important for handling differences in opinions about the development process, without halting the collaboration's progress. They experienced that they could speak freely without having to consider whether it was tactical to raise an issue about e.g. the division of a certain work-task between the companies' members of the joint team. It was described that, by being able to discuss their different perspectives on how the development process should be organised, they gradually began to understand one another, despite their different organisational and national backgrounds.

Engineers described their relationship with the project leader from Red Systems as informal. The colleague from Yellow Partner, who was used to more of a hierarchic organisational tradition, was experienced as having a more formal relationship with employees. These differences were not, however, experienced as major concerns. Nevertheless, they were seen as factors that had to be considered in order to handle differences in communication style. For instance, the reluctance to make independent decisions was greater among Yellow Partner's employees. Compared to employees from Red Systems, more issues had to be checked with the managers before decisions were made. It was experienced that in order to avoid taking responsibility for major issues, they preferred talking about technology details with limited significance for the development work. This meant that the project leaders had to deal with technological details ranging from physical installation of components to where and how the Explorer should be tested.

Both project leaders and engineers experienced that a continuous dialogue between them was enhanced by the joint office area. On the way to their offices, the project leaders had to walk through the office area, which created opportunities for *ad hoc* discussions. This happened several times a day – not least because they had to walk across the office to reach the coffee machine. By working in the same office area as the engineers, it was easy for them to see what was going on in the teams, and it was easy for people to walk by to discuss any up-coming issues. It was the experience of those working there that it was easy to get access to the project leader for a discussion, passing on information or asking questions.

One example of the close informal collaboration is the way decisions were made in the collaboration. The two project leaders should make decisions concerning overall technology issues – in particular concerning interfaces between subsystems. Decision-making on detailed technology issues first took place within the teams; only when they could not agree did the project leaders have to intervene. In order to supervise and support the technology development, every second week the project leaders had a technology management meeting. This was seen as a central forum for pushing technology development forward. The normal time for a meeting was approximately four hours.

The technology management meetings addressed one major technical topic per meeting. For instance, during these meetings it was discussed and decided how one specific subsystem should be physically and functionally integrated with other systems. Physical integration largely concerned mechanical interfaces between different subsystems. Functional integration was partly more complex because it concerned how different subsystems should influence one another in order to enable the Explorer to meet performance requirements. This was particularly complex because it had implications for the work integration between the companies. Other issues addressed at technology management meetings included general technology development. They also addressed plans for the next development phase as well as upcoming issues concerning the product technology, such as changing customer requirements.

It was stated that there were intensive discussions on the technology solutions before major decisions were made. One reason for the intensive debates was that the Yellow Partner managers were keen to allow engineers to give their opinion.

The project leaders wanted to make decisions based on engineers' expertise, and to ensure that once the decisions were made they gained legitimacy. There were often discussions until a solution acceptable to both companies was reached. The view expressed by both Red Systems and Yellow Partner employees was that virtually all major decisions were made in consensus. When a decision was made, it was generally respected by both companies' engineers, even though those from Sweden complained more before accepting the result.

During the studied period, every second week the project leaders and their teams worked in their home organisations. During those periods the intensity of their contacts were reduced. During an ordinary week in the home organisations, the two project leaders had one or two telephone conversations and exchanged a few e-mails. The content of this communication was largely administrative – e.g. planning for meetings. Instead, their collaboration was concentrated to the time they spent together on the joint office floor.

4.1.5.2 Co-located team

The nine major technology areas, except one, had, as mentioned, a team with persons from both companies. Together these teams constituted a larger joint development team. It was this team that facilitated the joint development process between the two companies. Its work focused largely on the development of the Explorer architecture and the design of interfaces between subsystems. It was, however, within the small teams that most of the joint technology development took place. Using small teams with employees from both companies was described as being very important for technology development in the collaboration. One engineer from Red Systems expressed this in the following way:

> "Shared teams instead of Red Systems and Yellow Partner teams have been very important for the collaboration. Working together creates a sense of us doing this together, both companies."

Enhancing face-to-face communication was a central aim when planning the joint organisation. The reason was past experience from one of Yellow Partner's projects. The experience from that project suggested that a prerequisite for a rich flow of technology is direct communication between project members. In a later phase, when the architecture had been developed, a more distributed organisation was planned to be used, with the bulk of the work performed within the companies' home organisations.

Each team had two or three engineers. The members of a team worked within the work package for which the team was responsible. This meant that the team members shared many tasks such as designing subsystem architecture and interfaces. The different teams had substantial influence over their everyday work, although the project leaders made major decisions.

The team members spent shifting weeks in the joint office landscape and in their home organisations. The reason for dual localisation was both to get the joint work started and at the same time to start work with in-depth technology development at home. The shifting location had implications for the knowledge communication between members of the team. During the periods in the home organisation, communication with colleagues at Yellow Partner declined. A few e-mails were sent, and occasional telephone calls were made in order to plan e.g. meetings for the next time they would meet. In contrast, when they worked in the joint office area they had daily discussions.

Each team had a small table that enabled the engineers to small-talk during the workday. The tables were big, which made it possible to put down large blueprint copies. These supported discussions on e.g. design issues, since people could easily visualise ideas.

There were only a couple of metres between the different tables, which supported discussions between the teams. People walked across the room to discuss with colleagues on e.g. technical relationships between their work-tasks. The following quotation from one of the project managers illustrates the experience of working together in a joint office space.

> “Sitting together is very effective for communication. It is as effective as communication at home.”

However, it was not always the case that technology results and information about current activities were distributed even between persons working around the same table. This had the consequence that sometimes people could work on the same issues without being aware of one another’s efforts. This created double work and caused problems of co-ordinating work within the teams. Another consequence, when it became clear that colleagues had worked on something without informing the others, was disagreement concerning work priorities. It was experienced that the companies’ different communication styles were a contributing factor. People from Red Systems were used to more openness on their work agendas than their colleagues from Yellow Partner were. For example, Yellow Partner’s engineers preferred to talk to the project leaders about detailed technology issues, before talking to colleagues from Red Systems working in their team and at their table. One project manager said:

> “People do not talk enough with one another. Some individuals keep things to themselves. We tell people it is important to be more open, make them communicate what they are doing to colleagues from the other company.”

It is described that during the Explorer’s first few months the atmosphere concerning sharing of technology between the companies was somewhat reluctant. However, gradually and as personal relationships emerged, communication on technology became more open. People became more willing to share their experiences from similar development projects and how they thought the current problems could be handled. There was a verbal openness on technology experiences from e.g. tests. Still, openness was more restricted regarding written technology such as blueprints from internal development. One reason for this reluctance to share documents on technology was that they contained information about competing products. It was expected by Red Systems that close collaboration over time would lead to trust between the individuals involved and that it would enable more in-depth knowledge communication. After a couple of months working together, one of the engineers from Red Systems made the following comment.

> "Openness in technology sharing is now a four on a scale of one to five – it started with a three."

It was described by one engineer that by being co-located the two companies' communication was as efficient as within Red Systems' internal projects. One reason for this development, it was argued, was the two project leaders' close collaboration, which functioned as a good example.

Direct, personal meetings face-to-face were experienced to enable communication on how e.g. interfaces could be designed. The general view among engineers from both companies was that the work situation was characterised by daily communication about the Explorer technology, between people from the two companies. One engineer from Red Systems stated:

> "There is a lot of face-to-face communication in the different teams. This is the most important way to create a shared view on different problems we are facing."

The development of informal relationships led to spontaneous meetings and discussions on upcoming issues. Dialogues on technology issues, such as interface problems, took place on a daily basis within and between the teams. The general communication pattern was frequent dialogues, several times a day, between people on the same organisational level and between the project leaders and team members. This experience is described in the following quotation from one of the project managers.

> "The spontaneous meetings are very important for preparing formal decisions – the technical content is agreed on in everyday conversations."

One major event during the joint team's first period of collaboration took place during autumn 2004. The different teams synthesised results from the two companies' previous experiences of prototype tests. Based on their different experiences, the engineers from both companies designed an architectural model for the Explorer. This was accomplished through dialogues in several of the working groups. The dialogues focused the companies' previous experiences from similar projects. The technology content discussed was largely about where and how different subsystems should be integrated on the Explorer. This process aimed to construct interfaces and design principles that would make the forthcoming development work effective. The results of the interface discussions, for example, were used in order to plan the division of work between the companies in the later phases of the project.

The depth of technology in communications varied between the working teams. The technical level in the architectural team was described as high with regard to the design of the Explorer. The team members were together pursuing design work that built on their collective expertise. This meant that the individuals in the team had to share the upper level of their knowledge. This was accomplished by working side by side and discussing technical details back and forth. For example, drafts of blueprints were produced and discussed and then new versions were created and scrutinised in detail by the team members. Other teams felt that the technological content was on a more moderate level of complexity. This was characterised by the team members discussing more general technological principles. In these teams, the scope of technology discussions was not concerned with solving complex problems. Thereby, it was not necessary to share detailed experiences and to create common views on technical solutions.

Although the dialogues on technology around tables and at e.g. the coffee machine were important during the everyday work, meetings were also used several times a week. One example was the weekly meeting where the project leaders from Red Systems, together with Yellow Partner's, summarised results accomplished after the previous meeting. Other planned meetings focused on specific problem-solving. These focused problem-solving sessions were often conducted in small groups of two to three persons – typically from the same team. The typical meetings on technology issues began with power point presentations and continued with discussions, often in the form of brainstorming exercises.

Not all competence necessary was located in the joint office area. The reasons were to some extent costs, and it took much time to recruit people. Some expertise was only needed occasionally. Therefore, often ad hoc, experts from Red Systems in Home Town flew down to Metropolis to work. This was a solution experienced as important in order to access necessary expertise without having to bring both companies' development organisations together under one roof.

E-mail was used to transfer reports and documents in the joint team, both when they were working in the joint office space and when they were separated. The data sent by e-mail contained technology, but not on a detailed level. Technology that is more detailed was distributed with persons travelling between Red Systems and Yellow Partner. In addition, a joint CAD system was being implemented in order to enable distributed design between the companies' internal development departments. It was, however, not fully implemented during the phase studied. Therefore, during the studied phase a large share of the explicit knowledge was shared through distribution of CDs with e.g. test results, blueprints and technical analysis.

The two companies also began using a joint server at the joint office location in order to store project data. The data stored in the common system contained both results that the companies had developed in other projects and results that emerged during the Explorer collaboration. The architectural team, for example, used data such as blueprints and test results that both companies had brought to the server. Most data were made accessible for both partners, but there was also proprietary technology that the companies had decided not to share. The idea of a server was to build a knowledge platform that could be used as part of the daily work between the companies. However, during the studied collaboration phase the joint computer system was experienced as playing a limited role for the communication. Instead, it was the discussions during the daily work that pushed the technology development forward.

4.1.6 Case summary

Red Systems entered the Explorer collaboration following an invitation from Yellow Partner. After a little more than a year of negotiations, joint work began at Yellow Partner's plant outside the European city Metropolis.

Even though Yellow Partner was formally the main contractor for the project, the collaboration was characterised by partnership. During the first phase of the collaboration, the conceptual design phase, a team of engineers were co-located in a joint office area. Two project leaders – one from each company, led the team. The two project leaders worked closely and decisions were largely made in consensus.

The development work was organised in nine small teams with two or three persons. The work of the teams was highly integrated and informal. Reducing misunderstandings between the companies due to different interpretations of e.g. technical terms was a major priority.

The following table summarises knowledge communication in the different integration mechanisms.

Integration mechanisms	**Knowledge communication**
Project management	Working in the joint office area enhanced daily communication on e.g. how the work should be distributed and how interfaces between subsystems should be designed Working integrated contributed to development of informal relationships with open communication on enabling problem-solving during the everyday meetings at the office Understanding emerged concerning differences in each company's organisational behaviour concerning e.g. communication style, development process and delegation of decision-making
Co-located team	Strong involvement in each other's work contributed to a need for sharing knowledge on a daily basis – e.g. blueprints and experiences from previous development projects Working in the joint office space created conditions for daily communication on technology issues between people – e.g. how to design interfaces between subsystems Gradual understanding of each other's terminology – and thereby technology – emerged, which enhanced communication

Table 5: Summary of knowledge communication in the Explorer collaboration's different integration mechanisms

4.2 The Seeker case: product development between Blue Systems, Black Partner and White Partner

In January 2003, the Swedish OEM company Blue Systems engaged in a joint venture with two companies located in other European countries, Black Partner and White Partner. The collaboration was set up for the development and production of a new-generation defence system – here named the Seeker – at a cost of a few billion SEK.

The three companies participating in the collaboration had roughly equal sizes, with a couple of thousand employees and a few billion in annual revenue. All three were part of different conglomerate company structures, which largely had limited influence on the collaboration. The companies in the Seeker collaboration had not collaborated before.

The governments in Sweden and two other European countries initiated the Seeker project. It was politically important to manifest defence industrial collaboration as a sign of the close relationships between the countries. The three governments also saw the Seeker collaboration as a way to share development costs for defence system projects none of them could afford alone. The three countries' defence acquisition authorities therefore began to prepare for industrial collaboration. Each country requested a share of the work for domestic companies equal to its cost share. This cost-work share arrangement is usual within the defence industry. It is driven by a political rationale to use defence investments as a way to create new jobs and support the competitiveness of domestic industry. This arrangement meant that the companies in the Seeker collaboration had not selected one another – which, as the following sections describe, had negative implications for their willingness to collaborate.

After less than a year, Black Partner left the collaboration when its government had decided not to acquire the Seeker. The collaboration continued until the summer 2004, when also White Partner's government decided not to continue its participation in the development project.

This case will describe the collaboration between Blue Systems and its partners in the two product development phases, with a focus on the influence of integration mechanisms on knowledge communication. The case will begin by reviewing the collaboration's background, the major strategic motives and the organisational form of the collaboration. The description thereafter addresses the development of the collaboration. The final part addresses integration mechanisms and knowledge communication between Blue Systems and the other companies in the Seeker collaboration.

4.2.1 Collaboration background

This section introduces the collaboration by describing the companies' different backgrounds and expected contribution to the collaboration. It will focus on their industrial backgrounds and its implications.

Blue Systems was an obvious part of the Seeker collaboration. It was the only company in the three countries with substantial expertise in the product segment. Only a few years before starting the Seeker collaboration, the company had delivered a similar product to the Swedish defence forces. This product was internationally recognised as having unique functional capabilities. It was planned that the Seeker would build on the previous product's architecture – although with significant improvements. Blue Systems was largely organised for development and manufacturing for its national government. Its business could therefore be categorised as very advanced in terms of technology, and by tradition it had a stable market. It had a self-image and major experience as an integrator of OEM products.

White Partner is a manufacturer in a highly competitive global industry with no experience of products in the Seeker's market segment. White Partner was invited to join the project since it had modern production expertise that was assumed to be useful in the Seeker collaboration. Hence, the company was expected to play an important role for the production of the Seeker. Its production site was located some 200 kilometres from Blue Systems.

Black Partner has a background as software developer for a government customer in its home country, and with some experience related to one of the Seeker's subsystems. However, the company had not previously been engaged in the development of a product like the Seeker. The company was located some 700 kilometres from Blue Systems.

The different companies' areas of expertise were seen as complementary. But their expertise in product technology relevant to the Seeker development was characterised by knowledge asymmetry. Blue Systems had a long history of developing previous product generations of the Seeker. The partners, however, did not have the experience of that product segment. White Partner was regarded as the less experienced company since it had limited experience of military production.

The knowledge asymmetry between the companies contributed to a concern within Blue Systems as to whether the partners would be able to fulfil their tasks in the collaboration. In particular, there were considerable doubts regarding White Partner's potential to understand the Seeker's quality requirements. White Partner, on the other hand, was concerned with whether Blue Systems had the financial strength to offer the customers a project accomplishment guarantee. From their point of view, Blue Systems was a financially unreliable partner. This contributed to a situation where none of the companies was willing to sign a deal that would make them mutually responsible for completing the Seeker project. This reluctance to engage in the collaboration enhanced uncertainty concerning the collaboration's realisation potential.

This section has outlined the major background to the collaboration. The following will describe the major strategic motives for participating and their influence on the collaboration.

4.2.2 Strategic motives for the collaboration

Since the mid-1990s, Blue Systems' national market was in decline and the international market was characterised by fierce competition. Its national customer had stated that it would not buy any new defence systems from Blue Systems unless an international partner shared development and production costs. Therefore, the Seeker project was regarded as important for the future of its business. However, it was not clear what the other companies wanted to achieve with the collaboration. One manager at Blue Systems made the following comment.

> "It was not clear what the other companies wanted with the project – beyond having a full order book."

The other companies had a similar view of Blue Systems. The company was seen as struggling with a declining market and having no choice but to collaborate. One of White Partner's managers argued that:

> "Collaboration was a necessary tool for filling their order book."

As for managers in the companies, it was felt that not knowing the other companies' strategic motives for participating in the collaboration contributed to mistrust. The lack of knowledge of the other companies' strategic motives, for instance, contributed to concern at Blue Systems about the potential risk of opportunism. There was some worry that the partners would use knowledge they accessed from Blue Systems in potential future competitive situations. The effect was a reluctant attitude within Blue Systems to share technology concerning e.g. vital production processes and major subsystems with the partner companies.

This concern was related to uncertainty about the collaboration's long-term impact on Blue Systems' role as system integrator. The company's identity was largely related to its tradition as a system integrator, and the risk of having to leave the role as sole prime contractor created some anxiety among people on different organisational levels. It was recognised that the company had no choice but to become involved in the collaboration, but it did not know where it was heading. Nevertheless, people on different organisational levels were hoping to find a way to make sure that the company would be the main contractor for the collaboration. However, the customers in the other countries were reluctant to allow that. One reason was national prestige and pride to be able to show the world that their nation could produce a product like the Seeker.

None of the other companies had to receive the Seeker deal in order to remain in business. They were both interested in the Seeker collaboration because it would generate extra cash flow during several years and it would enhance the company's international prestige. It was also expected that the tough technology requirements would contribute to development of employees' competence, which could be useful in other deals. To these companies it was not so important to receive the role as prime contractors. In the case of White Partner, however, both the owner of the industrial group and the national government were in favour of making the company prime.

The combination of uncertainty about each other's strategic motives and not being able to agree on how the forthcoming phases should be organised made the collaboration's strategic horizon short. The companies' managers were neither willing nor able to discuss how to collaborate beyond the current phase.

4.2.3 Forms of collaboration

A joint venture – The Seeker Corporation (SC) – owned and controlled equally by Blue Systems, Black Partner and White Partner, was established for the first phase of the project. The main reason for establishing SC was to balance Blue Systems' advantage of being the only company in the collaboration with substantial competence in the Seeker's technology. It was also a preferable solution from a political perspective, because it signalled that all companies were participating as equals. The following figure illustrates the formal collaboration structure used during the first phase.

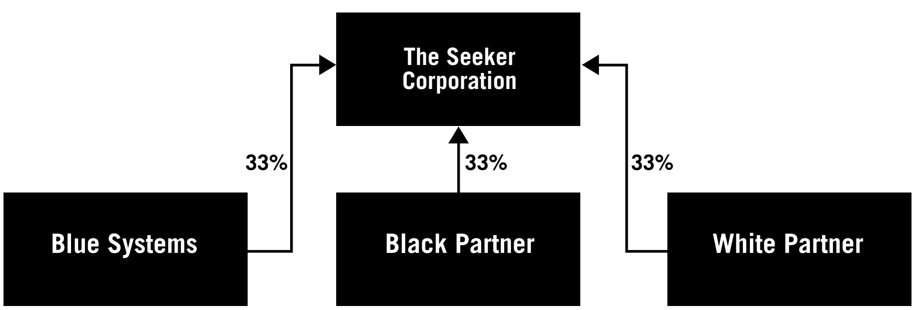

Figure 7: The seeker collaboration's parties

The SC was a joint venture, the main role of which was to manage contacts with the customer and to co-ordinate the three companies' technology development. The customer had a joint project organisation that managed all operational contacts with companies – this project organisation is in the following referred to as the customer.

Formally, Blue Systems and its partners were subcontractors to SC, i.e. the subcontractors owned the main contractor. In reality, however, SC had limited influence over the collaboration. The major reason was that the collaboration's product development was managed within each of the three companies. Each company during the first collaboration phase was responsible for different work-packages. This clear-cut division of the work meant that all technology development was located at each of the companies' internal development organisations.

After Black Partner had left the collaboration, as mentioned in the introduction, another form of collaboration was initiated between Blue Systems and White Partner. Formally, White Partner was a subcontractor to Blue Systems, but in reality, the relationship was more like a partnership. However, the companies' roles were distinctly differentiated. Work distribution between Blue Systems and White Partner was formalised through a contract specifying what each company should do. They developed a table of contents that defined the specific tasks each company should accomplish. The basic division of work was that Blue Systems was responsible for the product definition of the system and White Partner had the main responsibility for production resources and processes.

In order to accomplish the collaboration during the two phases, different integration mechanisms were used. This is the focus for the following section.

4.2.4 Development of integration mechanisms

This section describes the use and functioning of integration mechanisms during the Seeker collaboration's two phases. It concerns the period from January 2003 when the collaboration began until June 2004, when it was cancelled. Following this overview, the next section elaborates more in detail the characteristics and functioning of integration mechanisms.

The collaboration established between the three companies faced the challenge of accomplishing work between development departments located in different countries, with different industrial backgrounds and areas of expertise. In order to handle this, at the outset of the first product definition phase, a work breakdown structure defined the roles and tasks of each company. The work breakdown structure created a strict division of work between the companies. This division of work was described as partly a political compromise in order to create an industrial structure that was likely to accomplish the collaboration. To managers at Blue Systems it was experienced that this division of work was somewhat unfair, since the company had all necessary competences in-house, and in particular, White Partner did not have relevant experience. However, from the perspective of White Partner managers participating in the collaboration, this view was the reaction from a company with conservative ideas concerning e.g. production technology.

Each company was responsible for its work packages, since they could not agree on shared responsibility. Therefore, managers in the companies expected that little interaction would be required during the collaboration between their work-tasks. In order to facilitate the necessary integration, several integration mechanisms were established. To begin with, the SC had the role of integrating the results into four documents that described the products' technical capabilities, the production process, project management and project costs. Integration between the three companies was limited and concerned the design of interfaces between systems and demands on the production system. In order to facilitate the necessary operational integration, three kinds of forums were established – project leader teams and Working groups and System groups for operational-level integration.

The experience at Blue Systems was that communication on technology concerning the Seeker was limited. In the first phase, there was some communication between Blue Systems and Black Partner concerning interfaces between the Seeker system and the subsystem developed by Black Partner. According to a manager at Blue Systems, one effect of the limited collaboration of technology work was:

> "It could be months before we knew what they (Black Partner) had done."

During the first phase, there was also limited interaction with White Partner. The company focused on learning about product technology and the implications that the special requirements would have for their production system. It was not seen as necessary to be involved in each other's work packages. One of the deputy project leaders from Blue Systems said:

> "We expected each company to do what they should."

However, there were thoughts about establishing closer collaboration on operational levels between the companies. On operational levels, this was considered valuable to accomplish, but it had little support in the senior management. For a couple of months Black Partner had one engineer located at Blue Systems and there were plans to send one person to work at Black Partner. The plans were cancelled when the rumours began that Black Partner's customer would have to leave the project. White Partner had three engineers located at Blue Systems in Big City. However, they were not integrated into the work within Blue Systems. The following quotation from one of Blue Systems' engineers illustrates why it was difficult to create more close collaboration.

> "It was the engineers who were most keen on co-locating – the managers were not that interested since it would cost money."

There was constant concern whether the collaboration should be cancelled, which contributed to the reluctance to exchange employees. On the operational level, people established some informal relationships between the companies. These relationships were regarded as gradually enhancing e.g. the co-ordination between the companies' development efforts. A sequence of meetings was held, always at Blue Systems facilities, in order to co-ordinate activities between the three companies. For example, during such meetings Blue Systems gave technical specifications to Black Partner concerning interface demands on their subsystem. This was an ongoing process with new technical requirements emerging as the project proceeded. White Partner was not very active during this first period, since the production issues were not much in focus.

When Black Partner left the collaboration, the organisational structure was renegotiated. In the new collaboration structure, Blue Systems had the role of prime contractor and was responsible for delivering results to the customer. White Partner became a subcontractor to Blue Systems and was responsible for developing the production process. Integration was mainly regulated by plans for deadlines for different results. Communication in the collaboration concerned issues such as whether and how White Partner would be able to produce certain design solutions. In addition, a large share of the interaction concerned teaching White Partner about manufacturing requirements likely to be required for the production of the Seeker. For instance, one issue concerned how White Partner's welding system would handle the special steel used on the Seeker. There was, for example, transfer of blueprints and detailed discussions of past products, as well as process knowledge concerning how they had been built. This was necessary since White Partner did not have any experience of manufacturing products like the Seeker. According to one senior manager at Blue Systems:

> "White Partner did not understand in the beginning what it takes to produce the Seeker, but over time they began to understand."

However, the experience in both companies was that they gained little knowledge from the collaboration partners. There was both a reluctance to communicate and difficulty of interpreting the implications of the partner's knowledge. One consequence of not being able to understand each other's perspectives on technology was a sense of uncertainty about whether the partner company really would be able to achieve its share of the product development. It was described by managers from both companies as a reluctance to share responsibility for realising the Seeker with the other partner, because they could not trust its competence. This was experienced as a reason why it was difficult to plan how the work should be integrated in the forthcoming phases.

4.2.5 Different integration mechanisms' influence on knowledge communication

This section describes the integration mechanisms used in the collaboration between Blue Systems and its partners. It describes integration mechanisms' characteristics and their influence on knowledge communication between the companies. It is seen that the main role of these integration mechanisms, concerning communication of knowledge, was their influence on the other integration mechanisms.

4.2.5.1 Management board

This section presents the senior management integration mechanism used during the Seeker collaboration. The following discussion will focus on its characteristics and its influence on knowledge communication.

The SC had a board with top managers from Blue Systems, Black Partner and White Partner – the head of the division in each company responsible for the Seeker and the CEO from each company. The board's main concern was accomplishing the current phase of the collaboration – e.g. how each of the companies was meeting deadlines. It was a forum for collaboration, which directly created the conditions for the SC joint venture.

During their everyday work, the board members were briefed about the development of the Seeker collaboration from their employees. Hence, they followed the progress of the collaboration from both a technical and a commercial point of view. There were few direct contacts among the board members between meetings.

The board members met for meetings, with several months between occasions. The meetings were concerned largely with contractual issues, and to some extent with the development operations, while very little attention was given to product technology. The board had no influence over the operations within each other's companies, but they had to discuss whether each of them did enough to achieve customer requirements. Discussions on development operations concerned e.g. allocation of critical resources with the companies, such as competence, in order to accomplish the companies' different tasks. There was also major attention to costs and dependencies, because these could influence the individual company's risk. Project leaders handled technology issues, as long as it would not increase costs. Hence, it was never intended that management board should discuss technology. In addition, it was experienced that there was a reluctance to share knowledge with colleagues from the other companies. This reflected the uncertainty about one another's strategic intentions with the collaboration. There was also limited time during the board meetings for in-depth discussions, e.g. about one another's intentions with the collaboration. This lack of time for discussing the future of the collaboration was experienced as one important reason why difficult issues concerning the collaboration were not sufficiently dealt with by the board.

It was felt, both by board members and by those on operational levels, that the board members represented their own company in the first instance and the interests of the collaboration and SC were their second priority. There was no interest in really understanding the partners' perspectives on the collaboration. The general view is that the three companies' different interests gave SC a weak role with limited influence over the work in the three companies.

It was described by managers that the companies had different traditions of planning and conducting development work, which made it difficult to understand one another's point of view. Conflicting timetables, for example, could be a source of controversy between the senior managers. Since there was no higher authority than the board, it meant that a lack of agreement often could affect the progress of the whole project. According to managers on different levels in Blue Systems, one reason for the problems in leading the SC was that the collaborating companies did not have any joint strategy or vision for what they wanted to accomplish through the Seeker collaboration. There was, for example, no plan about how to accomplish the collaboration's forthcoming phases. In fact, mistrust meant that it was not an issue that the companies would share responsibility for delivering the Seeker to the customer. Instead, a great deal of management attention concerned which of the companies would be able to act as prime contractor. This was a role that none of them saw the others as capable of managing.

According to middle managers working with the Seeker collaboration within the companies, the board members' rather distant relationship to one another and the collaboration was a signal to keep distance to the other companies. People working at Blue Systems' R&D department expressed that they were unsure how open they should be with knowledge they had and that the partner could use. Since the board members did not share much knowledge with one another, it was asked why those on the operational level should share technology with their colleagues. One consequence, according to middle managers at Blue Systems, the SC joint venture had a difficult situation managing the collaboration, because the board did not push for enough open sharing of knowledge between the companies.

4.2.5.2 Seeker Management Team

In this section, the team used for co-ordinating the collaboration's general development and customer relationships is described. Its key characteristics are presented and its knowledge communication is addressed.

To begin with, the SC had, as mentioned, a management team of four persons – the joint venture did not have any additional staff. The team was located in Blue Systems' office building in Big City, Sweden. This meant that the members from Black Systems and White Systems worked in a foreign country, several hours' travelling distance from their home organisations.

This team was occupied primarily with following the progress of the work within the three companies and integrating their contributions. They were not directly involved in the operational management within the three companies. Instead, they handled delivery of reports with technology analysis to the customer's joint project organisation.

Three persons at SC worked with technology issues in relation to the three companies. Each person had contact with the company he came from – i.e. one person worked with the product system, one with a major subsystem and one with production. They had contacts with colleagues in the different companies both informally and during formal meetings. It was experienced that they had systematic contacts with key persons in the three companies at least on a weekly basis. They occasionally had more frequent contacts, e.g. they met people from Blue Systems in the entrance or the lunch restaurant. The fourth person was the joint venture's CEO. That role contained substantial contacts with the customer and planning for the collaboration's forthcoming phases. In addition, it meant some contacts, but not more often than weekly, with the project leaders from the three companies. In focus for these contacts were discussions that concerned the customer's requirements.

Formally, the SC management team had decision-making authority over the work being conducted in the Seeker collaboration as long as it did not interfere with the work within the three companies. However, in reality their influence was limited. The team could influence the general requirements through discussion with the customer, but not how the work was accomplished within the companies. The reason was that each company retained authority over its own activities and resources in the project. The consequence was that the team experienced an imbalance between the responsibility for delivering results to the customer, and the limited authority over the development work.

A large share of the team members' time was used for meetings with the customer where general technology specifications were discussed. The SC team transferred these specifications to the companies' development departments, often during meetings in the different teams used by the companies in order to enable co-ordination. The SC managers did not have the time to discuss any details concerning e.g. the technology analysis. Instead, their focus was to make sure the companies delivered documents with technology analysis that they could integrate and send to the customer.

The work within the team was characterised by daily contacts. They shared an office area, which contributed to opportunities for daily discussions, without having to plan for it. Their internal work was largely concerned with managerial administration, such as development of plans, integration of analysis made by the companies, and negotiations with the customer concerning technical specifications. It was experienced that this collaboration within the team proceeded without major obstacles. By working together, they learned to understand each other. They also developed fairly coherent views on their work tasks.

As mentioned previously in this chapter, members of the team had their personal work assignments, which were related to the development work within the respective company they came from. One reason for this division of work in the team was to build on their existing personal networks in the three companies. This made it easy for them to find the relevant persons to talk with, and to access data about current status of the technology being developed. However, it was experienced that one effect was that they never really were able to understand the companies other than their own home company. In that sense, the team did not develop a shared understanding of the work performed by the other companies during the collaboration phase.

This section has presented the SC management team, which was acting as the collaboration's interface to the customer's joint project organisation. The following sections will focus on the mechanisms used for enabling collaboration between the companies' product development operations.

4.2.5.3 Project management teams (phases I and II)

In the following, the focus turns to the different forms of project management integration used during the Seeker collaboration. There were four project management teams established between the SC and the three companies. In the second phase, two new kinds of project management teams replaced the previous one. The discussion here describes their main characteristics and influence on knowledge communication.

During phase 1, there was one team responsible for each of four main documents produced for the customer's joint project organisation – the technology, the production, the management and the costs document. The teams had one representative from each of the three companies and one from SC. Their task was to make sure that the content of the four documents was co-ordinated and that the four documents would constitute a total solution to meet the customer's demands. The project management teams had authority to make decisions e.g. concerning technology development tasks to be accomplished by operational-level integration mechanisms. Their role meant reviewing the progress of different work packages and providing instructions to operational-level integration mechanisms – the Working groups and Systems groups (which are presented in the subsequent sections).

Each project management team met formally, approximately every second month. However, informally they had somewhat more frequent meetings. Before meetings, each company would send documents with results from their internal development work. For instance, these documents could contain detailed descriptions and analysis of different subsystems' design and functionality. Other documents contained analysis of costs for different systems. These contributions were integrated into one document, which in terms of pages was substantial. During meetings these documents were discussed, but on a rather general level. Thus, discussions usually did not elaborate on details concerning e.g. subsystem performance. To the extent that details were addressed, they concerned interfaces between Blue Systems architecture and the Black Partner's subsystem. It was also experienced by Blue Systems project managers as unclear to what extent they should discuss technology details with the colleagues from the other companies. It was noticed that the senior management were reluctant to collaborate, and it was considered unclear whether the collaboration actually would reach production of the Seeker. This uncertainty contributed to a reluctance to share knowledge regarding e.g. previous experiences from similar development projects.

The level of technology described in the documents and discussed at the meetings was regarded by managers from Blue Systems as moderately complex. The level of complexity, e.g. newness and details addressed, reflected the fact that the collaboration was still in an early phase, and it was thus not really necessary to discuss technology in detail. Another reason was that the companies' different representatives had difficulty understanding one another – partly due to different competence backgrounds – which made it difficult to have advanced discussions. It could, for instance, be difficult to understand the reasons for arguments about technology choices or views on costs and product quality requirements.

During the second phase, two new management integration mechanisms was established. One of them was a so-called Integrated Product Team (IPT). IPT is a collaborative form commonly used within the defence industry. The idea is to co-ordinate the companies and customer(s) continuously during product development. This is a way for the customer to monitor development and provide input during the development work. During the Seeker collaboration, IPT provided feedback on the progress of the project, discussed interpretations of the customer's specifications and, in doing so, provided a way to reduce the risk of misunderstanding.

Blue Systems formally had the direct contact with the customer, but White Partner participated in the meetings as an observer in order to monitor the progress of the collaboration. During the IPT meetings the major issues discussed concerned the whole life cycle of the project – for example, how the product development organisation should be designed and what kind of subsystem structures should be used. One major issue discussed was who should manufacture different product modules. It was planned that a distributed production system should be used, with major modules built on different sites and then transported for integration at White Partner's manufacturing site. The integration of the two companies' CAD systems was also a major issue discussed during these meetings. This was a concern since the two companies had different CAD systems and, during the production phase, it would be necessary to be able to efficiently share CAD files. The IPT meetings had the authority to make decisions on general issues. However, they could not make decisions regarding anything that would influence the project's costs and technological content in any major way.

In addition to the IPT meetings, the project managers from Blue Systems and White Partner met for formal reviews of the progress of the project every six weeks. The project management meetings were a few forums for dealing with general project issues such as plans and budgets as well as for supervision of operations. It was largely *ad hoc* issues that were discussed – concerning both technology and the project's economy. Between these scheduled meetings, there were informal project management meetings. In addition, there was telephone and e-mail contact between the project leaders, mainly concerning administrative issues. Decisions about e.g. choice of components were largely delegated to project leaders. Any issue with potential influence on the project's budget had to be discussed with the companies' senior management before decisions were made.

4.2.5.4 Working Groups (phase I)

On the operational level, different types of co-ordination groups were used in order to integrate the work performed within the companies. In this section the kind of groups called Working groups are presented, with focus on their characteristics and knowledge communication.

In the first phase of Seeker collaboration, eight Working groups were established. Their task was to function as forums for the analysis of the customer's technical specification, how its problems could be solved and how the companies' contributions would relate to each other. Typical topics for the Working group meetings concerned cross-functional technology issues. For instance, the discussions concerned issues such as the design of the interface between the operator of the Seeker and the product. Other technology areas discussed in different groups were the design of the air-conditioning system and automation solutions for the Seeker. White Partner had representation in four of the Working groups, while Blue Systems and Black Partner were represented in all the Working groups.

A deputy project leader from the company responsible for the group's task managed each group. Deputy project leaders from the other companies participated in the working groups together with technical specialists. In addition to deputy project leaders, technical experts also attended the meetings. Which experts participated depended on the issues being addressed at the particular meeting. The customer and SC also had one or two representatives at the meetings. The usual number of people participating during the meetings was approximately fifteen.

The three companies owned their own contributions to the Working group. This reflects the fact that technical work took place within the individual companies. When Black Partner left the project, Blue Systems gained access to the results, but not the rights to use them in order to finalise the project. Instead, Blue Systems had to develop its own solutions.

The typical Working group meetings lasted for half a day up to two days. The meetings followed a time schedule with several meetings every month within the project. The individual Working group had meetings approximately every third month. The majority of the meetings were held at the Blue Systems office, in Sweden.

However, there were also meetings held at Black Partner. In the groups there were also informal meetings, e.g. the day after a formal meeting. The members of different teams also used telephone conversations and e-mail exchanges between meetings. These contacts were mostly used for administrative planning, e.g. to define an agenda for the next meeting.

In general it was experienced that communication activities were concentrated to the meetings every second month. However, the degree of communication differed between the groups. Knowledge communication, for example, was experienced as very much about give-and-take in groups such as that of man-machine integration. In other groups, such as that of automation, Blue Systems contributed all the content, Black Partner did not play an active role, and therefore the need for communication between the companies was low.

The view within Blue Systems is that the Working groups did not function as expected. The reason was that the participating companies had different levels of technical competence and therefore found it hard to understand each other. Blue Systems, for instance, felt that in collaboration its partners did not really understand the difficulties involved in developing and manufacturing the Seeker. There was also self-criticism within Blue Systems, where project leaders stated that they were not very good at listening to their partners. The combination of different areas of work, levels of knowledge and reluctance to listen contributed to a situation with different views on the Seeker. One deputy project leader from Blue Systems made the following comment:

> "Communication in the Working groups was okay but we had different points of view since we worked with different systems. So it was difficult to create a shared image of solutions and it was difficult to take discussions from general to specific issues."

It was, for instance, difficult to agree about what would be the quality requirements on the material used. This had implications for the production technology that would be used for manufacturing the Seeker. A major concern for managers in both companies was Blue Systems' and White Partner's different kinds of production processes. These differences meant that they had rather different views regarding e.g. the challenges concerning the production of certain materials. It was also difficult to create a common view on man-machine integration between Blue Systems and Black Partner. The reason was, according to one engineer, that the companies had rather different product philosophies e.g. regarding quality. It was also experienced as difficult to understand one another's technical terms; the same word could have different meaning to the companies. These different conceptualisations were also experienced on more general technological levels. There were for instance, no clear definitions of the technology area 'automation'.

The technology results developed were communicated in documents before a meeting, as well as during meetings. It was estimated by managers from Blue Systems that the technology communicated, e.g. concerning interfaces between subsystems, was on average a three on a scale[3] of one to five, where five means highly complex technology. A great deal of the communication concerned data in the form of written technical analysis of system requirements. Discussion played a limited role for the knowledge content communicated in these teams.

The Working group members did almost all the work within their home organisations. There was thus limited joint work during Working group meetings. Instead, most meetings were described as presentations of results. One reason for the low level of joint work at the meetings was described as being a result of the detailed division of work. The consequence of the different roles was limited common interest in work results. Hence, there were limited incentives for any extensive communication in the Working groups. One manager from Blue Systems commented on the effect of high work differentiation:

> "There was limited input from the partner – the meetings in all but two groups had one-way communication. In the groups with active participation there was an exchange of experience – this is how we do it, how do you do it?"

Another practical reason for the limited communication was the large number of approximately fifteen people participating in the meetings. This made it difficult to have focused communication. Instead, most meetings had the nature of data presentation. However, the number of persons involved in meetings was gradually reduced when it became clear who had reason to be directly involved. As the number of participants decreased, communication improved.

4.2.5.5 System Groups (phase I)

In parallel with the use of Working groups, the Seeker collaboration used so-called System groups during the first collaboration phase. Their characteristics and knowledge communication are focused upon in this presentation.

Fourteen System groups were established for the first product definition phase. Their role was to co-ordinate the work on system technologies that had an impact on the overall Seeker system. The focus in these groups was largely interfaces between different systems. Since Blue Systems was responsible for the product system, it participated in all fourteen groups. Eight persons represented Blue Systems in the

3 This scale illustrates respondents' subjective estimations. Their judgment does not relate to any definition of what defines technological complexity. Thus, their estimate should be seen as an indication of how people experienced the technology communicated. It is one illustration of how difficult or easy people perceived the knowledge communication in the collaboration to be.

different System groups – two persons participated in more than one group. Similar to the Working groups, the individuals participating in the System groups were deputy project leaders and technical experts. Black Partner participated in twelve of the groups and White Partner participated in nine. The customer also participated in the System groups with a total of six persons. In total, the usual number of people participating in meetings was fifteen.

The System groups had two-day meetings where they discussed interface issues between subsystems. Each group met approximately every third month and since there were fourteen groups, there was on average one meeting per week between Blue Systems and Black Partner. Before the meetings, the companies communicated documents with information on technical specifications that had been developed within each company. A typical document had approximately 20 pages and contained technical data. The data concerned analysis of e.g. the volume and weight of different subsystems. Revolving around the documents, discussions at meetings concerned interfaces from both a functional and a physical perspective, i.e. how different systems should be integrated. One of the deputy project managers said:

> "We did not question each other's technology and did not share much content; their subsystem was like a black box to us. Instead we used to discuss the physical integration between the systems."

The System groups' discussions also concerned what the companies had done and what should be done before the next meeting. Black Systems, for example, needed specifications for its system integration. As a system integrator, Blue Systems therefore defined requirements for what Black Partner should do in order to meet interface requirements. This, however, was not always easy to accomplish; there were misunderstandings because of different interpretations of specifications.

The work routines in the companies, though, were rather different and it was occasionally difficult to get answers to important questions in time. The main challenge was to understand the different views on product technology and the forthcoming production process. It was stated that the companies had different product and development process philosophies, which caused some frustration within the internal development organisation. Blue Systems, for instance, had a strong focus on quality and thereby high-cost components. In contrast, White Systems' values revolved around cost efficiency, and from that perspective the Blue Systems approach was hard to understand. These differences were explained by the companies' different history of working with products with rather different performance requirements.

4.2.5.6 Temporary development teams (phase II)

In this section, the temporary development teams used during the collaboration's second phase are in focus. They were similar to the Working and Systems groups but had a less formal role.

When Blue Systems and White Partner had reconfigured their collaboration, temporary development teams were established since the project could not afford the overhead costs of having permanent teams, such as Working groups and Systems groups. The total number of teams operating was approximately 10. The teams were established ad hoc in response to issues either as they arose or after they were identified early in the collaboration phase. At one point, for instance, Blue Systems mentioned that it wanted to use a certain material and a team was set up to analyse the implications for the process, and if any problems were identified the team's task was to suggest alternatives.

A temporary development team had a project leader – the same person was often project leader for a number of teams. The same person was, for example, project leader for quality assurance and quality control as well for the group working with steel issues. The representatives in the teams came from the Blue Systems technical support team in Big City and the special teams at White Partner working with the Seeker. The same persons, from both Blue Systems and White Partner, participated in several teams, so there was quite a close group of people from the two companies that collaborated. In addition, technical experts from Blue Systems participated when special technical issues were being discussed. Consequently, the development teams consisted of a core group of individuals participating in several teams and a larger group participating only if requested. Each team had a meeting every second or third month. However, since the team members participated in several groups they met as often as every second week.

A typical team meeting lasted for two to three hours. The meetings were formal events, but the atmosphere was felt to be informal. It was felt that the frequent meetings contributed to the development of familiar relationships between engineers from Blue Systems and their colleagues from White Partner. The work within the teams was self-organised in the sense that no one outside the team interfered with how they organised their work. Each team had a project leader responsible for arranging meetings and leading the joint work process.

The content discussed during the team meeting often concerned Blue Systems' previous experience from the development of previous products. Ideas about how the Seeker could be manufactured were also discussed and gradually became a more important issue. One reason was that as White Partner's representatives learned more about manufacturing requirements they began to come up with new ideas about how different manufacturing issues could be resolved.

The discussion in the teams often had blueprints from one of Blue Systems' previous products as a platform for the discussion concerning how the Seeker should be manufactured. The representatives from Blue Systems regarded their own attitude toward White Partner's suggestions as conservative. White Partner had modern process technology for efficient manufacturing of fairly large volumes. Blue Systems had a more traditional, partly handicraft, tradition of producing a few products over several years. These differences were expressed not only in the attitudes to production process, but also in discussions concerning quality and costs. It was experienced that while Blue Systems people focused on quality, their colleagues from White Partner were more concerned with cost. For example, a typical discussion could concern whether it would be worth paying several times more for a component that only enhanced product reliability by a few percent. These differences were difficult to overcome during the collaboration.

The team members normally communicated documents with information and analysis – 10 to 20 pages – between each other. The technology in the documents, which also was discussed during meetings, was regarded as moderately advanced. The reason was that they did not discuss technical details. The discussions on welding technology, for example, were experienced as moderately advanced. Team members described the technology as complex, but the discussions never really addressed details. It was expressed that one reason for not discussing details was that the work relationship between the companies did not require that. The main reason was that they did not, in the current phase, have to solve complex problems together; instead, that was dealt with in the companies' development organisations.

4.2.6 Case summary

The Seeker project was initiated by the governments in three European countries. Three companies, one from each of the countries, established the collaboration for the development and manufacturing of the Seeker. The first collaboration phase was organised around a joint venture – the Seeker Corporation (SC). The SC's role was mainly to co-ordinate the project. Senior managers from the three companies constituted the SC board; their main focus was co-ordinating administrative issues. All technical work was located at the three companies. The contributions from the companies were differentiated by a work breakdown structure. In order to co-ordinate the companies' work, different teams were set up where technology concerning interfaces was disseminated and discussed.

Black Partner left the collaboration during the first phase when its customer had decided not to continue with the Seeker. In the second product definition phase, Blue Systems and White Partner collaborated. Even though the collaboration was a partnership, Blue Systems was formally the main contractor and White Partner a subcontractor. Blue Systems was responsible for all issues concerning the Seeker, e.g. performance and design, while White Partner was responsible for preparing production. Their work was co-ordinated in meetings with project leaders and the customer representatives, project management meetings and within temporary development teams, which were the forums for joint work on technology.

Knowledge communication in the different integration mechanisms can be summarised as in Table 6.

Integration mechanisms	Knowledge communication
Management board	Meetings with a few months' interval were the major occasion for communication, e.g. on issues such as co-ordination of development process; product technology was not in focus The board members' daily work was to a limited extent committed to the collaboration and there was a reluctance to share knowledge with colleagues from the other companies The limited openness on knowledge and the reluctance to collaborate was seen by operational levels as a signal not to engage in open communication about technology
Seeker management team	Daily communication between people within the team and weekly with the companies, mainly concerning plans, customer specifications and technology results presented in documents The team members' work was largely concerned with managerial issues such as plans and they had little time for communication on technology concerning the product Knowledge about the work in the other companies were limited
Project management teams	Communication was concentrated to meetings approximately every second month – largely focused on general technology results and planning for forthcoming milestones Their work was focused on development within their respective companies and had little need for communication between meetings – occasional use of telephone and e-mail It was difficult to understand one another because of different competence backgrounds and views on e.g. product quality
Working groups	Communication was largely concentrated to meetings, with approximately fifteen people, every third month – on integration of the companies' results about different technology functions Between the meetings the group members worked with their company's work packages and little communication was needed between the members from different companies The members from different companies did not have a shared understanding of technology results presented during meetings
System groups	A two-day meeting every third month was the major communication occasion, with about fifteen persons – its focus was integration between subsystems. Both documents with technical data and presentations were used Work was performed within the companies, and limited communication were requested during those periods It was not difficult to interpret one another's technology results, but difficult to understand each other's views on results and solutions for e.g. interface integration
Temporary teams	Communication was concentrated to formal meetings every second or third month with a few persons present – it largely focused on documents with e.g. blueprints Between the meetings the teams had no joint work-tasks and requested little communication A few individuals worked in several teams and met the colleagues from the other company every other week – and they gradually began to understand one another's views on technology

Table 6: Summary of knowledge communication in the Seeker collaboration's different integration mechanisms

4.3 The Mover case: Green Systems and Far Partner

In 2003, Green Systems and Far Partner began the development of a technically advanced subsystem – here called the Mover. The aim with the collaboration was to take a technology leap that would give the companies a competitive advantage on their markets. The collaboration was of strategic importance to both companies, and considerable human, physical and financial resources were being invested.

Green Systems is a world-leading OEM in its industry with a tradition of in-house development of new products. The company is located in Sweden, at a city that here is called Swetown. Compared to many other companies in its industry, it has striven to retain more of its technology development within its development departments. It has an R&D organisation with several thousand employees, who are located at the company's site, in the city here called Swetown. Even though the company focuses on internal product development, however, some key technologies have historically been acquired from major suppliers. One such example is the Mover's product category.

The Mover collaboration was with an American subsystem manufacturer, which is here called the Far Partner. The company is located in the city that here is called AM Town. It is part of a major industrial group in the US. The industry group has a strong brand and some unique products, of which the Mover kind of product is one. Far Partner is only a minor part of its industry group, and its operations are to a limited extent integrated with the other companies.

When the Mover collaboration was initiated, the two companies had complementary competences, Far Partner being the one with in-depth technology and Green Systems having conceptual ideas and challenging requirements. There are six time zones between the companies. Thereby, it normally takes some 20 hours to travel between their locations. These were major contextual conditions when the collaboration was launched.

This section will describe the Mover collaboration during the first two years – 2003 to 2005. The case description will address the case from the perspective of how integration mechanisms in the Mover development influenced knowledge communication. The chapter will begin by describing the background to the collaboration, the main motives to collaborate, and the organisational form being used. Having described the case's context and organisation, the focus will turn to development of integration mechanisms, thereafter to each integration mechanism and its influence on knowledge communication.

4.3.1 Collaboration background

During the last decade, Green Systems has been involved in a couple of major product development collaborations. One of them concerned the development and production of a subsystem with major impact on Green Systems' products functionality and resulted in the product generation that the Mover should replace. Therefore, Green

Systems and Far Partner had experience of collaboration going back to the early 1990s. During this collaboration, Green Systems had a marginal role in the development operations. In addition to their first collaboration and the Mover, several minor R&D collaboration projects have been conducted.

The companies belong to the same industry. However, they are not competitors since they operate on different geographical and product markets. Green Systems' major market is Europe and a couple of other regions. Its products are complex platform systems consisting of several thousand components. Far Partner's major market is North America, and its products are major subsystems in platform systems. Both companies saw the fact that they were not competing as a central prerequisite for their close collaboration.

Green Systems' experience from the earlier collaboration was positive concerning Far Partner's technological competence, which was regarded as very competitive. However, it was less positive about how the company managed development and in particular, how they regarded product quality. To Green Systems, product quality is a major priority since its brand is associated with high performance and reliability. Far Partner has by tradition another competitive strategy, more focused on low-cost production.

The first joint product is now implemented in Green Systems' products. Despite some experience of difficulties, Green Systems' top management decided to establish a new collaboration. Thus, in 2003, the two companies began their second joint product development collaboration.

This section described the major historical factors influencing the establishment of the Mover collaboration. The following section will focus on the specific strategic motives underlying the choice to collaborate.

4.3.2 Strategic motives for the collaboration

When Green Systems and Far Partner joined forces they had a mutual interest. Both companies were facing new governmental regulations that should change market requirements. It was therefore necessary to take a technology leap within a few years.

Green Systems needed access to external technology in order to accomplish this. Collaborating with Far Partner was an interesting alternative since the company was a world-leading supplier of the required product type, and they had a history of partnership. An additional motive for Green Systems was to break its increasing dependence on the suppliers dominating the oligopoly supply chain in that product area.

For Far Partner a central motive was to share development and production costs. The company had struggled for several years with negative financial results. Without a partner willing to share development costs, the company would hardly be likely to be able to develop a new product generation. People in both companies agreed that the combination of these strategic circumstances was important for establishment of the Mover collaboration.

The Mover was a new subsystem that was planned to replace existing subsystems in both Green Systems' and Far Partner's products. From a technology perspective, the Mover development aimed to create a product that would have the highest performance capacity on the market. It had a new architectural design that was a key to enable the high-performance capacity expected. The conceptual idea was described as bold, and it was regarded as uncertain whether they would be able to realise the ambitious technology leap. However, the ambition was to realise the technology leap and thereby create a first mover advantage on the market.

A difference between the earlier product and the Mover was that Green Systems intended to build in-depth competence in the product technology, and to enhance its influence on the development process. The main reason for this was to avoid the quality problems they experienced with the early versions of the previous product – which was developed in a project where Green Systems had little active involvement in the development. The idea was that being more involved from the beginning would make it possible to monitor the development in detail and thereby identify potential quality problems. Thus the company's senior management wished to avoid being surprised by quality problems when introducing the Mover on the market.

Green Systems also wished to build up technological expertise about the Mover technology in order to support implementation of its products. The motive was strategic since the Mover system is of vital importance to the functioning of Green Systems' products. Any delay in market introduction or quality problems would be very costly since the Mover was planned to be used for several thousand products. Furthermore, it was seen as important to have substantial competence in the subsystem technology in case the company would need to establish a manufacturing line in Europe. This was an important option in case there would be substantial fluctuations between the SEK and the US dollar.

In this section the strategic motives behind the choice to initiate the Mover collaboration have been presented. The following will outline how the collaboration was organised.

4.3.3 Form of collaboration

The Mover collaboration was initiated in January 2002 with the signing of a letter of intent (LoI). Thereafter, three contracts were drawn up in order to regulate the collaboration. There was one contract for the product development, which was signed in October 2003. It was a joint development agreement with a 50–50 financial commitment. The formal collaboration structure is illustrated by the following figure.

Figure 8: The Mover collaboration

The figure illustrates that the companies had equal influence over the collaboration, in a formal sense. In reality, the vast share of work was planned to be located at Far Partner. At the same time, Green Systems' ambition to play a more active role was manifested in the product development contract between the two companies. The contract states: "A fully independent project organisation shall be established."

The idea was that development should take place within a project organisation located at Far Partner and with human resources from the company. The development project should, however, be governed by the two companies together. A council, later called the board, should be responsible for overall management issues such as budgeting, supplier selection and the business plan for industrialisation of the product. According to the contract, a project leader from Far Partner should lead the project. The two companies should appoint this person jointly. Furthermore, according to the agreement, Green Systems should contribute with five engineers. Both companies should be mutually responsible for the work process, the collaboration's managements, and realising the development of the Mover. The contract was regarded within the companies as being quite general, and interpretation of its meaning was dependent on a few individuals who had participated from the start in 2003. Therefore, the role the companies should play in the collaboration was not entirely clear and consistent.

The other contracts concerned the technology being developed during the collaboration. A technology agreement regulated the intellectual property rights and technology transfer between the companies. In principle, it stated that a company controlled jointly by Green Systems and Far Partner owned all rights to results. The third contract regulated what the company that owns the rights can do with them. The central idea behind having a jointly owned company that controls the intellectual property rights was to avoid competitors gaining access to the technology if Green Systems or Far Partner should be taken over.

Even though Green Systems was determined to play a more active role in the development of Mover, the formal form of collaboration was not a major issue. The two companies had a mutual interest in collaborating, and pragmatically designed a contractual structure that regulated the collaboration that was already in operation. In short, the agreement was that both companies should have equal rights to the technology results of the Mover development.

A joint venture was later established for the production of the Mover. This contract and that phase in the collaboration are, however, outside the scope of this case study.

4.3.3.1 Collaboration structure

The Mover collaboration's organisation had two parallel structures. The development of the Mover was located at Far Partner in the USA. Although Far Partner was leading the major part of the technology development, Green Systems in Swetown played an active role. Green Systems was active in reviewing results and carrying out prototype tests, as well as contributing to the management of the project.

Both companies had their line organisations deeply involved in the collaboration. At Green Systems, two groups were involved directly – a design team and a test team. A group leader, who reported to a middle manager that was a member of the Mover collaboration's board, headed each of these teams. Far Partner had a division – with approximately 50 engineers – that was engaged almost full-time in the Mover development. This meant that the project organisation and Far Partner's line organisation were largely synonymous. As an obvious consequence, it was not clear to what extent the project organisation could be independent.

4.3.3.2 Collaboration management

A board led the project organisation. It had three middle and senior management representatives from each of the two companies. The main role of the board was to make formal decisions on strategic issues such as plans, selection of subcontractors and other major issues related to the progress of the development. Even though decisions were formally taken by the board, many strategic decisions were dealt with by the project leader, e.g. regarding operations such as technology issues and suppliers.

A project leader managed the collaboration's operations, which were located at Far Partner. Later a deputy project leader was assigned from Green Systems. Formally, the joint project organisation was independent of Far Partner. However, as mentioned, the project organisation was in reality also a line organisation. The reason was that all development resources were located at and belonged to Far Partner's product development organisation. Hence, in addition to the project leader, managers in Far Partner's line organisation also had a say in the management of Mover development. How this dimension of the collaboration should be handled was not clear. As will be described in later sections, this unclear organisational structure became a source of frustration and irritation in Green Systems.

4.3.3.3 Division of work

Green Systems' test team was engaged in testing the performance of prototypes, verifying Far Partner's test results, and providing feedback to the design team in the project organisation at Far Partner. A design team worked with issues concerning the integration of the Mover in Green Systems' products. Their work gave input to the Mover design team regarding system requirements and interfaces. It was felt that knowledge of design requirements for integration into Green Systems' products was useful input for the design work at Far Partner.

In the beginning of the collaboration project, Far Partner conducted the development work and Green Systems controlled the technology results. The division of work was, however, not defined in detail. Understanding how the work should be divided was therefore largely dependent on the knowledge of those persons who had been working actively in the project since the beginning.

The principal division of work that was agreed on stated that the development of the Mover should be accomplished with Far Partner's engineers. Green Systems should, for example, work on design issues related to integration of the Mover in its forthcoming product generations. In addition, Green Systems was expected to be involved directly in Far Partner development through the testing of prototypes, and have the role of defining requirements and generating ideas and solutions to problems.

This overall distribution of work between the companies was decided on the basis of the two companies' competences at the beginning of the project. Far Partner had the expertise required for developing the Mover, and Green Systems had complementary resources. The complementary resources made it possible to run tests and support product design. In addition, Green Systems wanted to play an active role in ensuring that the Mover could be implemented efficiently in its products. Therefore, Green Systems contributed a purchaser, a design engineer, and a test engineer in addition to the deputy project leader.

As people at Green Systems working with Mover learned more, they became more active in contributing to the development. Consequently, there was a gradual shift from the initial and formal work distribution. It meant that Green Systems became involved more directly in the development work than was planned.

As one middle manager said:

> "Green Systems has learned how the system is functioning and the employees who have worked with the development are carriers of knowledge and pride."

One example is that design knowledge at Green Systems became important for the development of the Mover's physical design. One major consequence of the increased work integration was a growing need for access to knowledge about the technology developed and influence over work conducted at Far Partner. This was, however, not easy to accomplish. Therefore, as described subsequently, Green Systems experimented with different integration mechanisms in order to access more knowledge and gain a better understanding of the development of Mover.

4.3.4 Development of integration mechanisms

This section describes the development of integration mechanisms during the Mover collaboration and how knowledge communication between the companies was influenced. The section will review development in the project from early 2003 to the summer of 2005. The integration efforts are presented chronologically according to the time of their implementation.

Compared to the companies' previous product development collaboration, Green Systems wished to play a more active role in the development of the Mover. However, from the outset the persons from Green Systems involved with the Mover development felt that they did not have access to enough knowledge about the status of technology progress at Far Partner. They had access to blueprints, prototypes and documents with technical data. Yet it was experienced that these were not always updated and sufficient for really understanding the technology being developed and how the results were created.

It was thought that in order to understand how the development processes were proceeding, Green Systems had to know which technical problems occurred in the day-to-day operations and how they were handled. Since they largely lacked such knowledge, the persons directly involved in the project were concerned that they did not know enough to influence the development much. The lack of influence was a major concern to all managers involved. From experience, they could imagine what potential quality and cost problems they might face once the Mover reached production. Furthermore, decisions about technology solutions were made without Green Systems having any real opportunity to influence them. It was often unclear to the design and test teams in Swetown what the actual quality status was for the technology developed. This included how the work was actually proceeding in relation to plans.

It also became apparent that the two companies had different ways of integrating production planning in product development. Green Systems has a tradition of starting production preparations earlier in the development process in order to ensure full quality from the first production batches. Far Partner has a tradition of sequential development and production preparations and a stronger focus on time to market. During the first year of the Mover collaboration, production plans were not discussed in any detail. It therefore came as a surprise to Green Systems in December 2004 when they realised that Far Partner requested that the Mover system should be launched ahead of the date Green Systems had expected. It was apparent that at that time the companies did not have synchronised plans for the launch of the Mover.

In order to tackle the lack of knowledge, Green Systems tried to increase the integration between the team in Swetown and the development organisation in AM Town. As planned at the outset of the collaboration, Green Systems continued to move employees to the project organisation at Far Partner. Eight months after the signing of the development contract, four employees had been assigned to the project organisation – three engineers in operational functions and one deputy project leader.

In order to enhance communication on operational level, other measures were taken quite early after the start in 2003. One of them was the telephone conference routine initiated by a manager at Green Systems. The idea was that it could improve communication between the two teams in Swetown working on tests and development and their colleagues in the project at Far Partner. The telephone conference was used every week at the same time – afternoon in Sweden and early morning in the US. It normally lasted a couple of hours. As will be described in a later section, although appreciated this mechanism was not enough to meet the communication level required by Green Systems.

From early in the Mover collaboration, the management board had meetings approximately every second month. During these meetings, the management reviewed the development of the project. However, since the amount of data was large it was difficult to grasp how the Mover development was proceeding. One reason for this was the companies' different rhetoric. Green Systems has a tradition of focusing discussion on what does not function. In contrast, Far Partner usually addressed what is functioning and implicitly assumes that problems are taken care of. The difference in organisational rhetoric was experienced as a common source of misunderstanding and frustration in the collaboration. The implications of this difference were experienced not only by the board members but on all organisational levels. It was, for instance, recognised by persons at Green Systems that the cultural differences between the two companies from time to time made communication difficult. Nevertheless, the attitude toward these differences was pragmatic. A quotation from a manager in Green Systems illustrates a common view on the differences between the companies.

> "You have to accept that there are cultural differences and as long as you are aware of that you can find ways to deal with misunderstandings."

The view within Green Systems was that continuous dialogue on several organisational levels would gradually enhance an understanding of Far Partner's problems and ways of doing things. Therefore, Green Systems tried to increase communication in order to reach beyond what was being said in formal meetings and documents.

Both managers and engineers recognised that personal relationships played an important role for facilitating communication between the companies. Managers on different levels therefore actively developed relationships with individuals on their hierarchical levels. Personal relationships became a platform for frequent telephone conversations on both management and technology issues – often once a week. The informal relationships were also regarded as important sources of knowledge about the development situation at Far Partner. However, it was experienced that there were too few who had personal contacts in the partner organisation. It was also described that close management relationships were not enough to understand the progress of the collaboration in depth. One reason was that only a few managers had such close relationships and it was simply not possible for them to monitor all important technology issues. Engineers handled the technology details. On that organisational level, personal relationships between the companies were limited.

Several of the engineers at Green Systems involved in Mover had never met their counterparts at Far Partner. To the extent that there was any informal contact on the engineers' level, it was *ad hoc*. Consequently, about a year after the development project began, it was felt that contact in daily operations had to be improved. A line manager and a technical expert therefore began spending periods of two weeks at Far Partner between October 2004 and February 2005. This increased access to information and created a sense of being part of the development process in AM town. As the amount of travelling decreased, however, the access to knowledge declined and so did the experience of being part of the collaboration together with Far Partner.

Another initiative in order to improve Green Systems' access to knowledge and influence was to send a deputy project leader to the project organisation. This initiative was implemented in June 2004, and after about six months it was felt that Green Systems' management access to knowledge and real influence had improved.

The general impression expressed by those working with the collaboration was that Green Systems' gradual increase in integration mechanisms enhanced knowledge communication. The knowledge communicated was intensive, which enhanced updating of e.g. blueprint changes. It also contained more details about technology and increasingly focused on how problems could be solved together. Yet the feeling of not being really involved remained a concern to managers at Green Systems throughout the development process (until summer 2005 when this study came to an end).

This section has introduced the integration mechanisms used and how they functioned during the first two years of the Mover collaboration. Below is a more detailed description of different integration mechanisms and their influence on knowledge communication between the two companies.

4.3.5 Different integration mechanisms' influence on knowledge communication

This section describes the five integration mechanisms used and their influence on communication of between the two companies. It will first address the board and it will then describe the role of the deputy project leader. Thereafter, three different operational level initiatives to enhance collaboration are described – frequent travelling individuals, collaboration between engineers in the two companies, and individuals transferred to Far Partner.

4.3.5.1 Management board

The Mover project used a board with managers, which had the role of controlling the collaboration's operations. It was this control mechanism which the two companies used in order to manage the progress of the project jointly. It was agreed in the contract between Green Systems and Far Partner that they would establish a management board.

Since collaboration began in 2003 the board met approximately every second month – occasionally more often. Each company had three persons on the board. The representatives from Green Systems were the Senior Vice President of a technology division, the head of a technology area and the director of purchasing. Far Partner had three representatives from similar hierarchic levels. The main role of the board was to decide on strategic issues such as plans, selection of subcontractors and other major issues related to the progress of the collaboration.

The work proceeded and Green Systems received batches of technical data about e.g. product design, performance capacity, and interface integration in advance of board meetings. But by only reviewing these documents it was regarded as difficult for the board members to gain a grasp of the development – in particular since the documents often arrived shortly before meetings. In addition, the members of the board from Green Systems felt that cultural differences between the companies made it difficult to understand information from Far Partner. It was seen as difficult to evaluate information and to understand the nuances of what was being said. In addition to the information prior to board meetings, the board members were briefed about the development of Mover several times a week. They also had contact with their peers on the board and in particular, one of them participated in telephone meetings (the section on collaboration between engineers further describes these meetings). During these telephone meetings, they addressed the current situation in the collaboration concerning e.g. how the quality requirements could be met with the suggested design.

Being concerned that they did not have enough information to understand the project's progress well and hence be able to influence it, the board members were – particularly at the beginning of the project – keen to understand the technology development. Management from Green Systems therefore devoted considerable attention to technology issues. This attracted some criticism from the operational levels where people thought that the board was too preoccupied with these issues. It was worrying that the technology focus took so much time and that it detracted from the "big picture". One Green Systems engineer stated:

> "The board is involved in details instead of managing by defining overall frameworks for the project."

This situation was, however, seen as temporary. As the collaboration continued, the board gradually focused more on overall issues. In particular, there was a shift in the board's focus when the deputy project leader from Green Systems was assigned to work in the project organisation, within Far Partner.

Formally, the board made all major decisions in the collaboration, e.g. about accepting or rejecting product design solutions. However, in practice the role of the board was constrained by the strong project leader, who ran the everyday operations of the project. The project leader's strong role was referred to as an expression of a tradition in Far Partner of having heavyweight project leaders. The project leader, for example, made decisions on central technology issues that the board was expected to handle. It was unclear to Green Systems' managers what constituted the formal authority of the project leader in Far Partner organisations. It was experienced as frustrating to have such an independent project leader. In Green Systems, the line organisation has a stronger role and project leaders a weaker role compared to Far Partner. The board members from Green Systems also felt that the project leader had a role in distribution of information that was too dominant. Mostly the project leader was the board's only direct source of information about the progress of the work. It was therefore a concern among Green Systems' board members that they only received biased knowledge. The discussion to assign a deputy project leader reflects this situation. A more detailed description of that role will be presented later.

In the autumn of 2004, the board decided to give more influence to Far Partner's line managers for technology. The reason was that the project leader felt that his work situation was too fragmented and Green Systems did not have enough influence. Despite this change, little happened – the influence of the project leader remained strong. The board members from Green Systems remained dissatisfied with the project leader's management of the project.

The costs for the Mover increased more than expected and there was a constant challenge for Green Systems to get a grip on the development in the collaboration project. In response to this situation, Green Systems decided to push for replacement of the project leader. This was settled by the two companies' CEOs in the summer of 2005. It was also decided that Green Systems would transfer its line manager responsible for Mover in Green Systems to work as head of product development at Far Partner. A member of the board from Green Systems was thus given line responsibility and temporarily became Far Partner's line manager responsible for Mover development. This case study was finalised before that new role became operational, and so its influence is not included in the study.

4.3.5.2 Deputy project leader from Green Systems

In June 2004, Green Systems sent a deputy project leader to Far Partner after an initiative by the Green Systems members of the Mover board. The reason was to gain more insight and increase influence over the collaboration's operations. In addition, assigning a deputy project leader was seen as a way to access system competence regarding Mover. At the beginning of the collaboration, Green Systems had the ambition of appointing a Green Systems employee as project leader, but Far Partner regarded this as criticism. The solution was to deploy a deputy project leader from

Green Systems. This was planned to take place in 2003. However, it was delayed until 2004 because of, among other things, time-consuming administration for receiving job permission from the US authorities.

As the deputy project leader began the job, his role was unclear – both within the project and in relation to Green Systems. During the first month, people working on the Mover project at Far Partner questioned the deputy's authority. Tackling the situation of working in a new organisation in another country, having an unclear work description, and facing resistance from colleagues was not easy. To some extent, knowing that achieving the collaboration was important to the home organisation created a sense of meaning in the efforts.

In order to get started the deputy project leader began working with the quality control system used by Far Partner. The idea was to influence their work process with Green Systems routines. This was not easy to accomplish, but it was experienced as a way to gradually become involved with the development of the Mover.

After six months or so, he had earned sufficient legitimacy to function as deputy project leader. This meant that he was gradually becoming more and more involved in running the Mover project's operations. In order to manage this role he had to acquire knowledge of the whole subsystem. This was accomplished by spending substantial time talking to engineers in different functional areas. In addition to discussing the technology content of the Mover system, he had to develop a general understanding of the functioning of the system. One major reason was based on the realisation that there was a lack of co-ordination between the different functional areas of the project. One Green Systems manager commented on the perceived lack of co-ordination within the project:

> "The co-ordination in Mover organisation is weak – there is a focus on details and on particular tasks but there is a lack of knowledge of the whole picture and a lack of activities that enable the whole picture to emerge. Co-ordination is too focused on technology."

Discussion with engineers was one important source of knowledge about the Mover and its development process. The deputy project leader also had daily contact with leaders of functional units in Far Partner line organisation. These meetings concerned e.g. the product design and tests as well as other current problems within their functional areas. These discussions were largely concentrated to meetings. Most discussions, however, were informally taking place in the shared open office area within the development organisation. The open office area was located in one building at Far Partner's plant. It was experienced that working in a concentrated office area enabled daily meetings, often ad hoc, e.g. on the way to meetings or in the reception during mornings and afternoons.

The technology issues discussed during meetings, as well as informal dialogues around tables in the joint office area, concerned the whole Mover system. A combination of artefacts, documents and face-to-face dialogues was used for discussing aspects of the Mover's design. Artefacts were for example components that had been purchased from suppliers in order to be tested. Documents could e.g. contain detailed reports from tests of different components. There were daily face-to-face conversations on the development process and the functionality of the Mover's technology, including its design and interfaces to other systems.

In addition to working with aspects of technology, the deputy project leader initiated work aiming to implement a visualisation technique used by Green Systems in order to improve co-ordination in product development. Although this was experienced as difficult to achieve, it meant opportunities to get to know Far Partner better.

Gradually it was experienced that an understanding of both the technology and the development organisation was created. It was, for example, possible to make independent analyses of weaknesses in the design and relate those insights to production planning. This kind of analysis enabled insights to emerge about the collaboration's challenges in meeting deadlines for production start.

The communication with representatives for the home organisation concerned overall managerial issues such as project plans and technology related to the stability of the design. The main reason for these discussions was to improve Green Systems' insight into development in the project organisations and thereby enhance co-ordination in the collaboration. It was felt that the deputy project leader in particular contributed to strengthening the middle and senior management's access to knowledge about both technology and the situation in the development organisation.

It can be mentioned that shortly after this case study was finalised the deputy project leader replaced the Far Partner's project leader. Green Systems thus managed to substantially strengthen its influence over the collaboration.

4.3.5.3 Frequently travelling individuals

Within Green Systems and Far Partner there were functional line managers running the technology work. The two main functional areas were design and testing. At the beginning of the collaboration, these managers mainly focused on the internal work within their areas of responsibility. There was little interaction between line managers at Far Partner and their counterparts within Green Systems. During this period, the project leader acted as a broker between the two company's organisations. However, both managers and engineers in Green Systems felt that the integration between the development teams in Swetown and the project organisation was too weak.

It was considered a problem that Green Systems had too limited a presence in the technology management function in the Mover project organisation at Far Partner. It was, for example, felt that time schedules which were central for Green Systems did not receive enough attention simply because no one had a Green

Systems perspective. A common view was also that Green Systems received too little information about technology development at Far Partner. Consequently, the teams in Swetown considered that they were not sufficiently involved in the work at Far Partner. For instance, important decisions about technology were made without Green Systems being asked for an opinion. The following quotation from one of Green Systems managers illustrates this experience.

> "We were given final technology solutions without having any say in advance."

It was therefore recognised that Green Systems needed to increase knowledge communication on technology from Far Partner in order to be able to exercise more influence over the project. Technology discussions by telephone were not enough to give adequate feedback to Far Partner. It was seen as necessary to develop closer relationships with the engineers working with the development of technology for the Mover. Within Green Systems teams that were engaged in the Mover development, it was suggested that they should send people to work in the project organisations for short periods. The idea was that they should spend a couple of weeks with the partner and then fly home to report on the latest developments. Senior managers accepted this initiative. Thereafter, one of the team managers and a technology expert began to frequently spend alternating two-week periods at Far Partner during autumn 2004 and winter 2005.

The perceived effect of the frequent travelling was somewhat different at Green Systems and Far Partner. People at Far Partner stated that boundary-spanners from Green Systems were treated with suspicion and did not access much technology. From that perspective, they were not engaged sufficiently in the daily work to play a very active role. However, the view expressed by those at Green Systems working with the Mover is different. Their view is that frequent travelling enhanced access to knowledge of both product technology and the development process, such as the role of line managers and the relationship between functional units. Their presence in the project was regarded as very valuable, not only to develop a general understanding of the product and its technology but also to promote other interests, e.g. Green Systems' views on quality and production planning.

According to one of Green Systems' managers:

> "The effect of the initiative (sending people to work in the project for two-week periods) has been better access to knowledge about what is going on in the project and also greater influence over the work."

The experience expressed by the boundary-spanners was that being physically present in the project organisation gave them the opportunity to address problems informally. When working at Far Partner there were opportunities every day to access technology about e.g. component design, simply by asking questions. It is described that by working at Far Partner they were able to tackle problems before these became too big and caused a disruption in the collaboration. In addition, the view within Green Systems was that the physical presence made the company a more active part of everyday decision-making. This view is illustrated in the following quotation from one manager.

> "As Green Systems increased its activity on the detail level in the development work the collaboration processes have become smoother."

The two frequently travelling individuals also contributed to open up new contacts for communication between the two companies' Mover operations. For example, most communication on technology between the designers at Green Systems and Far Partner took place through the project leader. One reason was that Far Partner's line managers therefore felt that they did not have to assume responsibility for what Green Systems said. It was experienced that the frequent visits increased the line managers' feeling of being responsible directly to Green Systems. This enhanced constructive direct dialogues with the persons running the day-to-day operations in the project organisation. It was explained that this strengthened the operational work contacts between the two companies, even though it never reached the levels required by Green Systems.

4.3.5.4 Collaboration between engineers at the two companies

In Green Systems, the test team participating in the collaboration was responsible for e.g. running sustainability tests on components. Their colleagues in the design team were involved in the development of the Mover's architecture – in order to make sure it could be implemented on Green Systems products. Therefore, a major concern was the design of the Mover's physical interface between the Mover and Green Systems products.

The division of work created a need for work relationships between engineers from the two companies. This, however, was not easy to accomplish. According to respondents, the reason was that there were few personal relationships between engineers from the two companies. Most of them had never met, and at the outset of the collaboration they had limited knowledge of different people's skills and responsibilities at the partner company. Weekly telephone conferences were therefore initiated in order to enhance communication between the Mover teams at Green Systems and engineers and line managers at Far Partner.

The telephone conference routine was initiated in early 2003 as a means of bringing about integration. Normally the same persons participated in the meetings.

The normal pattern preceding these meetings was that Far Partner's project leader sent reports on testing results, or that Green Systems had identified problems during reviews of blueprints from Far Partner or from tests of prototypes. Approximately twenty individuals from the two companies participated in these meetings, although the same persons were not engaged every week. At the weekly meetings, each functional manager at Far Partner reported to Green Systems about the progress in his/her area of responsibility. The topics discussed at the meetings concerned, for instance, the progress of technology development, the problems that had occurred during the week and issues that needed further work. The discussions concerned both design and test issues. The technological content discussed was on a detailed level. Following the telephone meeting, Excel was used to structure activities and rank tasks to be accomplished in a priority list. The following meeting began with discussing the level of achieved priorities. It was not unusual that Green Systems experienced that Far Partner did not do what they had promised to. This was described as a signal of not being sufficiently respected by the partner company, which among individuals was a source of irritation.

The work between Green Systems and Far Partner meant iterations of technical data, blueprints, and documents with analysis and prototype components. This process started early in the collaboration. A sequence of iterations often started with a transfer of construction blueprints to the design team at Green Systems. This started intensive discussions on problems and alternative solutions within the team. Thereafter, Green Systems' team provided feedback, such as questions and suggestions for change, to the design team at Far Partner. Having received feedback from Green Systems the team at Far Partner – which was normally willing to listen – continued working on the design. It was described by engineers and managers at Green Systems that there were often several iterations between the companies before a problem was solved. One engineer said:

> "Blueprints are often sent to Green Systems for review up to ten times before the companies agree on a solution."

The testing followed a similar pattern. Far Partner sent competent prototypes to Green Systems where tests were carried out, such as performance tests. The test results were discussed during the weekly telephone conferences. At the meetings an action plan was established and it was agreed to what extent the teams at Green Systems in Swetown should be involved in implementing the changes that had been decided.

It was felt that communication on technology design was related to the form of communication. Face-to-face communication between the two companies' engineers was felt to be too limited. The view was that communication between individuals, e.g. face-to-face, focused a highly advanced technology. The complexity of the tasks and the difference between the companies would have required more informal face-to-face interactions. The knowledge communication content of artefacts was rated as less complex. Transfer of blueprints was regarded as easy – notwithstanding that interpretation of the exact ideas underlying them could be difficult. However, one concern was that information was lost during the transfer of files containing blueprints. The reason was that files had to be sent via e-mail. Efforts to create a shared database were delayed due to technical difficulties.

From the beginning of the Mover collaboration, Green Systems had an active role of reviewing blueprints and prototype tests. Based on analysis and test results, the individuals involved from Green Systems were frank in their criticism. Being unfamiliar with open discussions focusing on problems, engineers and managers at Far Partner found it difficult to receive criticism. From their perspective, it was perceived that Green Systems did not trust their competence. Initially, they disregarded much of the input from Green Systems. There was also a view of Green Systems as a customer and not as a partner. This view contributed to making Green Systems' opinions seem less important. Over time, however, top management at Far Partner made it clear that Green Systems was to be treated as an equal partner. In combination with people becoming accustomed to what were at times tough dialogues, there was a substantial increase in the acceptance of Green Systems' input.

It was, however, unclear to Green Systems' engineers and managers how decision-making authority was distributed in Far Partner's organisation. Decisions were made but it was not always clear by whom they were made and why. It was known that the work was conducted within the different functional areas, such as the test team. However, the insight on the work within and between these teams was limited. This was experienced as frustrating, because things were done and decisions made without enough consideration of first discussing them with Green Systems.

This experience was one major reason behind the previously described initiative to send people to work for short periods at Far Partner. Another initiative, but with limited expectations of playing an active role in the interaction between the companies operations, was the transfer of employees to Far Partner.

4.3.5.5 Employees transferred to Far Partner

Three persons were transferred from Green Systems to work as employees within Far Partner during the period studied. The main reason for sending these persons was to build up expertise that could be useful in case a production line for the Mover would be established in Europe.

The three persons were transferred during the first one and a half years of the collaboration. The first person was sent to Far Partner during the summer of 2003, before the development contract was signed. This individual was assigned to the Far Partner purchasing department. The main reason was to prepare for the production of the Mover, e.g. dealing with matters concerning which suppliers should be used. One major reason for sending the purchasing employee was also to establish Green

Systems' quality philosophy early in the development of relationships with potential suppliers. This was also seen as a way to access direct information about component costs. The person that was sent to Far Partner had previous experience from earlier collaboration between the companies. This meant he had prior knowledge of working with Far Partner and experience of the quality problems that were associated with the earlier collaboration.

After approximately a year of collaboration, people at Green Systems, working with the Mover development, suggested that one of them should be transferred to Far Partner in order to work on testing the product technology. It was seen as central to increasing Green Systems' presence in the development organisations in order to be able to identify any weaknesses in the Mover technology. This idea was based partly on the experience from previous collaborations. As mentioned, in that collaboration Green Systems had little direct involvement in the development process and was therefore unable to identify technology problems until production was up and running.

During the spring of 2004, almost one and a half years after the start, it was considered valuable by the persons working on development at Green Systems if they could strengthen the design team at Far Partner. Sending a person to that team was also seen as a way for Green Systems to increase its access to information and influence in the development of the Mover. An additional reason was to access in-depth knowledge about the technology making up Mover in order to, as mentioned, develop the option for production of the Mover in Europe.

Within the project organisation at Far Partner, Green Systems' employees were involved in everyday dialogues on technology within their areas of responsibility and related functions. There were, for example, several dialogues a week between the test team and people working on design, and between testing and those working on prototypes. There were also dialogues about purchasing on a weekly basis between purchasing and design and test engineers. These discussions concerned, for example, whether suppliers would meet their quality requirements on components.

The persons from Green Systems working at Far Partner experienced open access to technology and experience of developing technology for the Mover's product category. On a daily basis, they had access to component prototypes and documents describing technical analysis as well as face-to-face conversations about the Mover technology. This meant that they received access to the same reports, blueprint and test results as their Far Partner colleagues. They also learned from their colleagues' experiences from similar development projects. The explanation for the openness was related to their role as colleagues in the development organisation. It is stated that working in the Far Partner organisation gave access to a lot of technology. One of the transferred individuals said:

> "You get to hear a lot about the technology informally."

Another said:

> "Access to information and technology is very much dependent on working together at the same site on a daily basis. It is not enough with people going there once a month or having weekly telephone meetings."

It was perceived that the content being communicated to those working in Far Partner was high-level technology. Being active in the development work and being part of that environment, they also developed skills in the process through which Mover was developed, particularly the process within their functional areas.

When the employees from Green Systems began working in the project organisation at Far Partner, they used their personal networks at Green Systems to help their new colleagues to get in touch with peers. Once the contact was established, it was felt that it was easier for the engineers to pick up the telephone or send an e-mail concerning technology issues. However, as time passed the persons from Green Systems working in the US gradually became involved in the daily work and the social life at Far Partner. Over time their interactions with colleagues in Swetown declined. It was felt that communication of knowledge of the project back to Green Systems was limited. One explanation for the decline in contacts was that the Green Systems employees were formally employed by Far Partner. Therefore, they could not act as Green Systems employees. As expressed by one manager at Green Systems:

> "They are sort of stuck in between the two companies."

Another reason was that they lost contact with the home company because they did not have access to information about changes in the organisation, such as change in management positions and assignments. There was also little active interest from the home organisation to remain in contact with those working embedded at Far Partner. The effect was that the transferred individuals received specialised knowledge about their parts of the Mover and the project organisation but little of this was transferred to Green Systems. However, as mentioned, it was never intended that they would play an active role in connecting the two companies during the development of Mover.

4.3.6 Case summary

This case has described how Green Systems in Sweden gradually became more involved in the development of the Mover together with Far Partner, which was located in the USA. The increased involvement was part of Green Systems' strategy of influencing the development process in order to reduce uncertainty about product quality. In addition, the company had the ambition to build up competences that could be used for the establishment of a possible future production line in Europe.

Different integration mechanisms were used in order to access knowledge and to influence the project. No one integration mechanism was sufficient alone. The combination of several different integration mechanisms gradually increased access to knowledge and influence over the collaboration's technology development.

Knowledge communication in the different integration mechanisms can be summarised as in Table 7.

Integration mechanisms	Knowledge communication
Management board	The board members met every second month – before the meetings they received documents with technical data A few days of work with large batches with data and long presentations, every second month, made it difficult to really evaluate technology Those from Green Systems found it difficult to understand Far Partner's organisation and accept its communication style
Deputy project leader	Working within the development organisation enabled everyday dialogues with its members on technology and organisational routines such as quality controls Becoming involved in the development work created informal contacts and gave access to documents and peoples' experiences about the product technology in focus Gradual understanding emerged for both technology and Far Partner's organisation
Frequently travelling individuals	Working every second fortnight at Far Partner meant opportunities to discuss technology informally with people Being actively engaged in the work at Far Partner gave good access to technology and insights about its organisation Access to knowledge and development of informal relationships enhanced the companies' understanding of each other's perspectives, joint decision-making and a sense of collaborating
Collaboration between engineers	Weekly telephone conferences were the major means of communication – on technology analysis and work priorities Working on related tasks required substantial communication – it was fairly easy to communicate data, such as blueprints, but difficult to discuss content It was difficult to understand Far Partner's points of view on technology, work priorities and negative reaction to criticism
Transferred individuals	Working within the development organisation meant informal and daily communication on technology concerning e.g. design and test results Being part of the development organisation meant full access to results as well as colleagues' experiences of previous product development Over time deep knowledge about the product technology emerged as well as understanding of the partner's organisational work routines and its values concerning product quality

Table 7: Summary of knowledge communication in the Mover collaboration's different integration mechanisms

5 Types of integration mechanisms and their knowledge communication

This chapter explores integration mechanisms within the three cases studied and analyses their influence on knowledge communication. Eleven different types of integration mechanisms are identified in the product development collaborations studied. Their influence is analysed in terms of intensity, richness and types of knowledge communicated.

The previous chapter described the three case studies conducted for this thesis. This chapter explores integration mechanisms within these cases and analyses their major structural characteristics and influence on knowledge communication. Thereby, the chapter will address the first two research aims, as defined in Chapter 1:

- ➜ Explore integration mechanisms of different types that influence knowledge communication in product development collaborations between companies.
- ➜ Analyse how identified types of integration mechanisms influence knowledge communication in product development collaborations between companies.

The investigation model developed in Chapter 2 is used as analytical framework for the case analysis. By using the investigation model, the analysis focuses on factors theoretically relevant to address in order to accomplish this study's purpose. Section 3.5 presents an extensive discussion of the analysis process. In order to guide the reader, the following gives an overview of the chapter and the analysis.

Building on the investigation model, the analysis in this chapter has the following structure:

- ➜ First, each case analysis begins by exploring integration mechanisms that are indicated to influence knowledge communication.
- ➜ Second, the major structural characteristics of identified integration mechanisms are analysed – i.e. formal structure, location structure and cognitive structure.
- ➜ Third, the analysis addresses the indicators of knowledge communication – i.e. intensity, richness and types of knowledge content.

The analysis builds on the investigation model in order to systematically categorise and explain the empirical observations. Therefore, analysis of the different types of integration mechanism follows the same structure, which means that they address similar issues and use similar theories. The reason is that this study, based on the investigation model, chose to address certain factors. However, there are also variations in the use of literature, which reflects the differences in integration mechanisms' characteristics and knowledge communication.

The case analysis will follow the same sequence as the case descriptions in Chapter 4. Hence, this chapter first analyses integration mechanisms and their knowledge communication in the Explorer collaboration between Red Systems and Yellow Partner. Thereafter, integration mechanisms and knowledge communication during the Seeker collaboration are analysed. Finally, the chapter analyses the Mover collaboration between Green Systems and Far Partner.

5.1 Integration mechanisms and knowledge communication in the Explorer collaboration

Red Systems and Yellow Partner began the Explorer collaboration in September 2004. It was the first phase in a collaboration aiming for the development of a new technology platform for an emerging high-technology market segment. In this section, the first phase, between autumn 2004 and summer 2005, in the Explorer collaboration is analysed.

Red Systems' development organisation was located in Home Town, Sweden, and Yellow Partner had its development located in the European city that here is called Metropolis. Therefore, the geographical separation of some 2000 kilometres between the companies was a given fact. It also became clear during the early discussions between the companies that, in order to realise the collaboration, substantial capacity for communication would be required. From that perspective, the geographical separation was regarded as one obstacle for the collaboration's communication needs. In order to tackle this challenge, the companies agreed to establish a joint and co-located development team.

There were three major reasons underlying the decision to create an integrated collaboration. First, the Explorer architecture was not defined, which meant it did not have any defined physical and functional interfaces that would enable clear division of work. Therefore, developing shared architectural knowledge was necessary in order to enable integration of subsystems. Second, even though Yellow Partner was the lead company for the Explorer development, Red Systems had the ambition to understand the whole system in order to retain its systems integration capability. Third, both companies had the strategic ambition to improve their collaborative skills.

The studied phase of the Explorer collaboration used two different types of integration mechanisms – they are here categorised as the heavyweight project leader team and the co-located integrator team. One project leader from each of the two companies constituted the heavyweight project leader team. The co-located integrator team was an integration mechanism led by the project leaders and used in order to develop the Explorer's architecture. It had engineers from both companies and was located in a joint office area at one of Yellow Partner's sites. In the following, these two types of integration mechanisms are analysed.

5.1.1 Integration mechanism: Heavyweight project leader team

The following analyses the integration mechanism constituted by the project leaders from Red Systems and Far Partner. The background to this integration mechanism is that when starting the Explorer collaboration, Red Systems wished to gain management influence over the development. Therefore, senior managers at Red Systems regarded a heavy representation in the Explorer collaboration as important. A senior project leader was therefore commissioned to the joint development team as head of Red Systems' engineers and as deputy project leader for the whole project. Together with the project leader from Yellow Partner, this individual constituted the Explorer's project leader team, during the period studied.

The following analysis will address this managerial integration mechanism's structural characteristics and how it influenced knowledge communication. The analysis begins with its structural characteristics.

Formal structure

The analysis of the formal structure of the heavyweight project leader team will focus on the integration mechanism's role in the collaboration, the decision-making authority and the integration of work between the project leaders.

The Explorer collaboration was organised as a project, rather independent of the day-to-day operations within the companies' R&D organisations. In the literature, such an autonomous product development organisation is often led by a person with considerable independence and authority – a so-called heavyweight project leader (e.g. Wheelwright and Clark, 1995). The two project leaders of the Explorer collaboration had a strong role and they were autonomous from the home organisations concerning decision-making on technology issues and project administration. For example, they had authority to make decisions concerning strategic technology choices. They also had full responsibility for the development project's performance. In addition, they had full managerial authority over the personnel working in the project. Thereby, their role is similar to the heavyweight project leader discussed by e.g. Clark and Fujimoto (1991). An interesting difference, however, is the shared project leadership in the Explorer collaboration – i.e. it was a heavyweight project leader team.

The heavyweight project leader team shares characteristics with the managerial linking role developed by Nadler and Tushman (1987). However, the managerial linking role does not have the same team role which characterised the Explorer's project leadership. Therefore, it is reasonable to categorise it as a heavyweight project leader team.

The following figure illustrates the formal relationship between the project leaders and their real relationship – as a heavyweight project leader team.

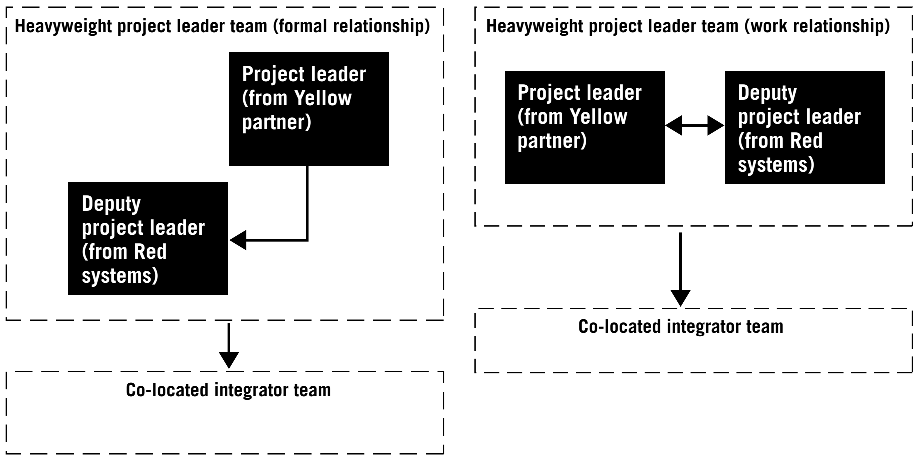

Figure 9: Heavyweight project leader team

Red Systems wished to have influence over the management of the collaboration, which the companies agreed on during the negotiations before starting the collaboration. Therefore, the work relationship was characterised by close collaboration between the project leaders, even though formally it was a hierarchic relationship.

Thompson (1967) used the term 'reciprocal interdependence' to describe work situations where two actors need continuous input from one another in order to perform their job. Such highly integrated work requires what e.g. Mintzberg (1978) called mutual adjustment between the involved parties. One major implication is that, for example, one company in collaboration is directly dependent on input from the partner, while at the same time it influences the partner.

A high degree of work integration emerged in the heavyweight project leader team. This is, for instance, indicated by the decision-making process. The findings in this case show that even though the two project leaders formally had different roles and different formal authority they worked closely together and made most decisions on technology and work process in consensus. It was necessary to agree on decisions in order to ensure both companies' commitment. If they could not agree, it was recognised as likely that the collaboration would be stranded.

Summary:

- ➜ A heavyweight project leader team, i.e. having high decision-making authority, with two individuals, was established to lead the collaboration.
- ➜ The team had high work integration, which meant that the two project leaders shared several work tasks and made important decisions in consensus.

Location structure

In what follows, the location structure of the heavyweight project leader team is analysed. The analysis focuses on the location structure's characteristics and its implication for interaction patterns.

The Explorer collaboration's joint organisation was separated from the home companies – 2000 kilometres from Red Systems and in a part of a building physically separated from other Yellow Partner operations. In this office, the two project leaders used to work every second week, and at the end of the studied period more often. Between the times in the joint office, they worked in their home organisations.

The heavyweight project leaders' offices were located next to each other at the end of the open office landscape. Thus they could easily "walk over", ask questions, just meet for brief discussions, and inform one another of upcoming issues concerning e.g. technology, employees or customers. This physical structure also meant that in order to reach their offices the two project leaders had to walk through the office area. Walking through the office landscape several times a day generated opportunities for e.g. *ad hoc* informal conversations with engineers. In addition, the rooms used for meetings were located just outside the two project leaders' offices, which meant that they were visually informed about meeting activities in the joint organisation. This co-location had a positive influence on communication between the companies, because it enhanced people's opportunities for face-to-face communication (e.g. Sharifi and Pawar, 2002).

According to Westling (2002), meeting informally is important for addressing complex issues during product development. The heavyweight project leader team's physical structure had the purpose of establishing conditions for such interaction. The background was Yellow Partner's positive experience of a similar location structure in previous product development collaboration. The analysis here shows that the choice to co-locate had the intended effect on the collaboration between the project leaders.

Summary:

➜ The heavyweight project leader team was co-located in an open office area, in order to enhance daily interaction.

Cognitive structure

In what follows, the analysis addresses differences in cognitive structures that the project leaders faced. It also discusses how the two project leaders handled the differences in cognitive structures.

One expression of differences between the companies' cognitive structures was their management styles. Before starting the Explorer collaboration, it was recognised by both senior and middle managers that the two companies had somewhat different management styles. For instance, Yellow Partner had a tradition with more centralised decision-making – which meant that more decisions were taken by the project leader than normally was the case in Red Systems' tradition. This may be an expression of both national and organisational differences (Hofstede, 1991). Nevertheless, it meant different views on e.g. how engineers should be engaged in the process of making decisions.

The rapid development of a joint decision-making process shows that the heavyweight project leader managed to handle differences in cognitive structures. Typically, a decision emerged through negotiations and mutual adjustments between the project leaders – based on input from the engineers.

This indicates a positive attitude toward win-win solutions in the everyday micro-negotiations within the heavyweight project leader team. One possible explanation is that the two project leaders shared the vision of the future product – that is, what Dougherty (2001) called a shared image as a means for enhancing collaboration. One additional reason is that gradually the two project leaders learned to know one another on a personal basis and thereby found ways to tackle misunderstandings (March and Stock, 2006).

Hence, it seems that the heavyweight project leader team began to develop what Weick (1979) calls a common frame of reference – i.e. shared cognitive structure – concerning how to manage the collaboration. This process of reducing the differences in cognitive structures is here called cognitive convergence.

Summary:

➜ Cognitive structures were gradually converging in the heavyweight project leader team – e.g. development of common views on the decision-making processes.

5.1.1.1 The heavyweight project leader team's influence on knowledge communication

In the previous section, the structural characteristics of the heavyweight project leader team were analysed. In this section, the analysis addresses how the heavyweight project leader team influenced knowledge communication.

From the literature, it is known that in order to solve complex problems it can generally be expected that companies organise for high communication capacity (e.g. Clark and Fujimoto, 1991). In the Explorer collaboration, the need for development of shared architectural knowledge was high. One reason was that the companies had to develop common knowledge about interfaces between subsystems, which were unknown when the collaboration began. The heavyweight project leaders were important for realising that ambition and thereby they needed to develop a high capacity for knowledge communication.

The analysis here will focus on the knowledge communication in the heavyweight project leader team – i.e. its capacity to communicate knowledge. It addresses this process from the perspective of the three knowledge communication indicators developed in Chapter 2 – i.e. intensity, richness, and explicit and tacit knowledge.

Knowledge communication intensity

This part of the analysis of knowledge communication focuses on intensity, i.e. how often the project leaders communicated with one another.

The two project leaders were largely engaged with the same issues, which meant they were spending a great deal of time working together. For instance, before making decisions on e.g. aspects influencing the Explorer's general architecture, there were everyday discussions. The role of these discussions was to analyse different alternatives and negotiate a solution acceptable to both parties. Hence, the work integration between the project leaders was a strong driver of the knowledge communication (e.g. Brown and Eisenhardt, 1995). The consequence was intensive knowledge communication.

During the weeks when the project leaders were working together in the project organisation, they met several times a day – both formally during meetings and informally at e.g. the coffee machine. One enabling factor was the co-location – they spent several hours a day only a few metres from each other's chairs. Hence, their informal interaction when they were working in the joint office area enhanced the knowledge communication intensity (Rogers, 1995).

In addition to the informal interactions, the two project leaders were also engaged in meetings with the development team on a weekly basis. For instance, they had technology management meetings every second week. These meetings were forums where the different teams presented and discussed results and challenges with the technology development. Each new week, after they had worked in the home organisations, began with a so-called Tuesday meeting – which aimed to discuss the coming week's work priorities and other administrative issues. Between the formal meetings, there were daily discussions with engineers in the team on the technology work currently taking place. Hence, the project leaders were important facilitators of the communication process within the project organisation (Clark and Fujimoto, 1991).

Summary:

➜ The heavyweight project leader team's high work integration and their co-location contributed to high knowledge communication intensity.

Knowledge communication richness

In the following, the analysis addresses the forms of communication used by the project leaders. In focus is the quality of the communication realised, e.g. speed of feedback.

One result of the heavyweight project leader team's physical co-location was informal interaction and dialogue during the ordinary workday. The project leaders were for instance involved in daily – and often brief – informal discussions face-to-face. These interactions took place both between the project leaders, and between them and the engineers. This face-to-face communication was largely driven by the high work integration that made it necessary for the project leaders to engage in daily and complex discussions.

The analysis here shows that substantial opportunity existed for direct feedback in communication as well as use of gestures and other means of expression (Dennis and Kinney, 1998). In addition, they were e.g. briefed about technology analysis through presentations of e.g. blueprint. This indicates a use of multiple languages in the communication (Daft and Wiginton, 1979). Hence, the heavyweight project leader team had rich knowledge communication.

Summary:

➜ The heavyweight project leader team's knowledge communication was rich, because of high work integration and co-location.

Knowledge communication content

This part of the analysis focuses on the knowledge communication content. That is, it addresses the knowledge content communicated by the heavyweight project leaders.

The Explorer collaboration revolved around development of new architectural product technology. Managers in both companies recognised that this would require creation of shared architectural knowledge. The reason was that, in order to enable integration of the results from the work packages which the companies had responsibility for, they needed to share knowledge concerning the product's general architecture. Therefore, a great deal of the knowledge communicated between the two project leaders concerned the Explorer architecture and, related to that, how the joint development work should be realised.

For example, during the typical technology management meeting there was discussion of an issue defined in advance of the meeting – e.g. the design of a subsystem. Discussions in other meetings concerned e.g. the work process, planning and technology issues such as interfaces. Hence, both product and process knowledge were in focus for communication. The knowledge communication often revolved around explicit knowledge such as blueprint. However, the points of views expressed reflected experiences made in the different companies. Through this process of sharing experiences of e.g. architecture design, they gradually began to communicate tacit knowledge (Hedlund, 1994).

One reason for this high knowledge communication capacity was the situation of working on the same issues, i.e. high work integration was an enabling factor. This made it necessary for the project leaders to access the same explicit knowledge and to discuss its content during meetings. The opportunities to interact face-to-face contributed to the intensity as well as the quality of communication. In addition, the process of cognitive convergence made it easier for the project leaders to understand one another, which contributed to the development of common grounds for interpreting knowledge. Thereby, it became easier to share tacit knowledge elements.

Summary:

➜ The heavyweight project leaders' high work integration and co-location contributed to substantial communication of explicit and tacit knowledge concerning the product technology and the development process.

➜ Cognitive convergence contributed to communication of tacit knowledge.

5.1.1.2 Summary of the heavyweight project leader team

This section has identified the Explorer collaboration's project leader team as an integration mechanism. The following table summarises its key characteristics and influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Heavyweight project leader team • High • High • Two
Location structure	Co-located (part-time distributed)
Cognitive structure	Converging
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	High High Explicit and tacit concerning both product technology and development process

Table 8: The heavyweight project leader team and its influence on knowledge communication

5.1.2 Integration mechanism: Co-located integrator team

This part of the analysis is concerned with the operational-level integration between Red Systems and Yellow Partner during the Explorer collaboration. The joint development work was organised around a group of co-located engineers from Red Systems and Yellow Partner. The following will first analyse its structural characteristics and thereafter its influence on knowledge communication.

Formal structure

In the following, the analysis addresses the formal structure of the Explorer collaboration's operational-level integration mechanism. The focus is on its role, decision-making authority, the number of people involved and the work integration.

The companies co-located a group of engineers on a joint office floor outside Yellow Partner's major R&D facilities. The primary purpose was to enable development of joint knowledge about the Explorer's architecture. This integration mechanism is similar to the categories of integrator role and integrator department (Nadler and Tushman, 1987). However, the Explorer's joint team is not really a role – it is more than that. With some twenty members, it is closer to an integrator department, but that term implies more of a permanent role, which is not the case in this collaboration. It was planned to grow during the first year and exist during approximately two more years. Once having defined the architecture, they planned to use a more distributed integration mechanism. In order to capture the temporary and dynamic character of this joint operational level interface, another term is necessary. The choice here is to categorise it as a co-located integrator team.

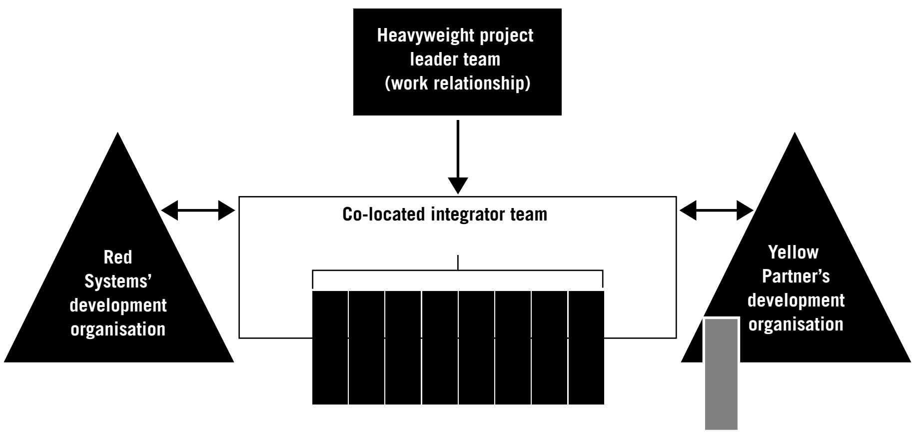

Figure 10: Co-located integrator team
The grey column illustrates that one of the task teams was located outside the joint organisation

The members of the co-located integrator team worked close together in small teams, with two to three participating individuals. The small teams – in total there were nine – addressed tasks within each of the major work packages in the collaboration. The primary purpose of these task teams was to utilise the companies' competences for development of the conceptual design and principal technology solutions. The total number of people working in the co-located integrator team was constantly changing – but approximately some twenty persons, not including those in the team located outside the joint team.

The idea was that, by working highly integrated in the teams, both companies should receive a good understanding of the technical specifications of the Explorer. The aim was to create a shared knowledge platform and thereby support interface integration between the companies' different work packages in later phases.

The teams had high autonomy in their work-tasks – the project leaders did not interfere much. Only major decisions had to be authorised by the heavyweight project leaders. Thus, decision-making authority was at least moderately high in the co-located integrator team.

The team members supported one another in their daily work and spent a large share of their time working together in e.g. workshops on product architecture. The close collaboration obviously generated a high degree of what Thompson (1967) calls reciprocal work interdependence. There was also reciprocal interdependence between the task teams concerning technical interfaces between different parts of the Explorer. The high degree of integration between the companies' different work packages reflects the fact that there were no defined physical or functional interfaces between subsystems. Hence, it was not possible to construct a clear division of work between the companies.

Summary:

➜ Work was highly integrated between the approximately 20 members of the co-located integrator team, in order to support development of shared product architecture.

➜ The members of the co-located integrator team had moderate formal authority to make decisions regarding technology.

Location structure

The analysis here will address the location structure's characteristics. It focuses on how people from the different companies were located and the effects on interaction patterns and relationships.

The co-located integrator team's core was the small teams responsible for the different work packages. These teams were the main arenas for everyday operations – i.e. it was largely within the small teams that everyday communication took place between the two companies. One explanation was each team's location around a shared table with work-stations (Hatch, 1997). These tables were quite large, which made it possible for several persons to gather around them to discuss e.g. blueprints.

The different teams had their tables in the same room, only a few meters apart. Thus it was easy to walk across the room to ask questions or just drop by on the way out. In addition, there were rooms for meetings within the office space, which contributed to enabling *ad hoc* meetings in order to discuss technology issues. This co-location enhanced development of informal communication channels between engineers from the two companies (Allen, 1977).

Summary:

➜ The members of the co-located integrator team were located in an open office area, which enabled informal and intensive interaction.

Cognitive structure

In the following, the analysis addresses the companies' different cognitive structures expressed in the co-located integrator team. It focuses in particular on the impact on understanding and how the differences were handled.

Coming from companies with different nationalities and company backgrounds, there were major cognitive aspects that the members of the co-located integrator team did not share when the collaboration started. For instance, the companies had their own technical standards and definitions of technical terms, which reflected different views on product development. In fact, prior to the late 1990s both Red Systems and Yellow Partner had developed their own products with limited influences from companies located in other countries. These differences meant that the companies had different cognitive structures which guided their perceptions of the world and the collaboration (e.g. Löwstedt, 1995).

Soon after starting the joint work, it was clear that the companies used different definitions of technical terms. This difference in language generated misunderstandings during discussions on technology issues. The exact meaning of technical systems was not always the same and technical terms were given different meaning. The difference in meaning was often so subtle that it was not obvious during discussions when team members from the two companies were talking about different things. Furthermore, they had different views about how and where, on the Explorer, different systems should be integrated – the different views on integration were related to the companies' different traditions of designing products. These differences in language and product philosophies were identified early in the collaboration as major challenges for realising the joint development.

A process of reducing differences began when people from the two companies realised that they interpreted terms differently. It took half a year of relatively intensive collaboration to reach this insight. Thereafter, a process began that aimed for development of a shared vocabulary. This process relatively soon contributed to a shared understanding of technical terms, which made it easier to tackle differences in views on technology and to understand each other's process definitions. Despite the initial differences, the co-located integrator team was able to increase the understanding of one another's views on technology and development approaches (Dougherty et al., 2000). They also began to develop common views on important Explorer technology and processes for conducting joint work. That is, at least they took steps in the direction of common perspectives. Thus, agreeing on explicit language definitions and using them in practice enhanced cognitive conversion in the co-located integrator team.

Summary

➜ Starting a process of developing a common vocabulary enhanced cognitive convergence within the co-located integrator team.

5.1.2.1 The co-located integrator team's influence on knowledge communication

The product development literature (e.g. Wheelwright and Clark, 1992) shows that e.g. intensive and rich communication is necessary for efficient product development. The following analysis revolves around this study's knowledge communication indicators: intensity, richness and types of knowledge content.

Knowledge communication intensity

The analysis here focuses on the knowledge communication intensity within the co-located integrator team. It discusses which factors in the integration mechanism's structures can explain the intensity indicated.

In the co-located integrator team, the work process was characterised by frequent meetings and informal discussions, e.g. around tables with blueprints. For instance, there were team meetings with discussions on different subsystems' interfaces. The formal meetings between teams normally took place every week. In addition, since the teams were located next to another there were intensive discussions during the ordinary workday. For example, by working in the joint office space it was easy to raise *ad hoc* questions with colleagues from the other company. Almost every day there were also informal meetings between the team members in meeting rooms about specific technology issues. The everyday interactions contributed to intensive knowledge communication between the individuals in the integrator team (Kahn and McDonough, 1997).

A large share of the communication was informal and part of everyday work activities. For instance, the teams discussed joint issues at their tables – e.g. around a draft with blueprints of the Explorer or a subsystem. Hence, the high work integration was a driver of the intensive knowledge communication. In addition, similarly to Allen (1977), the analysis here points at the critical role of co-location for generation of informal communication opportunities.

Summary:

➜ The co-located integrator team's co-location and high work integration contributed to high knowledge communication intensity.

Knowledge communication richness

This part of the analysis addresses the knowledge communication richness in the co-located integrator team. Hence, it focuses on the role of different types of communication media for this integration mechanism's knowledge communication.

In the co-located team, there were everyday discussions at meetings and informally around tables, which allowed people to express their thoughts and comment to each other. In order to express ideas, people engaged in verbal dialogues and used visual presentations of e.g. blueprints and written documents as complements. The direction of this knowledge communication can be described as horizontal, since communication largely took place between individuals on equal hierarchic levels.

For the individual members, these daily interactions gave frequent personalised information.

Dealing with fuzzy issues during the design of the Explorer, people from the two companies needed to engage in face-to-face communication. One reason is that creative processes, like brainstorming sessions, require immediate feedback to the sender of a message in order to enhance generation of e.g. new ideas – that is, what Rogers and Agarwala-Rogers (1976) call synchronous communication. In the terminology of the media richness theory, knowledge communication in the different meetings in the integrator team enabled immediate feedback, personalised messages and use of multiple languages. This was enabled by the face-to-face interaction between a small number of individuals (e.g. Daft and Lengel, 1984). It therefore seems that the knowledge communication in the integrator team can be categorised as rich.

One explanation for the high communication richness was the physical co-location of people from the two companies, enabling face-to-face communication. In addition, the high work integration created the need for rich knowledge communication.

Summary:

➜ The co-located integrator team's co-location and high work integration contributed to rich knowledge communication between engineers form the collaborating companies.

Knowledge communication content

This part of the analysis addresses the content of the knowledge communication realised. Hence, it focuses on the explicit and tacit knowledge communicated between engineers from the two companies.

The knowledge communicated in the co-located integrator team concerned both the product technology and how the development process should be realised. The product technology content concerned the product architecture, subsystems and, not least, integration. Process knowledge was also in focus and concerned issues regarding which kind of computer methods would be sufficient to use.

During the development process, the co-located integrator team shared both explicit knowledge from previous projects and existing and new explicit knowledge. Examples of such explicit knowledge communicated are blueprints, simulation models and test results. The knowledge communication on existing technology was regulated by the project's IPR system. In addition, there was some reluctance to share existing tacit knowledge, partly because it concerned the two companies' existing products – which compete on the market. The explicit knowledge communication was also somewhat difficult to communicate because the joint information system was not functioning as intended. It was obviously easier to communicate explicit knowledge produced in the joint office area. The reason was that e.g. blueprints could be printed and physically distributed and files could be shared with colleagues through the local network.

Explicit knowledge was important output of the joint work, but a great deal of the communication during the development work concerned tacit knowledge. One indication is, for example, that they were able to share previous experiences from e.g. tests of technology related to the Explorer. Gradually they became able to express common views on the Explorer's architecture, which indicate shared tacit knowledge.

The physical co-location contributed to the communication of both explicit and tacit knowledge. It enabled intensive communication on explicit knowledge such as written analysis. It contributed to communication of tacit knowledge through face-to-face conversion of different experiences and values underlying the design of products (Hedlund, 1994). For instance, people discussed intensively their joint work-tasks during meetings and around their tables, and through that process they created a common image of the Explorer's architecture.

Working together makes people share knowledge in order to solve tasks together. Thereby, they had to share much explicit knowledge. They also developed knowledge redundancy and became better able to understand one another's knowledge and its role in the joint project (Nonaka, 1990). The implication is that, working on the same tasks, people engage in communication containing tacit knowledge, which increases understanding of the partner's contributions.

In the Explorer collaboration, the emerging common language became an engine that enabled communication about technology which otherwise would have remained tacit. People articulated their implicit assumptions and gradually developed common definitions. Thereby, they gradually developed a common understanding of important concepts. By working closely together, it also became increasingly easy to understand one another's perspectives regarding both product technology and the development process. Both these kinds of cognitive convergence enhanced communication of tacit knowledge.

Summary:

- ➜ Co-location and high work integration enhanced communication of explicit and tacit knowledge in the co-located integrator team.
- ➜ Cognitive convergence between team members contributed to enhancing communication of tacit knowledge.

5.1.2.2 Summary of the co-located integrator team

This section has identified the Explorer collaboration's joint development team as one integration mechanism. The following table summarises its key characteristics and influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Co-located integrator team • Moderate • High • Approx. 20
Location structure	Co-located (part-time)
Cognitive structure	Converging
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	High High Explicit and tacit regarding both product technology and development process

Table 9: The co-located integrator team and its influence on knowledge communication

5.1.3 Summary of integration mechanisms and knowledge communication in the Explorer collaboration

This section summarises the analysis of integration mechanisms and their influence on knowledge communication in the Explorer collaboration. The analysis identified two different integration mechanisms – the heavyweight project leader team and the co-located integrator team. The analysis clearly indicates that these two integration mechanisms have substantial capacity to enable knowledge communication. Which integration mechanism factors can explain this capacity?

The companies' different work-tasks was highly integrated. Therefore, within the co-located team, different groups of engineers from the two companies were working on the same tasks. The two project leaders were interdependent in e.g. the decision-making process. One effect was intensive knowledge communication, because it was necessary to share knowledge in order to work together.

In the two integration mechanisms, co-location of people from Red Systems and Yellow Partner seems to have played a major role for the intensity and richness of the knowledge communication. The co-location meant opportunities to interact on a daily basis, largely informally. The consequence was rich and intensive communication, largely face-to-face, between people from the two companies.

A large share of the knowledge communicated was explicit. However, over time the tacit elements communicated increased. This was enhanced by cognitive convergence taking place as the team members developed a shared terminology and common understanding.

5.2 Integration mechanisms and knowledge communication in the Seeker collaboration

Chapter 4 described the Seeker collaboration between Blue Systems and its partners, Black Partner and White Partner. In the following, the Seeker collaboration will be analysed in order to explore integration mechanisms and how they influenced knowledge communication.

To begin with, here follows a brief recapitulation of the background to the Seeker collaboration. It began in January 2003 and it was cancelled in June 2004. It was a product development collaboration initiated by three European governments in order to enable cost sharing for the development of a new defence system. The industrial collaboration was created between three rather different companies – one company from each of the three countries. The basic principle guiding the formation of the collaboration was that each company should receive work equal to its government's costs. The companies participating in the collaboration, Blue Systems, Black Partner and White Partner, had quite different industrial backgrounds and asymmetric competences relevant for the development of the Seeker.

The product vision was a new system that would build on one of Blue Systems' existing platforms. This meant that Blue Systems should lead development of the product architecture. Black Systems should contribute with development of one major subsystem, and White Partner should be responsible for production. Each company's work was located at its home organisation. This meant that the Seeker collaboration had a development organisation distributed in three different countries – with between 200 and 700 kilometres separating one another's locations.

The Seeker collaboration used four different types of integration mechanisms. In the following, the first integration mechanism analysed is the senior management team. Thereafter the co-ordinator management team, the virtual project leader teams and finally the virtual integrator teams are analysed.

5.2.1 Integration mechanism: Senior management team

The background to this integration mechanism is that top management of all three companies wished to monitor the development of the collaboration. For Black Systems the collaboration was necessary in order to maintain one of the company's major business areas. To the other two, the Seeker was a prestige project that would generate extra revenue and development of new competences.

In order to lead the joint work during the collaboration's first phase, a joint venture was created in 2003. The companies wished to represent their different interests in the joint venture. Therefore, a joint venture board with members from the three companies' senior management was established. This integration mechanism's formal structure, location structure and cognitive structure are analysed in the following. Thereafter, its knowledge communication will be analysed.

Formal structure

The following will analyse the major characteristics of the integration mechanism's formal structure. It focuses on its role in the collaboration, the number of people involved, the decision-making authority and the level of work integration.

The Seeker collaboration's first phase used a joint venture in order to co-ordinate the development work and customer relationships. Each company owned one third of the joint venture, and therefore the members of the management board had equal responsibility and formal influence. The main purpose of the board was to enable the management from the three companies to exercise control over the collaboration. Therefore, each company had top management representatives – the senior manager for product development and the CEO.

A management board is often used in collaboration as a means for participating companies to represent their different interests (Galbraith, 2000). The kind of board used often depends on the form of collaboration. One collaborative form mentioned by Galbraith (2000) is the shared structure. In a shared structure, collaborating companies have common responsibility and authority over the project's operations. This kind of board was used in the Seeker collaboration. Reflecting the seniority of the members of the board, this integration mechanism is here categorised under the name 'senior management team'.

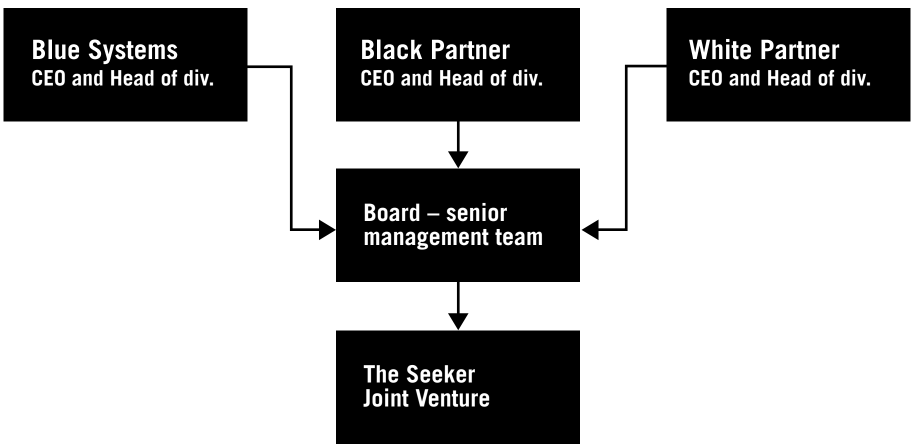

Figure 11: Senior management team

The figure illustrates the structure of the senior management team used in the Seeker collaboration. It was the integration mechanism with the highest formal influence, and it had the formal role of co-ordinating the companies' interests in the collaboration. The members of the team had no other work interaction than during their formal meetings. Their main interest in the collaboration was their own company's – e.g. concerning risks and costs with the Seeker development.

Reflecting the companies' differentiated work packages, the number of issues that the management team had to deal with was limited (e.g. von Hippel, 1990). Hence, work integration was low. In practice, this meant that the members of team required little need for input from one another in order to conduct their work contributions to the collaboration.

Summary:

➜ The senior management team, with two managers from each of the three companies, had substantial formal decision-making authority over the companies' joint venture. With few joint work-tasks, work integration in the team was low.

Location structure

In focus for the analysis here is the kind of location structure used by the senior management team. Of particular interest is the impact of location structure on the development of relationships and interaction between the team's members.

The members of the senior management team worked within their home organisations. They met occasionally at one of the companies' sites. These meetings were occasions where the members interacted face-to-face. Between the meetings, they had some contacts via telephone and e-mail – but only to a limited extent. Hence, the senior management can be categorised as a distributed integration mechanism (e.g. McDonough III et al., 2001).

The team members did not know one another on a personal level – hence the interpersonal links in the team was weak. Thus, in the terminology of Naphinet and Ghoshal (1998), the social capital in the integration mechanism was low. Research by Hansen and Løvås (2004) indicates that informal relationships reduce the moderating effect of geographical separation. With few if any such contacts, the geographical separation remained a strong barrier to interaction between the team members.

Summary:

➜ The senior management team had a distributed location structure, which restricted opportunities for interaction to formal meetings.

➜ Lack of informal relationships maintained the barriers for interaction created by the geographical separation.

Cognitive structure

In this part of the analysis, the focus turns to expressions of different cognitive structures. Attention is on the role of different cognitive structures for the understanding between the members of the senior management team.

The members of the senior management team came from three rather different companies. They had different industrial backgrounds and long histories of working according to certain values – e.g. regarding product quality and costs. Such differences are barriers to understanding in collaborations between companies (March and Stock, 2006).

In the Seeker collaboration, the cognitive differences were expressed in the views on the Seeker collaboration. The members from Blue Systems would have preferred not to engage in the collaboration, but they knew they had to do so in order to maintain their business. This view reflected the company's long history as

OEM manufacturer without having to engage in alliances. The board members from the other companies were not strategically concerned about the collaboration. To them the Seeker collaboration was another project with limited impact on their long-term development. The underlying reason was their background in other industry segments, making the Seeker a project more or less on the margin.

These different views on the collaboration contributed to e.g. misunderstanding and disagreements. For instance, it was difficult to understand one another's views about e.g. timetables. In addition, due to the lack of joint strategic aim, the team members primarily acted on behalf of their company instead of the joint venture, which meant that the interests of the collaboration became a second priority. Underlying this lack of cohesion were the differences in cognitive structures, which made it difficult to see each other's reasons for participating in collaboration. The senior management team did not, however, address these differences between points of view. One implication was that the difficulties of understanding one another remained largely unchanged.

Summary:

➜ The members of the senior management team had rather different cognitive structures, which constrained their capacity to understand one another. The cognitive differences did not change much during the collaboration.

5.2.1.1 The senior management team's influence on knowledge communication

The power over the joint venture was in the hands of the senior management team. It was established in order to co-ordinate the companies' interests in the collaboration. The following addresses how it influenced the knowledge communicated.

Knowledge communication intensity

This part of the analysis of knowledge communication focuses on intensity. Thus it pays attention to how often communication was taking place within the senior management team.

The senior management team had meetings with a low intensity, often with several months between the occasions. They met when they had to, which meant they did not follow a particular time interval. Therefore, they had few formal opportunities to engage in knowledge communication. Lack of personal relationships meant that they had few informal contacts between meetings (Hansen and Løvås (2004). Consequently, knowledge communication intensity in the board was low. The implication was that the senior managers had few opportunities to address common issues.

One reason for this intensity was their low work integration; the members of the senior management team did not experience a need for much communication. This reflected the clear division of work between the companies (von Hippel, 1990). Thus, their main concern was the work within their own companies. Joint issues were less of a priority. The geographical separation also meant that the managers had few opportunities to meet in informal meetings.

Summary:

➜ Knowledge communication intensity was low in the senior management team. The reasons were low work integration and distributed location structure, which required few meetings and constrained contacts between meetings.

Knowledge communication richness

The following addresses the knowledge communication richness achieved in the senior management team. It focuses on the kind of media used as means for communication.

The senior management team had no face-to-face meetings except for the formal occasions. Since there were few contacts between meetings, face-to-face communication was the dominant medium used. In addition, the combination of face-to-face communication, presentation of OH images and documents meant that parallel communication media were used. However, their meetings often contained tight schedules, which strongly reduced opportunities for dialogues and thereby constrained knowledge communication richness.

It is plausible that low work integration constrained the perceived need for more communication time. The implication was limited direct feedback, which according to Dennis and Kinney (1998) is important for rich communication. The opportunities for personalised communication were also limited. During a few occasions between meetings, with communication in the distributed location structure, people used e-mail and telephone. This suggests, taken together, that knowledge communication richness was low/moderate.

Summary:

➜ Reflecting the distributed location structure and the low work integration, communication richness was low/moderate in the senior management team.

Knowledge communication content

This part of the analysis focuses on the knowledge content communicated between the companies – on the type of knowledge communicated and explanations for the capacity realised.

The members of the senior management team had different industrial and organisational backgrounds. Their companies' technological competences were different, and the team members had personal experiences from development of different types of product technology. Consequently, their tacit knowledge concerning the Seeker was considerably different. Furthermore, the views on e.g. how to manage the collaboration were different since they had different organisational cognitive structures (Dougherty, 1992). These differences constrained the capacity to understand the knowledge communicated regarding the development process.

It was, for instance, difficult to understand each other's perspectives concerning how the development of Seeker should be organised. Instead of focusing on these differences in knowledge, there was a tendency to avoid discussing difficult issues. In focus for communication were current administrative issues. The board typically used meetings to discuss up-coming issues in the collaboration and to plan for forthcoming activities. This included allocations of resources to the development work. The content of these discussions largely revolved around documents. Thus, the senior management team was a forum with knowledge communication focused on a minimum of explicit knowledge.

The communication patterns reflect the structures of this integration mechanism. The low work integration made it seem unnecessary to engage in substantial knowledge communication. The geographical separation meant that it was difficult to meet and discuss difficult matters other than during formal meetings, with several months between the occasions. In addition, the cognitive differences made it difficult to understand one another's messages.

Summary:

➜ The senior management team's communication contained explicit knowledge, which reflects the low work integration and the distributed location structure.

5.2.1.2 Summary of the senior management team

This section has identified the Seeker joint venture's board as an integration mechanism. The following table summarises its key characteristics and influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Senior management team • High • Low • Six
Location structure	Distributed location
Cognitive structure	Low, if any, convergence
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	Low Low/moderate Explicit – largely concerning the development process

Table 10: The senior management integration mechanism and its influence on knowledge communication

5.2.2 Integration mechanism: Co-ordinator management team

In the Seeker collaboration, as first mentioned in section 4.2.3, a joint venture was established, the Seeker Corporation (SC). The joint venture had four employees that managed contacts with the customer's project organisation. They also had responsibility for integrating the results of the three companies' work, in the form of four major documents.

This integration mechanism is different from the other ones identified. The reason is that a large share of its knowledge communication took place with the other integration mechanisms used in the collaboration as well as directly with the companies' R&D departments. In a sense, the integration mechanism was engaged in integrating all the other integration mechanisms in the collaboration. Therefore, both its internal and external knowledge communication with other integration mechanisms and the companies are included in the analysis.

The following will first address what characterises this integration mechanism, and thereafter how it influenced knowledge communication.

Formal structure

In this part of the analysis, the integration mechanism's formal structure is addressed. The focus is on its role for the collaboration, the number of people involved, decision-making authority and work integration.

Four senior project leaders constituted the staff of the Seeker's joint venture – one from each company, except for Blue Systems which had two persons commissioned. Structurally, it was a general management team with the purpose of co-ordinating the three companies' technology development (Galbraith, 2000).

The Seeker management team is similar to both the integrator department and managerial linking role discussed by Nadler and Tushman (1987). However, the joint venture team is different from an integrator department since it had a management role. Moreover, it is different from the managerial linking role because several persons, i.e. a team, constitute it. Therefore, considering that it is a group of managers responsible for co-ordinating activities in three different companies, the SC management can be categorised as a co-ordinator management team.

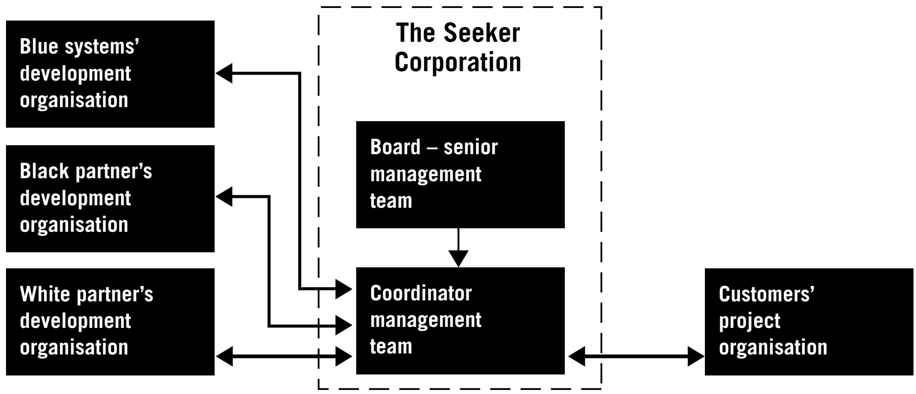

Figure 12: Co-ordinator management team

The figure illustrates the co-ordinator management team's key relationships. It was formally under the authority of the joint venture's board. The major role was to co-ordinate the work within the companies in order to deliver the collaboration's results to the customer. Therefore, the co-ordinator management team was an interface between the companies' development operations and the customer. In reality, the team had little decision-making authority. It did not control resources such as people and money for the development. In addition, the companies' internal R&D departments made the major decisions regarding technology.

In order to illustrate its co-ordinating role, the arrows in the figure symbolise work interaction in the co-ordinator management team's relationships. The team was formally defining work-tasks for the companies' R&D departments. In addition, it received the companies' results, e.g. technical analysis of subsystems. In practice, this co-ordinating role was concerned with quite general issues such as plans and, to a limited extent, the technology content of the companies' work. The integration of documents taking place was realised through collaboration within the team. In Thompson's (1967) terminology, the work interdependence was reciprocal within the team. The reason was the high degree of work integration between the members of the team. In the team's collaboration with the companies, however, substantial time lags occurred between initial requirements and the company's delivery – almost one year. There were several contacts in between, but the impact on the three companies' internal work was low once they had received specifications. Therefore, work integration co-ordinator management team with the companies must be characterised as low.

Summary:

➜ The co-ordinator management team, with four individuals, co-ordinated the three companies' development. It had limited decision-making authority and its work integration with the companies was low. Within the team, however, work integration was high.

Location structure

In the following, the analysis addresses the co-ordinator management team's location structure. In focus is the impact on development of personal relationships between the companies and of interaction patterns.

In Seeker collaboration, work was distributed between the companies' different R&D departments. This meant that several location structures existed in parallel (Bartlett and Ghosal, 1990). Hence, the collaboration's operations were distributed between companies located in three different countries.

The co-ordinator management team, however, was co-located on one floor within Blue Systems' main office building, in Big City, Sweden. The co-location seems to have contributed to daily interaction in the team. It was, for instance, experienced that they met informally during the ordinary workday – e.g. around the coffee machine.

The companies' geographical separation created a distributed location structure influencing the team's work contacts. One consequence was few face-to-face interactions between the co-ordinator management team and development organisations at Blue Systems and White Systems. The intensity in work contacts seem to have been similar with Blue Systems, despite their being located in the same building. Thus, the location structure did not influence formal meetings. However, spontaneous meetings in elevators, the parking lot and the lunch restaurant contributed to some more informal contacts with Blue Systems employees.

Summary:

- ➜ The co-ordinator management was co-located. This contributed to development of informal interaction between the team members.
- ➜ The team was separated from the three companies. It was physically separate at Blue Systems (although in the same building) and geographically separated from the other two companies.
- ➜ Formal interaction was not influenced by the difference in distance between the team and the companies, but working in the same building partly enhanced informal interaction with colleagues from Blue Systems.

Cognitive structure

The following analysis addresses the role of cognitive structure for the co-ordinator management team. In focus is the impact on understanding between people from the different companies.

The persons working in the co-ordinator management team came from different national and organisational backgrounds and they had experiences from different technologies. However, these differences did not have any substantial influence on the team's internal collaboration. By working close together, they developed a shared understanding for their joint work-tasks. It is likely that the experience of belonging to a new organisational context, independent of the home organisations, enabled the team to handle cognitive differences. That is, the co-ordinator management experienced the effect of breaking the boundaries with home organisations expected in autonomous product development organisations (e.g. Wheelwright and Clark, 1992).

The experience was, however, that it was difficult to understand the colleagues' home organisations. For instance, it was not clear to the team members from Blue Systems why White Partner participated in the collaboration, what it wished to accomplish, how it organised work and what it really understood about the Seeker technology. To some extent, each member could handle the effects of colleagues' limited understanding, by managing all major contacts with their home organisation. This restricted the contacts that the other members of the team had with the colleagues' home companies. Thus the team never developed a common understanding of e.g. the companies' different languages and work routines (Dougherty et al., 2000).

Summary:

- ➜ The members of the co-ordinator management team succeeded in carrying out a process of cognitive convergence among themselves.
- ➜ Differences in cognitive structures between the co-ordinator management team and the three companies remained unchanged.

5.2.2.1 The co-ordinator management team's influence on knowledge communication

The co-ordinator management team was responsible for integrating the results of the company's work. In order to accomplish this task, the team required communication with the operations within the three companies. What was the communication effect realised, in terms of intensity, richness and types of knowledge?

Knowledge communication intensity

In focus here is the knowledge communication intensity realised by the co-ordinator management team. The analysis addresses both intensity within the team and between the team and the three companies' R&D departments.

The co-ordinator management team was the interface between the customer's joint organisation and the three companies. Hence, one important task for the team was to communicate to the three companies what the customer requested in terms of technology analysis and product realisation plans. Therefore, the members of the joint venture participated in companies' co-ordination teams. These teams were the main forum for the project leaders from the three companies to meet, discuss and co-ordinate the development work. They also participated in meetings with the deputy project leaders and specialists from the three companies in the so-called working and system groups. Hence, the co-ordinator management team had a central role in the network between the companies, which made them active in important communication (Rogers, 1995).

Each of these teams met approximately every second month. Therefore, the knowledge communication intensity between the co-ordinator management team and each of the companies was low. However, the communication intensity between the co-ordinator management team and the companies was higher since it met several teams. One major factor in the knowledge communication intensity was that the co-ordinator management team and the companies, except for Blue Systems, had different geographical locations. This separation allowed few opportunities for informal and *ad hoc* communication between meetings. In addition, the clear-cut division work meant that the need for communication was limited. Hence, despite their central role in the collaboration, knowledge communication intensity between the co-ordinator team and the companies' different teams was between low and moderate.

The co-ordinating role meant that the members of the team had contacts with more than 30 teams, which co-ordinated work between the companies. This required quite integrated work and often daily interaction between the members of the co-ordinator management team. This was a driver for intensive knowledge communication within the team. The co-location created opportunities for daily and informal contacts, enabling intensive knowledge communication within the team (Allen, 1977; Hansen and Løvås, 2004).

Summary:

➜ Reflecting the rather moderate work integration and distributed location, the co-ordinator management team's knowledge communication with the three companies had low/moderate intensity.

➜ Knowledge communication within the co-ordinator team was intensive due to quite high work integration and physical co-location.

Knowledge communication richness

The following addresses the knowledge communication richness within the co-ordinator management team and the three companies. It focuses on aspects such as the kind of media used, and the opportunities for feedback and personalised messages.

As mentioned in the analysis of intensity, the members of the team often met every day in face-to-face dialogues. The high work integration between the team members required that they communicated e.g. technology specifications and results received from the companies, between one another. This created rich knowledge communication with e.g. direct feedback and use of multiple languages (Daft and Lengel, 1984).

The knowledge communication richness between the co-ordinator management team and the other three companies, however, seems to have been between low and moderate. The reason is that a large share of the communication took place in formal meetings, with quite limited opportunities for discussions. One major reason for this difficulty was the large number, approximately fifteen, of individuals participating in the meetings. The work integration between the companies was low, which meant few occasions with face-to-face interaction and thereby limited opportunities for rich communication. This distributed location structure contributed to quite low communication richness, since it meant few opportunities for informal face-to-face communication (Daft and Lengel, 1986).

Summary:

- ➜ The co-ordinator management team's high work integration and physical co-location enabled rich knowledge communication.
- ➜ The use of large meetings allowed low to moderate knowledge communication richness with the companies.

Knowledge communication content

The analysis has shown that the co-ordinator management team was functioning as the major interface between the companies' operational work and the customer's project organisation. The following addresses the knowledge content communicated by the co-ordinator management team.

The knowledge communication within the co-ordinator management team and the companies largely concerned the development process – it gave directions and received results. In addition, the co-ordinator management team had some focus on technology content of the results. However, they did not interfere with details of the three companies' results. Thereby, the team's knowledge communication with the companies largely concerned explicit knowledge expressed in different documents.

One underlying reason was the clear-cut division of work between the companies. This was reflected in low work integration and it meant limited need for knowledge communication in the collaboration (Nonaka and Takeuchi, 1995).

The geographical distance to Black Partner and White Partner meant that there were few opportunities to engage in *ad hoc* knowledge communication. Furthermore, the physical separation within Blue Systems' building constrained informal interaction with colleagues in that company.

In addition to handling explicit knowledge received from the companies, the members of the co-ordinator management team had to make joint analyses of e.g. the customer's requirements. This work within the team required that they shared an understanding of the Seeker's product technology, at least on a general level. This was accomplished through the process of working together. By working closely together and sharing an understanding of their joint task, the members of the co-ordinator management team were able to communicate tacit knowledge concerning the development process (e.g. Nonaka et al. 2006). Dialogues in the joint office area were essential for accomplishing this. Thus, in addition to explicit knowledge they also communicated tacit knowledge within the team.

Summary:

➜ Reflecting the low work integration and distributed location, knowledge communication between the co-ordinator management team and the three companies largely contained explicit knowledge.

➜ Knowledge communication within the co-ordinator management team contained both tacit and explicit knowledge.

5.2.3 Summary of the co-ordinator management team

This section has analysed the Seeker collaboration's co-ordinator management team. The following table summarises its key characteristics and influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Co-ordinator management team • Low • Low/high in team • Four
Location structure	Distributed location, co-location
Cognitive structure	Low, if any, convergence regarding companies, convergence in team
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	Low/moderate with companies, high in team Low/moderate with companies, high in team Explicit with companies, some tacit in team

Table 11: The co-ordinator management team and its knowledge communication

5.2.4 Integration mechanism: Virtual project leader teams

When starting the Seeker collaboration, it was considered important to be able to co-ordinate management of operations between the three companies. Therefore, the three companies agreed to create project leader teams. The analysis here focuses upon the characteristics of the project leader teams and their influence on knowledge communication.

Formal structure

The following focuses on the formal structure of the integration mechanisms, here gathered under the term 'virtual project leader teams'. The analysis will revolve around the role of the teams, the number of people involved, the decision-making authority and the work integration.

The project leader teams shared characteristics with the managerial linking role that Nadler and Tushman (1987) developed. The team members were carrying information between the companies, and also had the authority to make decisions for their own companies concerning technology issues. Since members of the teams were located within their home organisations, they met only occasionally. Between those occasions they had to rely on e-mail and telephone as means of communication. Therefore, the project leader teams can be categorised as *virtual project leader teams*.

Even though the project leader teams used in the collaboration's first and second phases had differences, they are similar in terms of both function and important structural characteristics.

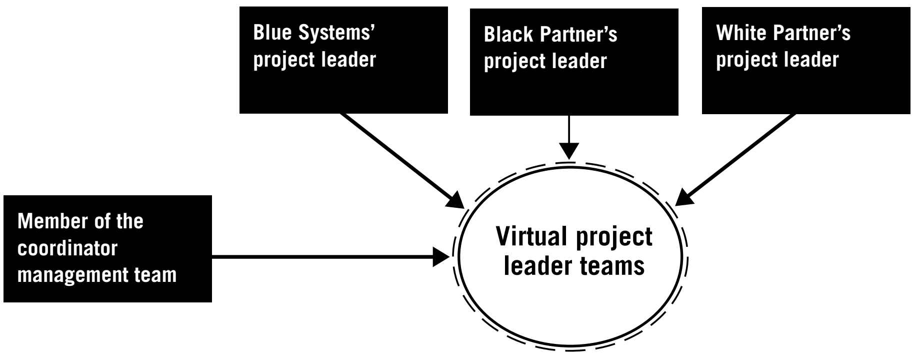

Figure 13: Virtual project leader teams' structure during the SEEKER COLLABORATION'S first phase

This figure illustrates the virtual project leader teams between the three companies during the first phase of the Seeker collaboration. Together with a member of the co-ordinator management team, the three project leaders constituted these virtual project leader teams. In the earlier section 4.2.5, it was described that, during the first phase in the Seeker collaboration, the project leaders from the three partner companies and SC met in so-called co-ordination teams. There were four different co-ordination teams – one for each main document developed. A major focus for the teams was to make sure that the four main documents together constituted a whole product that met customer specifications. The role of these teams was not to decide on the work within the companies; this authority remained within the companies. Instead, these teams were forums for reporting progress and discussing work priorities based on requirements defined by the SC management. The companies abandoned this structure after the first phase, and instead initiated a new form of virtual project leader teams.

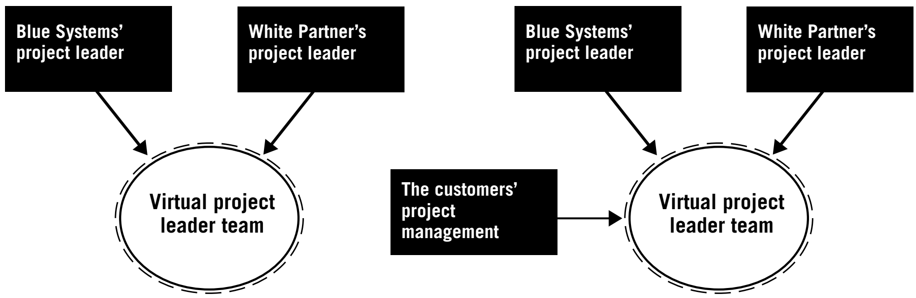

Figure 14: THE TWO virtual project leader teams during the second phase in the Seeker collaboration

The two figures illustrate the virtual project leader teams that were used in parallel during the collaboration's second period. A project leader team managed the relationship between the two companies. The project leader from Blue Systems and the project leader from White Partner constituted the team. The focus of their meetings largely concerned the progress of work in relation to plans. Even though they discussed technology issues, it was on a quite general level. While the project leader from Blue Systems represented the prime contractor and White Partner's project leader represented the supplier, the project leader team considered the collaboration more of a partnership. One reason for this partnership way of collaborating was the uncertainty concerning which company would be prime contractor in the following project phases. In addition to the project leaders' meetings, they also had meetings together with the customer's project organisation. These meetings were forums for the customer to monitor development and to handle up-coming issues concerning e.g. technology choices together with the companies' project leaders.

The collaboration between the project leaders reflects the work differentiation in the Seeker collaboration. It was what Galbraith (1973) calls product-based work differentiation; each company focused on its special work-tasks. This meant that the project leaders' need to work together was limited.

Summary:

- ➜ Virtual project leader teams – between two and four individuals – were used in order to co-ordinate managerial tasks between the companies' development organisations.
- ➜ Decision-making authority was fairly high concerning technology, but low regarding organisational and budget issues.
- ➜ Work integration was low, since they had few joint work-tasks.

Location structure

This part of the analysis addresses the location structure. In focus are the location structure's characteristics and implications for interaction patterns and relationships between people from the collaborating companies.

The project leader teams had a distributed location structure. That is, most of the time they worked within their home organisations, which were located several hundred kilometres apart. The distance between them involved between three and five hours of travelling. As a consequence of the distance, there were few visits at each other's sites in addition to the formal meetings. Hence, the geographical separation was a barrier to interaction between the project leaders (McDonough III et al., 2001).

Moreover, the project leaders did not know one another before the companies began collaborating. One consequence of the project leader teams' distributed location structure was limited opportunity for developing close personal contacts. Therefore, they had few informal contacts. Since informal relationships play a major role in enhancing interaction between dispersed organisations, this lack of contacts is one reasonable explanation for the limited interaction patterns (e.g. Hansen and Løvås, 2004). This illustrates an issue of importance to collaborating companies. Without existing informal contacts between companies, integration mechanisms with distributed location structures will not change that, but rather conserve the situation with limited informal relationships.

Summary:

➜ The virtual project leader teams' distributed location structure – located in three different companies – contributed to limited interaction between the members of the teams.

Cognitive structure

The following addresses the role of cognitive structure in the project leader teams. It gives attention to differences between the companies that made interpretation of one another's perspectives difficult during the collaboration.

As mentioned previously in this chapter and in Chapter 4, the companies participating in the Seeker collaboration had different backgrounds – e.g. in terms of competence levels, nationality and industrial experience. These are reasons for the companies' differences in cognitive structures (e.g. Prahalad and Bettis, 1986). The following shows that the different cognitive structures were hindrances for efficient collaboration in the virtual project leader teams.

The companies' different cognitive structures were expressed in disagreements on technology solutions. One factor explaining this is the different values underlying the companies' views on technology quality. Blue Systems had a strong quality-centred product philosophy. This was based on its long tradition of developing products with extreme performance capacity. Somewhat in contrast, White Partner had a history with focus on low cost and large volume production. It was operating in an extremely competitive global market segment where cost pressures were the major challenge. Hence, people from White Partner found it difficult to understand and accept Blue Systems' often costly technology preferences. Instead, they argued for e.g. less expensive, but what they considered good enough, components. That view made little sense to people at Blue Systems. A similar difference in perspectives was expressed in discussion on the production planning. Blue Systems was doubtful whether it would be possible to meet the high quality requirements with the process technology used by White Partner for bulk production. The differences that existed when the collaboration began did not change much during the one and a half years of collaboration.

Summary:

➜ Different cognitive structures, in the virtual project leader teams, made it difficult to understand one another's views on e.g. the Seeker's technology.

5.2.4.1 The virtual project leader teams' influence on knowledge communication

In the previous section, the characteristics of the virtual project leader teams were analysed. In the following, the analysis addresses their influence on knowledge communication. It will begin by addressing communication intensity, thereafter richness, and finally focus on the knowledge content.

Knowledge communication intensity

In what follows, the analysis addresses the knowledge communication intensity within the project leader teams. This means that it focuses on interaction patterns influencing how often people were able to communicate about knowledge.

During the Seeker collaboration's first period, the virtual project leader teams had meetings approximately every third month. The purpose of the meetings was to discuss how the project was proceeding in relation to milestones. To a limited extent, the progress of the technology development was addressed – e.g. concerning how and where different systems should be integrated on the Seeker. Thereby, the knowledge communication intensity was low.

Between the formal meetings, during both periods, the distributed team members had some occasional telephone contacts concerning administrative issues such as the agenda for the next meeting. They also used e-mail e.g. for sending documents with technology results before meetings. In addition, there were informal meetings directly after the formal meetings. Despite the occurrence of some contacts between meetings, the virtual project leader teams had low knowledge communication intensity.

One reason for the low knowledge communication intensity was the low work integration between the companies' work packages. The project leaders' relatively low meeting intensity reflected the fact that all development work was performed within each of the companies (von Hippel, 1990). This meant a limited need for co-ordination of operations by the project leaders. The limited informal relationships between the project leaders are also one important explanation for the limited communication intensity. The geographical separation made such relationships difficult to develop. Hence, the combination of low work integration and limited personal contacts meant they were not central in each other's communication networks (Rogers and Agarwala-Rogers, 1976).

Summary:

➜ The virtual project leader teams' knowledge communication intensity was low, largely because the work integration required limited collaboration and the distributed location structure restricted opportunities for interaction.

Knowledge communication richness

In this part of the analysis of the virtual project leader teams, the focus turns to its knowledge communication richness. This means that the analysis addresses e.g. the capacity for individualised messages and the speed of feedback.

During the first phase in the collaboration, the project managers' location structure constrained e.g. direct feedback and use of multiple communication languages between meetings (Daft and Wiginton, 1979). During the meetings, e.g. presentation of documents in combination with discussions enhanced communication richness (Dennis and Kinney, 1998). The opportunities to engage in more advanced discussions with several iterations were, however, limited due to shortness of time. This communication richness was enough in order to brief one another about current development and discuss plans on a general level.

The second phase had meetings between the project leaders in order to co-ordinate overall project issues, such as plans and whether the companies should integrate their CAD systems for the production phase. There were also formal meetings together with the customer, where Blue Systems presented the progress of the project and the customer expressed its view on work progress and e.g. addressed interpretations of and changes in technical specifications. Direct discussions face-to-face were increased, compared to the first development phase. This indicates that project leaders became increasingly important for one another's work. The implication was that the richness of knowledge communication increased (Rogers, 1995).

The analysis here indicates that, although knowledge communication was sometimes rich, there largely appear to have been quite limited opportunities for rich knowledge communication. The limited opportunities for face-to-face communication in the distributed location structure are one explanation for the relative communication richness accomplished. The low degree of work integration is another explanation for the knowledge communication richness. The reason is that it generated a limited need for the project leaders to share knowledge with each other.

Summary:

➜ The virtual project leader team had low/moderate knowledge communication richness, due to low work integration and virtual location.

Knowledge communication content

The analysis of the virtual project leader's knowledge communication has so far addressed the intensity and richness. The following will focus on the knowledge content communicated.

As mentioned, the Seeker collaboration used clearly differentiated work packages between the companies. Therefore, discussions of technology revolved around definitions of product interfaces, and only to a limited extent the technology developed within each of the companies. The focus of these discussions was e.g. how Black Partner should design interfaces in order to enable integration between its subsystem and the product platform developed by Blue Systems. The discussions of the development process largely concerned the production of documents in relation to given milestones.

It is indicated that it was sometimes difficult to understand each other's perspectives concerning e.g. system interfaces. It was also difficult to understand each other's views on product quality and costs. One major reason for these variations in interpretation was the project leaders' different cognitive structures. The effect was a limited capacity to understand and absorb one another's knowledge (Cohen and Levinthal, 1990).

In brief, it seems that the knowledge communicated in the virtual project leader teams was largely explicit, e.g. in the form of documents. Both e-mail and discussions during meetings enabled this communication of explicit knowledge. To some extent there was, however, a need to understand each other's tacit knowledge. Still, the limited interactions face-to-face and the different conceptions of e.g. technology impeded the communication of tacit knowledge. In that sense, the low work integration and distributed location structure, in combination with different cognitive structures, were insufficient for realising the knowledge communication required.

Summary:

➜ The virtual project leader team's knowledge communication was largely concerned with explicit knowledge. This was a result of the low work integration and distributed location structure.

➜ To some extent communication of tacit knowledge was required, but it was not achieved due to limited opportunities for face-to-face interaction and to differences in cognitive structures.

5.2.5 Summary of the virtual project leader teams

This section has identified the Seeker project leader teams as an integration mechanism. The following table summarises its key characteristics and influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Virtual project leader teams • Moderate • Low • Between two and four
Location structure	Distributed location
Cognitive structure	Low, if any, convergence
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	Low Low/moderate Explicit concerning both product technology and development process

Table 12: The virtual project leader teams and their influence on knowledge communication

5.2.6 Integration mechanism: Virtual integrator teams

The development of the Seeker was located at the three companies' development organisations. Since each company was responsible for different work packages, the everyday work integration was limited. However, it was nevertheless necessary to have co-ordination between the companies' different work packages, e.g. so as to define interfaces between subsystems. In order to accomplish this, the companies used different operational-level integration mechanisms. These mechanisms are analysed together in the following because they share important characteristics.

Formal structure

The analysis here revolves around the characteristics of the virtual integrator teams' formal structure. It addresses the role of different teams, the number of people engaged, their decision-making authority and the work integration.

To begin with, as described in Chapter 4.2.5, the Seeker collaboration had three different categories of teams – the so-called Working groups, System groups, and Temporary teams. The Working and System groups were used during the first phase and the Temporary teams were set up during the second collaboration phase.

These teams are similar to the cross-unit group (Nadler and Tushman, 1987), in the sense that they were forums for integration between the collaborating companies – a liaison role with several persons. One important difference is the distributed structure of these teams. Therefore, a virtual integrator team is a better categorisation.

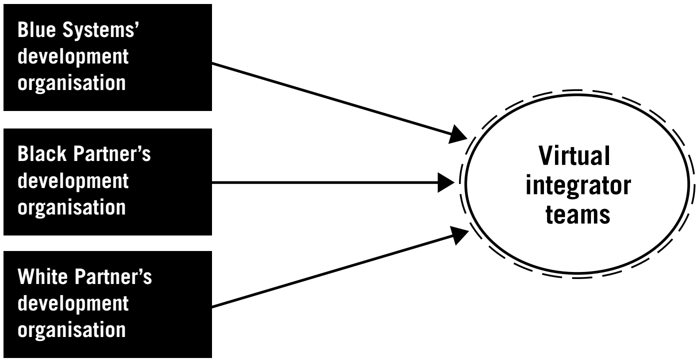

Figure 15: Virtual integrator teams (as during the first phase)

The figure illustrates the virtual integrator teams. It was a forum for interaction between engineers from the collaborating companies. In the second phase, Black Partner had left the collaboration.

The so-called Working groups were established in order to integrate work concerning cross-functional integration – such as man-machine integration – during the first phase. The results of the groups' work should be included in the four documents that the SC was due to deliver to the customer. In total eight Working groups were active during the first product definition phase. The members of the groups were the deputy project leaders from the three companies, and two or three engineers from each company. In addition, the customer's project organisation – the Seeker Project Group – often had representatives at the Working group meetings. The same person could be engaged in several Working groups, which created a network of persons between the companies meeting one another regularly. In total, about fifteen persons participated in the typical Working group meetings.

The members of the groups worked within their home organisations and met during formal meetings. Thus, there were few joint work activities among the members of different groups, except for discussions during meetings. This meant that work integration was rather low.

The System groups were very similar to Working groups, in terms of both how they were organised and how they were functioning. The System groups' major task was to co-ordinate development of interfaces between subsystems and the platform system – e.g. between communication technology and the Seeker's platform. There were fourteen groups and each group met approximately every third month.

Similar to the Working groups, the same persons were often involved in more than one group, which meant that some individuals participated in meetings with partners more often. Those who participated at the meetings were deputy project leaders and a couple of engineers from each company. In addition, the customer and a member of the Seeker management team participated.

The joint work in the Working and System groups took place during their meetings. After a typical meeting, the representatives for the different companies went home and began to work with the aims defined for the next time. Thus, work integration was low between the members of the teams. The decisions made during the meetings concerned what work-tasks were to be accomplished before the next meeting. Hence, the decision-making authority was limited in the Working and System groups.

During the second phase, Blue Systems and White Partner established the temporary development teams. The role of a temporary team was to address a particular issue and once they had solved it, the team was disbanded. The members of the teams were deputy project leaders from Blue Systems and technical experts. Hence, a lower number of people was engaged in those teams compared to Working and System groups – approximately a handful. The scope of decision-making authority concerned the particular tasks they were dealing with in the specific team. From White Partner the same individuals participated in all teams. The different teams did not meet frequently – approximately once every second month. However, since the same individuals participated in several teams they often met colleagues from White Partner every other week.

During their meetings, team members typically discussed a particular issue, and analysed different alternatives e.g. concerning applying robotised welding technology in the manufacturing process. However, between the meetings they had little contact. In that sense, work integration was temporarily higher, even though most of the time it was low.

Summary:

➜ The virtual integrator teams had low work integration; some of the temporary teams had somewhat higher work integration.

➜ The different teams had authority to plan their work, but not to make major decisions concerning product technology.

➜ The Working and System groups had approximately fifteen members, while temporary teams approximately had a handful.

Location structure

The following discusses the virtual integrator teams' location structure. It addresses the distribution of the team members and the interaction patterns realised through the location structure.

In the Seeker collaboration the companies were, as mentioned, located in different countries. Each company had responsibility for work-tasks that should be accomplished within its organisation. Thus, there was little need for joint work activities. The combination of division of work-tasks between the companies and their geographical separation influenced the location structure of the virtual integrator teams (Galbraith, 2002). The implication was that the individual team members were located in their respective company's development organisation. They only met in order to co-ordinate the work within their different organisations. Hence, a distributed location structure was developed.

This distributed location structure meant limited opportunities for meetings. A few individuals, participating in several teams, had contacts face-to-face with colleagues every other week – not necessarily the same persons every time. Hence, the frequency of contact on a person-to-person level was rather limited.

Summary:

➜ The virtual integrator teams were distributed between the collaborating companies, with interaction mainly taking place during formal meetings.

Cognitive structure

This part of the analysis of the virtual integrator teams focuses on the characteristics of their cognitive structures. It discusses the implications of the companies' different background and how they were handled during the collaboration.

Since they came from different countries and different industries, there were, as mentioned, differences in the cognitive structures between Blue Systems and its partners. The differences in cognitive structures mentioned here are largely the same as those discussed in the analysis of the virtual project leader teams. For instance, Blue Systems' members of the virtual integrator team had experience of developing advanced systems for military customers. This meant that they had developed a tradition of optimising technology quality. Cost aspects of e.g. component choices played a secondary role. Their colleagues from Black Partner also had experience from defence technology development, but other technology areas and lower system levels. White Partner had other views on technology requirements since they operated on a market with commercial customers. In particular, they had a tradition of focusing on component costs, so they found it difficult to understand why their colleagues from Blue Systems preferred more costly and, in their view, only marginally better components. These differences are important are expressions of differences in cognitive structures (Lyles and Schwenk, 1992).

The differences in cognitive structures are interesting in the light of the fact that the employees working in the virtual integrator teams had similar engineering educational backgrounds. This made it relatively easy for employees from the companies to understand each other on a general technology level. Hence, in a way they shared professional backgrounds (Schön, 1983). Yet, despite this similarity, it was difficult to understand each other's perspectives on e.g. specific technology requirements. This reflects the strong impact of the companies' different industrial backgrounds in shaping cognitive structures (Porac et al., 1995). The consequence was, as for the virtual project leaders, unchanged difficulty in understanding one another's perspectives on technology. During the collaboration, there were no direct efforts to handle these differences.

Summary:

➜ The members of the virtual integrator teams had different cognitive structures, which constrained their understanding of one another's views on technology. There was little convergence in the integration mechanisms.

5.2.6.1 The virtual integrator teams' influence on knowledge communication

In the following, the knowledge communication in the virtual integrator teams is analysed. It will first address intensity, thereafter richness and finally the types of knowledge communicated.

Knowledge communication intensity

In the following, the analysis addresses the knowledge communication intensity realised by the virtual integrator teams. In focus is the frequency of meetings between people from the different companies' R&D departments.

During the collaboration's first phase, the people in the Working and System groups met approximately every second month and a typical meeting lasted between one half day and two days. The reason for this low intensity was that most of the work was taking place within the companies, with limited need for input from the partner companies.

According to literature, informal networks play an important role for communication across organisational boundaries (e.g. Hansen and Løvås, 2004). In the Seeker collaboration, several persons participated in more than one group. Therefore, there was a partly informal structure of individuals meeting more often than the different Working group and System groups. However, the informal networks did not play active roles in the knowledge communication. For instance, this was expressed through limited use of e-mail and telephone between meetings. Instead, the main intensity in electronic communication took place during the days before meetings. Thus, the knowledge communication intensity was low.

The interaction pattern in the temporary teams was somewhat different. Each team arranged meetings depending on the issues it was created to solve – which meant that they had no formal schedule for when they should meet. Since some persons were engaged in several teams, they could meet their colleagues from White Partner every other week. In between the meetings, there were quite few contacts among the team members. Therefore, the knowledge communication intensity is categorised as low, or possibly moderate between some individual members of the temporary teams.

One important reason for the low knowledge communication intensity was the companies' differentiated work packages. They did not have to meet often in order to accomplish their work packages. In addition, the distributed location structure gave few opportunities for *ad hoc* communication.

Summary:

➜ The virtual integrator teams' knowledge communication intensity was low, the reasons being low work integration and distributed location.

Knowledge communication richness

This part of the analysis of the virtual integrator teams focuses on the richness of knowledge communication. The analysis addresses the kinds of media used and why the teams used them.

During the meetings in Working and System groups, deputy project leaders presented their results from their company's work. In addition to presentations, there were discussions on interpretation of the customer's requirements. They developed action plans that defined work-tasks to be performed by the next meeting. During these meetings, a large number of individuals normally participated – often approximately fifteen persons. The consequence was limited opportunity for direct feedback and personalised information. The reason for using large meetings was to keep all involved actors informed about the work progress, but this constrained the capacity to discuss technical problems. In between the meetings, there was some communication of documents containing technical data. Hence, following media richness theory (e.g. Dennis and Kinney, 1998), the knowledge communication richness in the teams was low to moderate.

The temporary teams were set up for resolving certain technology issues. In order to accomplish a particular task it was necessary to have active participation of people from Blue Systems and White Partner. Largely these team discussions concerned Blue Systems' technology and production experience. The underlying motive was to explore how the existing knowledge could contribute to White Partner's tasks during the Seeker collaboration. These team meetings were opportunities for asking questions and receiving direct feedback. By working together during meetings, they enabled the use of several different means of communication. Hence, the effect that the different communication media had was at least moderately rich knowledge communication, in some of the teams. One plausible reason for this higher-level richness was that these teams focused on solving technical problems and therefore needed more advanced communication.

Summary:

➜ Most of the virtual integrator teams had low knowledge communication richness. The higher work integration in some of the temporary teams enabled higher communication richness.

Knowledge communication content

The analysis so far has addressed the intensity and richness of knowledge communication in the virtual integrator teams. This part focuses on the content of communication.

One example from the first phase is used in order to illustrate the content of knowledge communication in virtual integrator teams. Blue Systems had responsibility for the design of the Seeker, and during the first project phase there were thus several discussions with Black Partner concerning integration of its subsystem on the Seeker. Blue Systems gave instructions and system requirements to Black Partner. The latter came back with documents containing technical analysis e.g. regarding subsystem interfaces, which Blue Systems integrated in documents describing the whole Seeker system. Hence, knowledge communicated within the virtual integrator teams was largely explicit and concerned the product technology as well as general planning of the development process. However, it was not always easy to understand one another's knowledge, e.g. definitions of the subsystem's technical and functional interfaces. There were often misinterpretations of the knowledge communicated by the partner.

The communication of explicit knowledge was driven by the low work integration. The underlying reason was that it was considered possible to use a clear-cut division of work based on clearly defined work packages. Because of the division of work, it was believed that there would be limited need for handling complex technology issues between the companies. However, the challenges creating interfaces between the Seeker platform and the subsystem developed by Black Partner indicates that the knowledge communication requirements were higher than expected. One reason is that Black Partner did not share Blue Systems' tacit knowledge regarding interface requirements. Thus, there was a need for higher capacity to communicate tacit knowledge than indicated by the division of work. Accomplishing that type of knowledge communication would have required that the companies had reduced the different cognitive structures that made common interpretations difficult to achieve (e.g. Dougherty, 1992). It also would have required more of face-to-face interaction, which was difficult to accomplish in the distributed location structure. Thus, the companies were not able to communicate sufficient knowledge in the virtual integrator teams.

Summary:

➜ The knowledge communicated in the virtual integrator teams was largely explicit. This reflects the low work integration and their distributed location structure. More communication of tacit knowledge were required, but was difficult to achieve, e.g. because of differences in cognitive structures.

5.2.6.2 Summary of the virtual integrator teams

This section has established that the Seeker collaboration's operations were co-ordinated through different virtual teams. The following table summarises the key characteristics of this type of integration mechanism's and its influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Virtual integrator teams • Low • Low/moderate • Approx. 15 (less in temporary teams)
Location structure	Distributed location
Cognitive structure	Low, if any, convergence
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	Low Low/moderate Explicit content – regarding both product technology and development process

Table 13: The virtual teams and their influence on knowledge communication

5.2.7 Summary of integration mechanisms and knowledge communication in the Seeker collaboration

The analysis of the Seeker collaboration identified four different types of integration mechanisms: senior management team, co-ordinator management team, virtual project leader teams, and virtual integrator teams. These different integration mechanisms have similar capacity for communication of knowledge, i.e. low intensity, mainly low richness, and mainly explicit knowledge. The analysis of the integration mechanisms indicates that in particular the low work integration and the distributed location of work are important explanations for the capacity to communicate knowledge.

To begin with work integration, the collaboration had a clear-cut differentiated work breakdown structure. The consequence was that work integration was low between the people participating in integration mechanisms. Thus, the need for work-related communication was seen for most of the time as quite limited in the integration mechanisms.

The work was also located in each of the three companies' internal product development departments. In other words, engineers and managers were located in their home organisations. This had the consequence that the integration mechanisms had a distributed location structure. Being located at different places, people in the integration mechanisms had limited interaction and their opportunities for face-to-face communication were few. Thereby, integration mechanisms' distributed location contributed to the low intensity in communication and the low communication richness.

The four integration mechanisms enabled realisation of communication of explicit knowledge, such as documents with technical analysis. This reflects the low work integration and the interaction patterns in distributed location structures. However, the integration mechanisms could not enable communication on tacit knowledge, e.g. because of the few opportunities for face-to-face interaction and interaction and because of different cognitive structures.

5.3 Integration mechanisms and knowledge communication in the Mover collaboration

In the earlier section 4.3, it was described how Green Systems and Far Partner collaborated. In focus for their collaboration, during the case study, was the development of a new subsystem for a complex OEM product. The subsystem, in this study, is called the Mover. The Mover collaboration, which was their second major product development collaboration, is analysed in the following.

To begin with, one major motive for Green Systems' engagement in the new development collaboration was that regulatory requirements made it necessary to take a significant technology leap. In addition, the existing supply structure had an oligopoly structure, which made purchasing the subsystem on the market very expensive. Far Partner's main motive was to remain a player in its niche, and in order to accomplish this it needed a partner that could contribute financially.

The development of the Mover was largely located in Far Partner's R&D organisation. The reason was that the company had the critical competences for realising the development. Being a premium manufacturer, Green Systems considers high product quality essential for its brand. Therefore, worries based on experiences from previous product development, concerning unexpected quality problems, contributed to the ambition to influence the Mover's design. It was expected that the implementation of different integration mechanisms would enable Green Systems to actively participate in the development.

The integration efforts were quite limited when the Mover collaboration began. When the initial ones were insufficient to meet Green Systems' requirements, the solution was to add new integration mechanisms. In total, the analysis identifies five different integration mechanisms, which had complementary roles. The following analysis will address these mechanisms' characteristics, as well as how they influenced knowledge communication.

5.3.1 Integration mechanism: Senior-middle management team

The following addresses how managers from Green Systems and Far Partner collaborated in the Mover collaboration's board. Their official role was to monitor the project's development, and to make strategic decisions concerning the product technology, the production planning, and supply chain development. The discussion concerns this integration mechanism's structural characteristics and its influence on knowledge communication.

Formal structure

The analysis of this management integration mechanism begins with addressing its formal structure. Therefore, the analysis revolves around the role in the collaboration, the number of people involved, their decision-making authority and work integration.

According to Galbraith (2002), a board often facilitates managerial integration in collaborations. The collaboration between Green Systems and Far Partner was no exception. A board of three managers from each company had the overall responsibility for the collaboration. Green Systems had a heavy representation with two senior managers and one middle manager, and Far Partner had an equal representation. Hence, the term 'senior-middle management team' seems applicable to this integrative role.

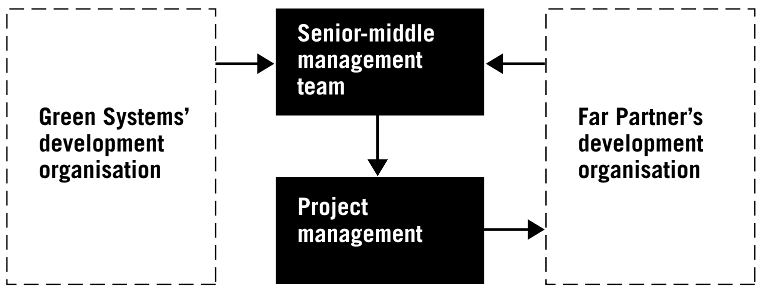

Figure 16: Senior-middle management team

The figure illustrates the board's formal role. It was a joint management function for the Mover project. The role of the board was to co-ordinate the interests of the two companies during the development of the Mover. They were responsible for the collaboration's progress and they had formal decision-making authority over all major issues.

The work within the board concerned monitoring technology development and plans for e.g. supply chain development. Their work relationship was mainly concentrated to board meetings. However, there were also contacts in between the meetings – largely informally. Their joint work was dependent on the knowledge they received from the development organisation, located at Far Partner.

According to Pfeffer (1981), control over information is a source of power in organisations. Green Systems board members experienced that they had too limited influence. The reason was that they had limited control over knowledge flows. Their Far Partner colleagues did not experience this limited access. The managers from Green Systems expected limited influence largely because of the Mover project's organizational solution, with Far Partner being the operator. An operator role implies unequal operative influence between collaborating partners (Galbraith, 2002). In the Mover collaboration, Far Partner's responsibility for the project's operations meant that Green Systems board members had few direct contacts with people working with the Mover development, at Far Partner. In contrast, the board members from Far Partner were also senior line managers responsible for the development of the Mover. Therefore, they had high work integration with the project's development operations. Thereby they also had direct access to knowledge about the progress of the Mover project. Thus, the division of work between the companies directly influenced which knowledge the board members received. To those from Green Systems, the low work integration with operational levels constrained access to knowledge.

Summary:

➜ The senior-middle management, with six members, had decision-making authority over all the major issues concerning the collaboration. However, the members from Green Systems experienced too limited influence, which reflected their low operational work integration with the development organisation at Far Partner.

Location structure

The following addresses the senior-middle management team's location structure. It focuses on the implications of the geographical separation for e.g. interaction patterns between team members from the different companies.

Green Systems members of the board were located at the company's plant in Sweden, and those from Far Partner were located at Far Partner's plant in the USA. In practical terms, six time zones and one day of travel separated them. It meant that their workdays only had a couple of hours' overlap. One effect was that telephone discussions had to take place in the afternoon, Swedish time, and the early morning in the USA. Managers experienced the many travelling hours more as a cost and time obstacle than as exhausting. Nevertheless, it constrained the opportunities for meetings face-to-face.

To Green Systems members of the senior-middle management team, the distributed structure meant geographical separation from the development organisation. Similarly to results of e.g. Lindkvist (2001), this had the implication that they developed few personal contacts within Far Partner's organisation. Instead, they had to rely on the people that Far Partner's project leader invited to their meetings. Consequently, their informal contacts with the development organisation were limited.

Summary:

➜ The senior-middle management team had a distributed location structure. One negative implication for those located at Green Systems was limited contact with the development organisation at Far Partner.

Cognitive structure

This part of the analysis addresses the senior-middle management team's cognitive structure, or rather the major differences between the members from the two companies. It addresses major expressions of the difference in cognitive structure and implications for mutual understanding.

In the Mover collaboration, two different traditions of distributing power in product development met. Far Partner has a tradition of using what e.g. Clark and

Fujimoto (1991) call heavyweight project leaders. In contrast, Green Systems has a strong line organisation and more lightweight project leaders. These differences in experience of the project leader role became a major source of frustration in the board.

This different view became apparent concerning knowledge dissemination. The project leader for the Mover collaboration controlled information and knowledge flows to the board from the project organisation. Coming from a tradition with strong line organisation and with the ambition to influence the project, Green Systems members of the board found it frustrating to have such a strong project leader. In particular, receiving presentations from the project leader without being able to verify their accuracy with operational level managers and with engineers were experienced as rather unacceptable.

One reason for these different views is, as Schein (2004) pointed out, that organisations develop unique views and practices for distribution of power and status. In the Mover collaboration, this influenced the kind of roles expected of the project leader. The underlying factor accentuating these different views was the concern among Green Systems managers regarding whether they knew enough about the Mover development. Their colleagues from Far Partner, in contrast, were used to heavyweight project leaders and did not experience the concern of not knowing enough. Partly, one obvious explanation is the fact that the members of the board from Far Partner were located in the same building as the heavyweight project leader. Hence, they thereby had access to more knowledge about the progress of the project. The important point to make here is that the differencies in perspectivies meant different points of views on change of formal knowledge dissemination in the project. For instance, the members from Green Systems wished to have more points of contacts with insights about how the project was developing. At first, their colleagues at Far Partner did not understand this perspetive.

The managers from both companies were aware of these differences in perspectives, and there were efforts to discuss them with the colleagues from Far Partner, but only limited change in points of views was observed.

Summary:

➜ The members of the senior-middle management team from Green Systems and those from Far Partner had different cognitive structures, which constrained development of communication routines.

5.3.1.1 The senior-middle management team's influence on knowledge communication

The senior-middle management team members from Green Systems strove to play an active role in the collaboration. This required substantial access to knowledge about the Mover's technology and its development process. Despite their ambition, they experienced that their influence was limited – largely due to lack of access to knowledge. The following discusses this experience from the perspective of the senior-middle management team's capacity for knowledge communication.

Knowledge communication intensity

Here follows a discussion on the knowledge communication intensity realised in the senior-middle management team. It addresses the frequency and kind of interactions taking place.

The main means of communication were meetings every second month. The meetings were normally located at Far Partner's plant in AM Town, USA. This meant that Green Systems board representatives had to travel some twenty hours in order to attend a meeting.

Before meetings, the team members received documents with technical data. This was the main occasion of knowledge distribution to Green Systems members of the board. Between the meetings, the members from Green Systems had limited communication with the development organisation. The team members from Green Systems and Far Partner, however, had some telephone contacts in between the meetings. In particular, a couple of them had relatively frequent telephone conversations, often once a week. The other managers in the board received some knowledge about the project *ad hoc*, often on a weekly basis. This knowledge, however, often did not come directly from Far Partner but from Green Systems employees working in the collaboration.

One reason for the knowledge communication intensity indicated was that that the role of board did not require daily work interaction with the project's operations. Furthermore, the distributed location structure strongly constrained informal and *ad hoc* interaction.

Summary:

➜ Knowledge communication intensity was low to moderate within the senior-middle management team, and between the team and the development organisation. This reflects the distributed location structure and low work integration.

Knowledge communication richness

In the following, the analysis addresses the communication richness realised in the senior-middle management team. This means that the discussion focuses on the major means of communication and their effects.

Before the meetings in the senior-middle management team, batches of technical data arrived for Green Systems members shortly before the flight over to the project organisation. This meant that there often was too little time for the Green Systems team members to process the data.

As mentioned, their chief communication interface with the project organisation was the project leader. The project leader distributed data before meetings and he was the primary source of knowledge during meetings – other persons from the project organisation had a limited role in discussions. Often the meetings were characterised by extensive presentations with slides by the project leader, which reduced opportunities for discussion. Thereby, this heavyweight project leader controlled the knowledge communicated.

In addition, since there were few direct contacts with the project's operations, there were few opportunities to double-check knowledge. Hence, it was difficult to obtain a second opinion about the development in the project. To the board members from Green Systems this was experienced as frustrating, because they could not be sure that they really knew where the development of the Mover was heading.

The analysis here points at a communication between team and the development organisation with few opportunities for direct discussions and personalised information, which are indicators of richness (Daft and Lengel, 1984). The communication between the members of the board from the two companies were better. Partly, one reason is because they spent some time together outside office during the visits of the board members from Green Systems at Far Partner. However the opportunities for rich communication were limited. Thus, based on the analysis here, the knowledge communication richness can be categorised as low to moderate.

The level of communication richness clearly reflects the limited opportunities for face-to-face interaction. The distributed location structure can explain this. In addition, the work integration with hardly any work contacts with the operations in Far Partner's organisation can explain the limited level of richness achieved.

Summary:

➜ Reflecting low work integration and distributed structure, knowledge communication richness was low/moderate in the senior-middle management team.

Knowledge communication content

The following discusses the type of knowledge communicated in the senior-middle management team. This means that it addresses whether the content of communication was in the form of tacit or explicit knowledge.

As mentioned in the analysis of richness, the board members received batches of data the day before meetings – i.e. every second month. These batches often contained details about the technology developed and the project's process. That is, the content communicated was largely what e.g. Johannesen (1999) called explicit technical knowledge.

The limited access to knowledge from the project's operations was increasingly becoming a strategic concern to Green Systems. The reason was a worry that potentially unacceptable quality problems passed without notice. The knowledge that they were missing largely seems to have concerned the robustness of the Mover's technology. One major reason for this experience of missing knowledge was difficulty in obtaining and discussing design data. In order to handle this uncertainty the board members from Green Systems wanted to access more knowledge about the Mover. Therefore, they tried to enhance knowledge communication by adding additional integration mechanisms. This effort to monitor the development indicates strong commitment to the collaboration.

Their own ambition of knowledge communication was, however, difficult to realise due to the low work integration, which gave few natural work contacts with people working with the development at Far Partner (e.g. von Hippel, 1990). The distributed location structure meant few opportunities for informal meetings, which according to Westling (2002) are important enablers of communication. Telephone talks and e-mail were not used to any major extent as complements in order to access more knowledge. Partly this also reflects the lack of personal contacts within the development organisation.

Summary:

➜ The knowledge communication within the senior-middle management team and with the development organisation largely contained explicit knowledge. This was enabled to a great extent through distribution of documents from the development organisation and meetings.

➜ The knowledge communicated was not enough to make Green Systems feel comfortable about the status of the development work.

5.3.1.2 Summary of the senior-middle management team

This section has established that the Mover collaboration's board functioned as an integration mechanism. The following table summarises this integration mechanism's key characteristics and influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Senior-middle management team • Formally high • Low • Six
Location structure	Distributed location
Cognitive structure	Low, if any, convergence
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	Low to moderate Low to moderate Explicit – concerning both product technology and the development process

Table 14: The senior-middle management integration mechanism and its influence on knowledge communication

5.3.2 Integration mechanism: Integrative manager

The background to this integration mechanism is, as mentioned in the case description, that the contract stated that Green Systems should commission a deputy project leader to work at Far Partner. The underlying reason was that Green Systems wished to have a person to take care of its interests during the everyday operations within the development organisation. Managers were expecting that such a role would make sure that Green Systems' values concerning product quality were considered in the everyday decision-making, and that it would enhance the board members' access to knowledge about the development of the Mover. In the following, the characteristics of this integration mechanism and its influence on knowledge communication are analysed.

Formal structure

The analysis here will address the formal structure of the integrative manager. The discussion revolves around its role in the collaboration, the decision-making authority and the level of work integration.

The deputy project leader had a role similar to what Galbraith (1973) called a 'managerial linking role'. This role is an integration mechanism with substantial decision-making authority. Companies use a managerial linking role when task uncertainty is high and the situation is new to the organisations. Thus, the deputy project leader in the Mover collaboration can be seen as having a managerial linking role. However, it was a more complex role than the role described by Galbraith (1973). The reason is that it was a job with two major tasks. One task was to represent Green Systems in the collaboration's operations. The other task was to represent the project organisation in contacts with the board. In order to perform this dual role it was essential that the deputy project leader became deeply involved in the operations at Far Partner. The term used for capturing this role is 'integrative manager'.

The following figure illustrates the integrative manager's structural relationship to other actors in the Mover collaboration.

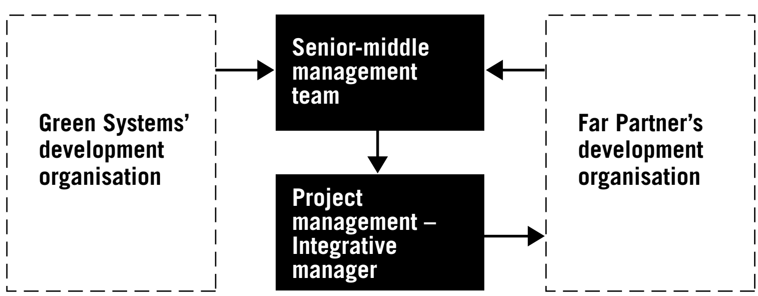

Figure 17: Integrative manager

The figure shows that that the integrative manager formally was part of the project organisation together with the heavyweight project leader. Formally, the project leaders borrowed resources from Far Partner's development organisation. In practice, this meant that the real project organisation contained a large part of their line organisation.

The integrative manager was sent to the collaboration's development organisation one and half years after the collaboration started. Gradually, the integrative manager became involved in the daily operations at Far Partner. This was done largely by starting to work with quality issues and production planning. From that base, personal contacts emerged which enhanced the scope of work. Support from managers in the board made it possible to acquire responsibility for project management tasks, such as reporting to the board. In order to accomplish that role, it was necessary to understand the Mover's technology and Far Partner's organisation. This, in turn, made it necessary to create a network of contacts in the development organisation. Over time, this generated high work integration and substantial influence over the collaboration's operations.

Summary:

➜ The integrative manager gradually developed a position characterised by high work integration and influence within the development organisation.

Location structure

This part of the analysis addresses the location structure within which the integrative manager was working. It focuses on the major characteristics of the structure and their implications for interaction with colleagues in the development project.

One of the ideas behind establishing the integrative manager was to give Green Systems a physical presence in the daily management of the Mover development. In that sense, the integrative manager created a link across the geographical separation between the companies (De Meyer, 1991). On the other hand, it separated the integrative manager from the home organisation in Sweden.

The location at Far Partner meant that the integrative manager shared office location with the development organisation. In the open office landscape there were only a few metres to several of the colleagues from Far Partner. The whole project organisation was within a distance of no more than some 50 metres. This created opportunities for daily interactions with colleagues on different organisational levels. Largely the interaction, outside the formal meetings, took place during brief *ad hoc* meetings. Thus, similarly to Westling (2002), this illustrates the important role of location for informal interaction.

Summary:

➜ Physical co-location contributed to development of intensive interaction between the integrative manager and people in the development organisation.

Cognitive structure

The following addresses the integrative manager's experience of the difference in cognitive structure between Green Systems and Far Partner. The discussion focuses on the implications of difference and how they were handled.

Establishing the role of integrative manager and thereby enhancing knowledge communication was challenging. In the beginning of the collaboration, there was reluctance among those working with the project to accept a new managerial role – particularly since there was no prior deputy project leader role, which meant that the position had no status. It was also difficult for the integrative manager to understand the functioning of Far Partner's organisation. For example, Far Partner's views on trade-offs between costs and quality, the manufacturing planning process, and hierarchic relationships were major differences from Green Systems. In order to become operational, the integrative manager had to understand these differences and to be able to handle them, which took some time.

It seems that the initial suspicion among people working in the project organisation was reduced through a combination of the integrative manager's personal dedication to the work and support from managers in the home organisation. By working in the development organisation, the integrative manager was able to enhance the understanding of roles, rules and routines at Far Partner (Dougherty et al., 2000). After approximately half a year the deputy project leader gradually began to play an active managerial role and, after approximately one year, could replace the heavyweight project leader.

This indicates that cognitive differences began to converge with the dominant cognitive structure at Far Partner. This was accomplished through the combination of daily interaction with people in the development organisation and active participation in its work process.

Summary:

➜ The integrative manager gradually enhanced the understanding of Far Partner's cognitive structure. This was enabled by high work integration and co-location.

5.3.2.1 The integrative manager's influence on knowledge communication

The previous section analysed the integrative manager's key characteristics. The analysis here focuses on the knowledge communication realised by the integrative manager. The analysis will first address communication intensity, thereafter the richness realised and finally the types of knowledge communicated.

Knowledge communication intensity

The following discusses the integrative manager's influence on knowledge communication intensity. In focus is the frequency of opportunities to engage in knowledge communication with colleagues from the partner company, and how the intensity can be explained.

According to Rogers (1995), centrality in networks influences the intensity of communication. In the Mover collaboration, the integrative manager gradually earned respect from people in Far Partner's organisation and thereby increasingly became involved in discussions on the Mover's technology. Establishment of the role within the project organisation enhanced everyday dialogues about everything from the quality of the product, and communication routines, to planning for product launch. There were informal *ad hoc* discussions and formal meetings more or less every day. This enabled intensive knowledge communication between the integrative manager and the development organisation. In addition, access to documents with e.g. analysis increased.

One reason is that being co-located within the project organisation created opportunities for both formal meetings and informal face-to-face communication with colleagues (e.g. Daft and Lengel, 1986). Thus, the co-located physical structure played a central role for the development of intensive knowledge communication. Furthermore, by increasingly becoming involved in the management of the collaboration, the integrative managers became an important actor, which contributed to enhance knowledge communication intensity.

Summary:

➜ The integrative manager achieved high knowledge communication intensity through co-location and high work integration within the development organisation at Far Partner.

Knowledge communication richness

This part of the analysis revolves around the knowledge communication richness. It concerns the level of richness realised and reasons for the capacity.

On normal days the integrative manager had face-to-face discussions about the Mover's technology with people in the development organisation. This meant that working with the development organisation generated frequent opportunities to ask questions about technology and organisation. This contributed to direct feedback from colleagues and personalised information (e.g. Agarwala-Rogers, 1976).

In addition, other means for communication were blueprints, visual presentations of analysis and physical prototypes of components. Thereby, the knowledge communication was characterised by language variation (Daft and Wiginton, 1979). This everyday knowledge communication enhanced the integrative manager's overall understanding of the Mover technology. Hence, knowledge communication can be categorised as rich.

One reason for high knowledge communication is face-to-face interaction. The physical co-location in the development organisation enabled these meetings.

Furthermore, the high work integration enhanced rich communication e.g. because of the need to discuss how the product design could be improved.

Summary:

➜ The integrative manager's knowledge communication was rich, with colleagues at Far Partner. Important reasons were the physical co-location and high work integration.

Knowledge communication content

The knowledge communication content is the focus of this part of the analysis. It addresses the kind of knowledge communicated and which factors were influential.

A large share of the integrative manager's knowledge communication within the development organisation concerned the Mover technology and, in particular, its design. The content communicated became broader, and contained more details, as the integrative manager learned to understand Far Partner's organisation and became accepted by its members.

As mentioned previously in the analysis here, the integrative manager began to understand Far Partner's work routines and gradually became familiar with its dominant values concerning product quality. The implication was improved knowledge communication in the sense that new issues were identified and discussed – e.g. concerning differences in the two companies' production planning processes.

This illustrates that the integrative manager – by being familiar with both companies' cognitive structures – could explore knowledge that was tacitly embedded and difficult to recognise from the perspective of one of the companies. Hence, through understanding of both companies, a split vision was developed. It was not easy to develop the kind of contacts and access the knowledge necessary for creating such understanding. This indicates a strong commitment to the collaboration and sense-making of his role (Gioia and Chittipeddi, 1991).

The analysis indicates communication of both explicit and tacit knowledge. Explicit knowledge communication largely concerned the work-tasks in the development organisation, e.g. development analysis of design proposals. The communication of tacit knowledge was related to the explicit product knowledge. It concerned e.g. the experiences and underlying reasons for design solutions. However, knowledge communication also concerned organisational aspects, such as work routines. Visualisation was used in order to make e.g. quality routines explicit. However, describing its use and value in practice contained elements of tacit knowledge. This kind of knowledge communication was constrained by the company's different cognitive structures. Differences in the cognitive structure rendered it difficult for the integrative manager to make colleagues at Far Partner understand the point of using proposed routines for e.g. project progress analysis.

The underlying driver of knowledge communication was work integration. That is, working with different technology and organisational aspects in the development organisation made communication necessary. The physical structure between the integrative manager and colleagues enabled face-to-face communication. In addition, the cognitive convergence enhanced understanding of tacit elements in communication, yet not always to the extent desired.

Summary:

➜ The integrative manager achieved substantial communication of both explicit and tacit knowledge.

➜ This was made possible through high work integration that focused on communication, co-location that enabled interaction, and cognitive convergence that enhanced understanding.

5.3.2.2 Summary of the integrative manager

This section has established that the deputy project leader functioned as an integration mechanism. The following table summarises this integration mechanism's key characteristics and influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Integrative manager • Increasingly high • High • One
Location structure	Co-location
Cognitive structure	Converging
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	High High Explicit and tacit concerning both product technology and process development knowledge

Table 15: The integrative manager and its influence on knowledge communication

5.3.3 Integration mechanism: Boundary-spanners

This integration mechanism's background was the experience among both managers and engineers in Green Systems that they were receiving too little knowledge about the development in the project organisation at Far Partner. Therefore, in order to enhance interaction, two persons from Green Systems started travelling frequently to Far Partner. The idea was that they should spend two weeks at Far Partner and two weeks in the home organisation. This was expected to increase the influence on the "ground" and increase access to knowledge. Hence, it reflects Green Systems' strategic ambition to have an influential role during the development of the Mover. Green Systems senior management approved the initiative and in October 2004, one technical expert and one group leader began spending alternating two-week periods in the project organisation. This meant that one of them was always working in the project organisation and one in the home organisation – hence the boundary-spanning role was constantly operational.

Formal structure

The analysis here focuses on the integration mechanism's formal structure. It addresses its role in the collaboration, the number of people, the decision-making authority and the level of work integration.

The literature describes boundary-spanning individuals as a human bridge between organisations that enhances information-sharing: e.g. Allen (1977); Tushman (1979); De Meyer (1991). The typical boundary-spanner is a person with both experience in the field of operations and a substantial contact network within the collaborating organisations. This description fits the role of the two persons from Green Systems that in 2004 began to travel frequently between the two companies.

The two boundary-spanners working in the Mover collaboration were highly skilled and experienced. One of them, the technical expert, had extensive experience of working with product development in the USA. They had strong networks within their home organisation, and technical competence that earned respect in the eyes of the colleagues at Far Partner. They shared the view that Green Systems would need access to more knowledge in order to be able to receive enough influence over the development.

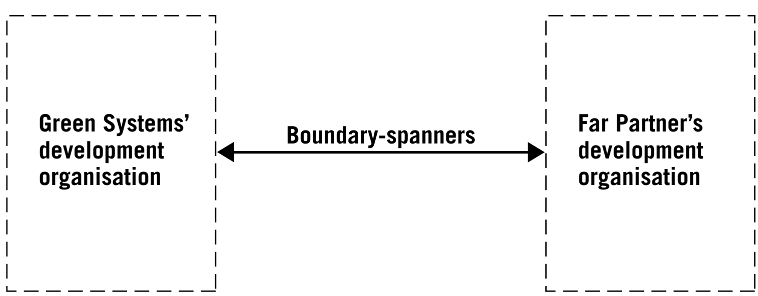

Figure 18: Boundary-spanners

The arrow in the figure illustrates the boundary-spanners' integrative role between the companies. The two boundary-spanners were involved with the development work at Green Systems. During their visits to Far Partner, they had no formal roles or decision-making authority. However, on their own initiatives, despite some initial resistance at Far Partner, they became gradually more involved with the everyday work in the development organisation. Thereby they were able to work with colleagues on specific technical problems.

Summary:

➜ The two boundary-spanners were highly integrated in Green Systems' development work, and they were able, without any formal role or authority, to become involved in the development work at Far Partner.

Location structure

In this part of the analysis, the focus turns to the location structure created by the two boundary-spanners. It means that the following discusses how they handled the geographical separation between the two companies during the development of the Mover.

As pointed out by e.g. De Meyer (1991), geographical separation is a major hindrance to efficient knowledge communication in global product development. In the Mover collaboration, this was a reason for initiation of the boundary-spanning role.

The two boundary-spanners worked co-located at both companies' development organisations. They spent most of their time in open office landscapes with most colleagues within a range of a few minutes' walk. This enabled them to access colleagues with whom they wished to discuss the technology development. It also contributed to making them visible in both organisations.

One implication of the boundary-spanners' dual locations was that the effect of geographical separation between the companies was reduced. This increased the opportunities for development of personal networks at Far Partner. This network was used by the boundary-spanners in order to link people in the two companies' development organisations, similarly to what Allen (1977) wrote about the role of gatekeepers for coupling the organisation with the outside world.

Even though their frequent travelling created a link reducing the impact of geographical separation, distance was a factor making the boundary-spanning role difficult to sustain more than a few months. In that sense, the geographical separation remained a moderator of the boundary-spanners' capacity to create linkages and to communicate knowledge between the companies.

Summary:

➜ The boundary-spanners worked co-located in office areas at both companies, and they contributed to development of a distributed location structure between the companies.

➜ The boundary-spanning role was difficult to sustain because of the geographical distance between the companies.

Cognitive structure

The focus for the discussion here is the role of cognitive differences between the companies for the boundary-spanners' work. In particular, the analysis addresses how the boundary-spanners handled the difference in cognitive structures.

One reason for establishing the boundary-spanning role was the difficulty of influencing Far Partner to make it understand Green Systems' points of views. For example, when engineers at Green Systems asked colleagues at Far Partner to reconsider a design proposal, it was often not interpreted as something that should be done. This was frustrating to those asking such questions because they expected that the recipient should do what they asked. It suggests that the companies had rather different communication styles, which indicates different cognitive structures (Taylor and Osland, 2005).

One effect of the boundary-spanners' visits to Far Partner was that they could explain Green Systems' intentions. They were thereby able to help people in the development organisation to improve interpretation of Green Systems' messages. Another effect concerned how middle managers and engineers at Far Partner regarded Green Systems. The boundary-spanners were somewhat able to make them view the collaboration as a partnership instead of a customer-supplier relationship. The boundary-spanners' colleagues at Green Systems developed a sense of belonging with the development organisation at Far Partner. The reason was that they received frequent and detailed information from Far Partner through the boundary-spanners. Yet the experience in Green Systems of really being part of the development work was reduced when the frequent travelling declined. Hence, the active boundary-spanning role had a direct impact on the sense of co-presence (Giddens, 1984) between the collaborating companies.

The analysis indicates that the boundary-spanners were able to enhance the understanding between Green Systems and Far Partner. That is, they initiated a process of cognitive convergence between the companies, although the most significant part was their own improved understanding of Far Partner.

Summary:

➜ The boundary-spanner was able to improve the everyday collaboration between the two companies. One reason was the two boundary-spanners' increased understanding of Far Partner's cognitive structure.

5.3.3.1 The boundary-spanners' influence on knowledge communication

The boundary-spanners' role was introduced in order to enhance knowledge communication between the two companies. How did they accomplish that task? The following will analyse the boundary-spanners' knowledge communication process from the perspective of its intensity, richness and types of knowledge communicated.

Knowledge communication intensity

The following addresses the knowledge communication intensity achieved by the boundary-spanners. In focus are the factors that influenced the intensity in their communication at Far Partner.

Back home at Green Systems, they played central roles in the development work and were thus engaged in intensive knowledge communication. A similar role was not given in the project organisation when they began travelling to Far Partner. However, a direct consequence of the boundary-spanners' physical presence in the Mover development organisation was that they had opportunities to discuss technology issues on a day-to-day basis. Being able to just walk around and talk to people gradually enhanced the daily knowledge communication intensity. The knowledge communication took place with both line managers and engineers in Far Partner's development organisation. Knowledge communication also took place during the frequent project meetings that the two boundary-spanners participated in during their stays. Hence, by being physically located at Far Partner's development organisation, the boundary-spanners generated activities that gave intensive knowledge communication.

After a few months, the extensive travelling declined. The literature recognises this problem with sustaining boundary-spanning roles (e.g. Allen, 1977; Orlikowski, 2002). In the Mover collaboration, the frequent travelling was exhausting for the boundary-spanners and costly for the project. Both managers and engineers expected that the intensive participation in the project organisation would have lasting effects on knowledge communication. However, when the travelling was reduced, the knowledge communication intensity declined.

This indicates the importance of physical presence in the development organisation for knowledge communication intensity. However, it also suggests that physical co-location is important for enabling work integration that initiates knowledge communication.

Summary:

➜ The boundary-spanners achieved intensive knowledge communication through physical co-location and work integration.

Knowledge communication richness

The analysis in this part addresses the knowledge communication richness realised. It revolves around the factors influencing the richness.

The case description indicates that the two boundary-spanners relatively rapidly, despite initial suspicion, managed to participate in meetings with the project members at Far Partner. These meetings focused different aspects of the Mover technology. For example, there was substantial attention to the Mover's physical design, since it would have fundamental influence for its performance capacity. Draft of blueprint was often in focus for the discussions on the physical design. This meant that multiple languages were used during the meetings and there were opportunities for direct feedback from colleagues (Daft and Lengel, 1984).

The periods at Far Partner also gave opportunities for informal discussions with people. Development of informal relationships created fast lanes for finding answers to questions, often directly. It contributed to development of personal networks, which were used for identifying sources of knowledge. Compared to having to send an e-mail or making a phone call from Sweden, this was a much faster way to receive answers.

The analysis shows that physical co-location in the development organisation gave opportunities for rich knowledge communication. In addition, the active engagement in work activities was important. For example, participating in work meetings during the stays provided opportunities to discuss the Mover technology in detail directly with its designers.

Summary:

➜ The boundary-spanners enhanced the realisation of rich knowledge communication with Far Partner by being physically co-located and by actively participating in their work.

Knowledge communication content

In this final part of the analysis regarding the boundary-spanners' knowledge communication, the focus turns to the types of knowledge content communicated.

The knowledge content in the boundary-spanners' focus was the Mover's whole technology system. In particular, they were concerned with the robustness of the Mover's design. By working in Far Partner's organisation, it became easier to go and ask people directly for e.g. drafts of blueprint. Thereby, access to explicit knowledge content was enhanced. The analysis of the cognitive structures indicated that the boundary-spanners enhanced their understanding for Far Partner's organisational behaviour and views on technology. Informal discussions and dialogues during meetings gradually gave access to the thinking underlying e.g. design solutions. The enhanced interpretation of Far Partner's ideas and technology is thus related to the cognitive convergence. Spender (1996) argued that knowledge is inseparable from its organisational context. The boundary-spanners enhanced their understanding of tacit knowledge about the Mover technology by getting to know the context where it was developed.

Thus, the analysis here suggests that the boundary-spanners' co-location at Far Partner, and the relatively high work integration, enhanced communication of explicit and tacit knowledge. In addition, the cognitive convergence contributed to enhancing communication of tacit knowledge.

Summary:

➜ The boundary-spanners enhanced communication of both explicit and tacit knowledge. This was accomplished by actively working within Far Partner's development organisation and learning to understand their colleagues' cognitive structure.

5.3.3.2 Summary of the boundary-spanners

This section has established that the frequently travelling individuals from Green Systems functioned as integration mechanisms, here called boundary-spanners. The following table summarises this integration mechanism's key characteristics and influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Boundary spanners • Low • High • Two
Location structure	Co-location and distributed location
Cognitive structure	Converging
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	High High Explicit and tacit, largely regarding the product technology

Table 16: The boundary-spanners and their influence on knowledge communication

5.3.4 Integration mechanism: Virtual network

This integration mechanism emerged as a response to the division of work in the collaboration. The background is that Far Partner was the company with the competence necessary for development the Mover. This asymmetric competence distribution between the two companies explains the location of the project organisation at Far Partner. However, since Green Systems wanted to play an active role, the companies' senior management agreed that some development and testing should take place at Green Systems. Thereby, a geographically dispersed development organisation was established. This geographical separation and the organisational difference in the Mover collaboration created challenges for the collaboration's operations. To managers and engineers at Green Systems' test and design team, enhancing contacts with Far Partner became a priority.

Formal structure

The analysis of this integration mechanism begins with addressing its formal structure. This means that the discussion addresses the role for the collaboration, the number of people engaged, the decision-making authority and the work integration.

De Meyer (1991) established that a network is useful for communication in distributed product development organisations. In the Mover collaboration, personal contacts between engineers, group leaders, middle managers constituted a network. In total, some twenty individuals were engaged in the network on a regular basis. It became an informal platform for communication between the dispersed organisational units. Hedberg (2002) argued that a network of actors with many nodes and a temporary existence is a virtual organisation. This is similar to the operational level contacts described here; hence the term 'virtual network' is appropriate for this integration mechanism.

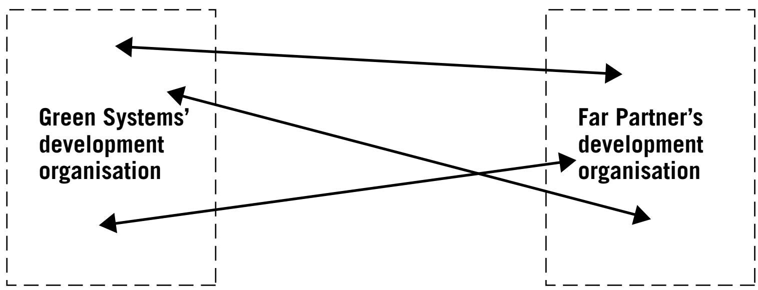

Figure 19: Virtual network integration mechanism

The figure illustrates the structural characteristics of the virtual network integration mechanism. It was a structure with several partly overlapping interpersonal linkages.

In the Mover collaboration, Green Systems participated with a team of design engineers and with a test team. Their main task was to support the development organisation at AM town, USA. The test team ran tests on prototypes of different subsystems, and the design team reviewed blueprints and contributed design suggestions. This work integration required, for example, communication of drafts of blueprints in order to evaluate design ideas. The effect of the collaboration in the virtual network was contacts at least on a weekly basis.

The operational level in both companies could influence e.g. its own work priorities, but it could not make decisions concerning choice of e.g. product design. Regarding work in the network, there was unclear distribution of decision-making authority – e.g. to what extent engineers in one company had to listen to colleagues from the partner company. This became a source of misunderstanding and frustration.

No formal structure, other than the division of work as stated in the development contract, regulated the collaboration on development at operational level. Instead, the virtual network emerged as the result of initiatives by people working in the two companies. As a consequence of collaboration in the virtual network, the distribution of work was changed between the companies – i.e. Green Systems increasingly became more engaged and thereby more influential. In practice this meant that people from Green Systems e.g. were actively influencing work priorities at Far Partner. Hence, work integration increased over time.

Summary:

➜ Reflecting the division of work-tasks, a virtual network with moderate work integration emerged between engineers in the two companies. The virtual network had no formal decision-making authority.

Location structure

The geographical structure of companies is one of the main conditions that this study addresses as a factor influencing integration mechanisms. The following revolves around the location structure that influenced the virtual network's development of personal relationships and interaction between the two companies.

According to Galbraith (2002), division of work and geographical separation influence the choice of organisational structure. In the Mover collaboration, it is clear that the companies' moderate work integration and their location on different continents influenced the development of the virtual network.

As mentioned in the previous section, Green Systems increasingly became engaged in the development operations. That is, the division of work gradually shifted, which meant that integration increased from low to moderate. One implication is that the companies had to collaborate on the development of the Mover on a more regular basis than was the case when the collaboration just had started. Because of the geographical separation, there were few opportunities for meeting face-to-face. Hence, as recognised in the literature, geographical separation was a challenge to operational-level collaboration (Boutellier et al., 1998). In fact, most engineers newer met their colleagues from the partner company. Since this condition did not change much, the lack of personal contacts remained a concern for those engaged in the two companies' development operations.

Summary:

➜ The geographical separation between people in the virtual network remained largely unchanged, which inhibited development of personal relationships and contacts required.

Cognitive structure

Dealing with cognitive structures is one challenge that this study assumes to characterise many integration mechanisms. The following discusses the character and consequences of different cognitive structures for the virtual network.

In the virtual network, people with different organisational backgrounds, national origins and native languages collaborated for the first time. The companies had a history of product development together, but for the majority of employees this was their first product development collaboration. In Green Systems, people considered it difficult to understand Far Partner's ways of thinking about product technology. In particular, their views about quality were different. During the daily work, differences in the way of formulating problems and critique caused frustration. For instance, it was difficult for people at Green Systems to understand Far Partner's tendency to avoid problems in its reporting of current events.

This analysis clearly indicates that the members of the two companies' development organisations engaged in the Mover collaboration had rather different cognitive structures. One expression of this difference was their different communication styles (Taylor and Osland, 2005). It was also apparent in their different images of the Mover's technology and how it should be developed (Dougherty, 2001). These differences contributed to the experienced difficulty of understanding one another in the virtual network. Despite efforts, there was little cognitive convergence in this integration mechanism.

Summary:

➜ Different cognitive structures in the virtual network were a source of misunderstanding between operational-level engineers from the two companies.

5.3.4.1 The virtual network's influence on knowledge communication

The virtual network was an integration mechanism characterised by few contacts face-to-face and little informal relationships. The analysis here focuses on how this integration mechanism influenced knowledge communication, in terms of intensity, richness and types of knowledge communicated.

Knowledge communication intensity

The following elaborates on the knowledge communication intensity realised by the virtual network. It focuses e.g. on the type of interactions taking place and the major reasons for the intensity.

In the Mover collaboration's virtual network, co-ordination of different work activities between the companies continuously required a flow of knowledge. The reason was the increased work integration. Thereby, as Sheremata (2000) argued, intensive communication became important for efficient product development. However, this was difficult to accomplish since there was a lack of personal contacts between the two companies.

Therefore, the companies initiated weekly telephone meetings as a routine for communication between Green Systems and Far Partner. The telephone meetings became forums for discussions about test results in Swetown, analysis of design and requirements for implementing the Mover on Green Systems' products. Thereby, more intensive knowledge communication was realised. However, the lack of personal contacts often made access to knowledge difficult – despite the weekly telephone meetings. The main reason was that people did not know whom to call in the partner organisation.

In brief, communication in the virtual network was moderately frequent, with weekly telephone meetings and some *ad hoc* telephone discussions and e-mail communication. However, this knowledge communication intensity realised in the virtual network was not enough to match the increasing work integration.

Summary:

➜ Work integration enhanced knowledge communication intensity, but the distributed location structure constrained that effect. Therefore, the knowledge communication intensity realised was moderate.

Knowledge communication richness

In this part of the analysis of the virtual network's knowledge communication, the focus is on the knowledge communication richness. Therefore, discussions here concern the use of different media and what constituted the reasons for the level of richness realised.

In the Mover collaboration, engineers at Green Systems often had to talk to colleagues at Far Partner in order to understand the ideas underlying blueprints. Lack of personal contacts and few opportunities for face-to-face meetings made it difficult to fulfil this requirement. Even though there was some e-mail dialogue, e.g. requesting data, it did not meet the needs of knowledge communication.

Therefore, the telephone meetings became an important communication routine on the operational level. However, it was not sufficient to deal with difficult technology issues. In particular, it was difficult to really communicate social messages related to technology issues – e.g. explain ideas underlying design proposals.

Thus, it seems that knowledge communication richness was low relative to the experienced need for access to knowledge. The reason for the relatively low knowledge communication richness was the limited opportunity for face-to-face meetings (Daft and Lengel, 1996). The capacity to discuss technology details indicates that knowledge communication had between low and moderate richness.

Summary:

➜ The distributed location structure enabled low to moderate knowledge communication richness, which made it difficult to meet knowledge communication requirements.

Knowledge communication content

This part of the analysis addresses the knowledge content communicated in the virtual network. It focuses on the type of knowledge communicated through the virtual network.

In the virtual network, the knowledge communicated was largely explicit in the form of artefacts such as prototypes, blueprints and analysis of different test results. Hence, the kind of product technology developed defined the agenda for communication. The weekly telephone meetings enhanced the complexity and volume of the knowledge communicated. For instance, the introduction of the telephone routine enhanced discussion of detailed construction design issues. However, this knowledge was not enough to enable Green Systems to experience that they really knew the status of the technology. One reason was that the agenda for meetings allowed only a limited scope of issues. In addition, the lack of personal contacts may explain why it was difficult to identify other issues that would have been valuable to discuss.

This indication is similar to Szulanski's (1996) argument that much knowledge is sticky and therefore difficult to identify within organisations. Furthermore, as e.g. Spender (1996) argued, much knowledge is context-dependent. One implication is that it is difficult to understand knowledge coming from organisations with different cognitive structures (Dougherty, 1992). Hence, the different cognitive structures constrained to the type of knowledge communicated in the virtual network.

The explicit knowledge communicated was relevant from the perspective of their tasks. However, in order to understand the technology expressed in explicit form, communication of tacit knowledge and better contextual understanding would have been required. Thus, the analysis in this section points at the difficulty to realise desired knowledge communication when the integration mechanism used is insufficient. That is, it is not enough to be motivated for realising knowledge communication – the needs and ambitions must be matched with relevant integration mechanism structures.

Summary:

➜ The distributed location structure enabled communication of explicit knowledge, which was not easy to interpret due to lack of shared tacit knowledge and different cognitive structures.

5.3.4.2 Summary of the virtual network

This section has established that on the operations level a network of contacts emerged between the companies, which functioned as integration mechanism. The following table summarises this integration mechanism's key characteristics and influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Virtual network • Low • Moderate • Approx. 20
Location structure	Distributed location
Cognitive structure	Low, if any, convergence
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	Moderate Low to moderate Explicit, largely concerning the product technology

Table 17: The virtual network and its influence on knowledge communication

5.3.5 Integration mechanism: Transferred individuals

The following addresses the integration mechanism here called transferred individuals. The background to this integration mechanism is Green Systems' strategic intent to play an active role and develop competence for possible production in Europe. The following will analyse this integration mechanism's major characteristics and influence on knowledge communication.

Formal structure

The analysis here begins with addressing the formal structure of the integration mechanism. It focuses e.g. on the role in the collaboration, the decision-making authority and the work integration.

Green Systems transferred three persons to work within the product development organisation at Far partner. Transferring individuals to work in a partner company is, according to extensive literature, useful as a way to access its tacit knowledge (e.g. Nonaka and Takeuchi, 1995). An explicit aim in the Mover collaboration was to build technological competence for the production phase. Therefore, in order to understand the Mover technology, the persons from Green Systems worked within different functional departments in Far Partner's line organisation.

Figure 20: Transferred individuals

This figure illustrates the transferred individuals in Far Partner's product development organisation. In a formal sense, Far Partner employed them during the development of the Mover. However, they remained employed by Green Systems and there was an explicit expectation that they would return home after having participated in finalising the development of the Mover. The persons transferred to Far Partner had engineering backgrounds. Their task as at Far Partner was to work within different functional units. Hence, they did not have formal decision-making authority.

They soon became engaged in work activities with their different functional units. This means that they became involved in the daily work-tasks. They participated in the daily work routines, with e.g. meetings, and had areas of responsibility within their functional units.

Summary:

➜ Green Systems transferred three individuals to work within Far Partner, who became integrated in the daily work at their functional units.

Location structure

The following focuses on the transferred individuals' location structure. It discusses the implications of location for their interaction patterns with colleagues at Far Partner and Green Systems.

The individuals transferred to work at Far Partner not only became formally integrated; they were also physically co-located with their colleagues. They worked within their functional units, which used an open office area. This created opportunities for daily interaction with their colleagues in their functional areas. Working together in a shared physical office area enhanced interaction intensity and development of shared understanding of e.g. the product developed (e.g. Kahn and McDonough, 1997).

In the beginning, they had frequent contacts with the home organisation in Sweden. Hence, for some time the transferred individuals also had a distributed location structure. However, fairly soon they became occupied with the work in their new organisation. This contributed to enhancing communication intensity in their co-located structure at Far Partner. At the same time, communication in the virtual linkages to the home organisation at Green Systems declined, because of e.g. little time and few work reasons to retain contacts. Thus, the co-located structure was the major location characteristic of this integration mechanism.

Summary:

➜ Employed by Far Partner and integrated in its functional units, the transferred individuals were co-located within the Mover development organisation.

Cognitive structure

This part of the analysis addresses the cognitive structure and how it was changed over time. The focus is on the development of cognitive structure both in relation to Far Partner and in relation to Green Systems.

Over time, as Weick (1979) argued, it is possible to reduce cognitive differences through communication. This explains why the transferred individuals experienced enhanced understanding of their new organisational context and its knowledge. This was not an easy process, but it enabled enough cognitive convergence to make them become operational in their new organisation and to acquire insights about the values underlying the development of the Mover.

The transferred individuals' strong focus on their new context reduced their contact with the home organisation. Consequently, their knowledge about the situation at Green Systems gradually vanished. This is an example of Allen's (1977) observation that people moving to another organisation over time are likely to lose contact with the previous organisation as time passes. One important reason is that their networks in the home organisation eroded as people e.g. changed positions. This meant that they gradually also lost insight into the daily work situation at Green Systems. This does not mean that they lost insight into the dominant cognitive structure at Green Systems, but they had little access to knowledge about current developments. Hence, they could not much link their increasing understanding of Far Partner with knowledge about Green Systems.

Summary:

➜ The transferred individuals managed to develop sophisticated understanding of the cognitive structures of Far Partner.

5.3.5.1 The transferred individuals' influence on knowledge communication

The following sections analyse the knowledge communication realised by the transferred individuals – it will revolve around intensity, richness and the types of knowledge content communicated.

Knowledge communication intensity

This part of the analysis focuses on the knowledge communication intensity realised. It addresses the role of different integration mechanism characteristics.

The transferred individuals worked within the project organisation at Far Partner. In their positions, they had daily discussions within but also between functional units at Far Partner. The communication could e.g. concern the implications of test results for product design or for the development of prototypes. Thus, they developed networks at Far Partner that largely reflected their area of work responsibility. Within their networks, the transferred individuals engaged in rather intensive knowledge communication with colleagues at Far Partner's development organisation. This suggests that the network position in the organisation played a major role for the communication pattern (Rogers, 1995). The network position influencing work-related communication reflected the individuals' formal position. Hence, as Allen (1977) argued, transferred individuals communicated mainly with colleagues on the same or a slightly higher hierarchic level.

In the beginning, after having moved to Far Partner, the transferred individuals used their network in Green Systems in order to help colleagues in the project organisation get in touch with relevant competences in Swetown. Thereby, they used their contacts in the two organisations in order to enhance knowledge communication. However, as everyday work in the project organisation absorbed their time, the communication intensity with Green Systems decreased.

The analysis here points at the importance of work integration and location structure for the transferred individuals' communication intensity. It also indicates that communication networks are quite easy to establish, and easy to lose, since contacts with previous networks decline. Hence, location and work integration are critical factors for creating conditions for communication intensity.

Summary:

➜ The transferred individuals realised high knowledge communication intensity, through high work integration and co-location at Far Partner's development organisation.

Knowledge communication richness

In the following, the knowledge communication richness realised by the transferred individuals is analysed. The focus is on factors in the integration mechanism that influenced the richness of communication.

As mentioned, the transferred individuals were physically co-located at Far Partner's development organisation. They were located in an open office landscape and worked intensively together with colleagues. This contributed to enabling rich knowledge communication with e.g. personalised feedback and face-to-face dialogues (e.g. Daft and Lengel, 1986).

They were engaged in work activities in different functional units, as members of the development organisation. This meant that they were present during meetings, with access to documents and blueprint concerning the Mover. During the everyday work, they had opportunities to speak face-to-face with colleagues in both their own and other functional units. Through these face-to-face interactions, the transferred individuals were able to discuss technology details, ask questions about organisational issues and receive feedback about their own ideas. Thereby, the transferred individuals enabled rich knowledge communication.

Summary:

➜ The transferred individuals' co-location and high work integration within Far Partner enabled high knowledge communication richness.

Knowledge communication content

Here follows an analysis of the knowledge communication content realised. The focus of the discussion is on the types of knowledge communicated and the reasons for capacity enabled.

Moving people to work in another organisation is a tool for transferring tacit knowledge (Inkpen, 1996). It is, however, not enough just to transfer people. They also need to understand their new organisational context and work closely with colleagues in order to access tacit knowledge. Nonaka and Takeuchi (1995) discuss socialisation as a way to enable transfer of tacit knowledge. Socialisation, they argue, is realised by actively working in an organisation's operations.

As mentioned in the analysis of cognitive structure, the three individuals gradually became familiar with Far Partner's technology and organisational values. It was experienced that working in the project's operations enhanced their understanding of the contextual aspects of the technology being developed – e.g. the views on quality and performance. This enhanced their capacity to engage in knowledge communication of tacit knowledge. The reason is that, by being aware of the values and beliefs underlying e.g. design preferences, it became easier to discuss aspects of the development process.

This process was integrated in the intensive and rich communication within the project, which meant that they received access to colleagues' experience of developing technology related to the Mover. Hence, working embedded in Far Partner operations, co-located with colleagues, enhanced knowledge communication about tacit knowledge embedded in senior colleagues' experience as well as enhancing an understanding of their cognitive structures.

The daily work together with colleagues at Far Partner also meant, as mentioned, access to explicit knowledge such as blueprint. The explicit knowledge was easy to access since it was present during the everyday work. Thus, the analysis indicates that the transferred individuals were well positioned for communication of both tacit and explicit knowledge communication.

Summary:

➜ The transferred individuals achieved communication of both explicit and tacit knowledge, through the combination of work integration, co-location and cognitive convergence.

5.3.5.2 Summary of the transferred individuals

This section has established that the transferred individuals served as an integration mechanism. However, as an integration mechanism the role was largely latent. The reason was that their main task was to build technological competence that could be used by Green Systems in later project phases. The following table summarises this integration mechanism's key characteristics and influence on knowledge communication.

INTEGRATION MECHANISM	
Investigated characteristics	**Results**
Formal structure • Decision-making authority • Work integration • Number of people	Transferred individuals • Low • High • Three (each of them functioned as integration mechanism)
Location structure	Co-location
Cognitive structure	Converging
KNOWLEDGE COMMUNICATION	
Investigated indicators	**Results**
Intensity Richness Content	High High Explicit and tacit, largely regarding product technology but also the development process

Table 18: The transferred individuals and their influence on knowledge communication

5.3.6 Summary of integration mechanisms and knowledge communication in the Mover collaboration

This section will summarise the analysis of the integration mechanisms identified and their influence on knowledge communication in the Mover collaboration. The analysis identifies five different integration mechanisms. As a response to the first integration mechanisms' difficulties in matching required knowledge communication, Green Systems initiated implementation of integration mechanisms with high capacity for knowledge communication.

The first integration mechanisms, senior management team and virtual network, remained active after the implementation of the integrative manager and the boundary-spanners. Together these integration mechanisms constituted a portfolio for knowledge communication.

In addition, transferred individuals functioned as integration mechanisms. Their role was to build knowledge that Green Systems could use in a potentially forthcoming production line in Europe. Thereby, the role was not to influence knowledge communication between the companies during the development project.

The analysis clearly indicates that the knowledge communication requirements were higher than first expected. Hence, integration enhancing face-to-face communication was necessary. The analysis indicates that the integration mechanisms' knowledge communication capacity was influenced in particular by the level of work integration, the location structure, and to what extent cognitive convergence was achieved.

Work integration is a structure that directly influenced knowledge communication intensity. For example, the senior-middle management team experienced low intensity and one explanation is the low work integration. The integration mechanisms that had higher work integration experienced higher communication intensity. The pattern was similar concerning communication of explicit and tacit knowledge. For example, the senior-middle management team and the virtual network accomplished communication of mainly explicit knowledge. The other three mechanisms enabled communication of both explicit and tacit knowledge.

Location structures follow similar patterns. Co-location enhances knowledge communication intensity and richness, and it enables sharing of both explicit and tacit knowledge. Conversely, distributed location structure contributes to lower intensity and substantially lower richness. Distributed location also has little capacity for communication of tacit knowledge.

The differences between Green Systems' and Far Partner's cognitive structures were major concerns during the collaboration. The integration mechanisms with high work integration and co-location experienced a decrease of cognitive differences – through emerging cognitive convergence. The effect of convergence was an enhanced capacity to communicate tacit knowledge.

5.4 Summary of the three case analyses

The case analysis has identified eleven different types of integration mechanisms, and it has addressed how they influence knowledge communication. The identified integration mechanisms have different characteristics and they enable rather different levels of knowledge communication.

This section summarises the main results from the analysis. The summary will first present results from the Explorer collaboration, thereafter the Seeker collaboration and finally the Mover collaboration. It focuses on structural characteristics of integration mechanisms and their knowledge communication effects. Finally, it discusses the implications of this chapter's results.

5.4.1 The Explorer collaboration

The Explorer product development collaboration was driven, during the studied period, by Red Systems in Sweden and Yellow Partner in another European country. The collaboration formally built on a development contract between the companies. They both had the ambition to create the technological and the organisational platforms for the forthcoming phases. The Explorer was an effort to develop new product technology architecture. One overall aim was to take a technology leap into a new product segment. It was thereby a major opportunity for both Red Systems and Yellow Partner to develop and to learn new technology that could be used in other projects. The collaboration could enhance each of the two companies' position on the new product segment. The companies' management expected that their close collaboration would create an axis for future collaboration.

Managers understood before starting the collaboration that a key to realising the development of the Explorer was creation of shared architectural knowledge. In order to accomplish this, it was necessary to organise the collaboration so that it would enable knowledge communication between the companies.

The analysis identified two types of integration mechanisms, the heavyweight project leader team and the co-located integrator team. The analysis of the Explorer collaboration's integration mechanisms and their knowledge communication generated the following results.

Heavyweight project leader team
Structural characteristics • The heavyweight project leader team was characterised by high decision-making authority over the project, high work integration, co-location, and cognitive convergence.
Knowledge communication effect • Intensive and rich knowledge communication, containing both explicit and tacit knowledge.

Table 19: Summary of the heavyweight project leader team and its influence on knowledge communication

Co-located integrator team
Structural characteristics • Approximately 20 individuals (in the studied phase), with moderate decision-making authority over technology issues; high work integration, co-location in a shared office-space, and cognitive convergence.
Knowledge communication effect • Intensive and rich knowledge communication, containing both explicit and tacit knowledge.

Table 20: Summary of the co-located integrator team and its influence on knowledge communication

5.4.2 The Seeker collaboration

Three European governments initiated the Seeker collaboration in order to meet military requirements of a new defence system. The industrial collaboration reflected ambitions of the governments in the three countries to create a fair cost-share and work-share distribution. From each country, one company participated. The companies were Blue Systems from Sweden, Black Partner and White Partner from two other European countries. They were thus located in different countries, several hours' travelling distance apart.

The companies had different and largely unarticulated strategic motives for participating in the collaboration. The product developed built on one of Blue Systems' previous product generations. Hence, it was an incremental new product technology that was about to be developed. The fairly well known architecture made it possible to define work packages and thereby create a clear-cut division of work between the companies. The companies had different backgrounds and asymmetric competence levels, which enhanced mistrust, misunderstanding and frustration. Overall, the companies experienced that the need for knowledge communication was low in the collaboration. The analysis indicates they may have underestimated the knowledge communication required in order to handle differences in e.g. the companies' interpretation of technology quality requirements and views on component costs.

The analysis of the Seeker collaboration identified four types of integration mechanisms. The following will summarise the main results concerning these integration mechanisms and their knowledge communication.

Senior management team
Structural characteristics
• Six individuals (two from each company), low work integration, high decision-making authority, distributed location and largely unchanged cognitive differences.
Knowledge communication effect
• Low intensity, low to moderate richness, containing explicit knowledge content.

Table 21: Summary of the senior management team and its influence on knowledge communication

Co-ordinator management team
Structural characteristics
• Four individuals, high work integration (low in relation to the companies), low decision-making authority, co-located (distributed location in relation to the companies), and cognitive structures converged within the team (but unchanged in relation to the companies).
Knowledge communication effect
• High intensity (low/moderate with the companies), high richness (low/moderate with the companies), containing both explicit and tacit knowledge content (largely explicit with the companies).

Table 22: Summary of co-ordinator management team and its influence on knowledge communication

Virtual project leader teams
Structural characteristics
• Teams with two to four individuals, low work integration, moderate decision-making authority, distributed location and largely unchanged cognitive differences.
Knowledge communication effect
• Low intensity, low/moderate richness, and largely explicit knowledge content.

Table 23: Summary of the virtual project leader team and its influence on knowledge communication

Virtual integrator team
Structural characteristics
• Approximately 15 individuals, low decision-making authority, distributed location structure, low/moderate work integration, cognitive differences were unchanged.
Knowledge communication effects
• Low intensity, low/moderate richness, and explicit knowledge content.

Table 24: Summary of the virtual integrator team and its influence on knowledge communication

5.4.3 The Mover collaboration

Following more than a decade of collaboration, Green Systems in Sweden and the American manufacturer Far Partner initiated their second major product development collaboration. The purpose was to develop and produce a new subsystem, here called the Mover. The aim was to create a product that would have considerably higher performance capacity than any other competing product. It was a modular new product, which had a different architectural design compared to existing products on the market. This enhanced uncertainty regarding what it would take to realise the new product.

Realising the development of the Mover was a strategic priority to both companies' senior management. To Green Systems the Mover was important in order to enhance the company's position as provider of high-quality and high-performance products. To Far Partner the collaboration was an opportunity to share costs for the development of a new product generation in its primary area of competence.

As Green Systems became increasingly more active in the collaboration's operations, the initial division of work was blurred. Although the larger share of development work remained at Far Partner, Green Systems increasingly became involved in the development. This created a situation with a need for more knowledge communication between the companies.

The analysis of the Mover collaboration has identified five types of integration mechanisms. The following presents the main results concerning these integration mechanisms and their influence on knowledge communication.

Senior-middle management team
Structural characteristics
• Six individuals (three from each company), high decision-making authority, low work integration, distributed location, cognitive differences were largely unchanged.
Knowledge communication effect
• Low/moderate intensity, low/moderate richness, mainly explicit knowledge content communicated.

Table 25: Summary of the senior-middle management team and its influence on knowledge communication

Integrative manager
Structural characteristics
• One individual, high decision-making authority, high work integration, co-located at Far Partner, cognitive convergence.
Knowledge communication effect
• High intensity, high richness and both explicit and tacit knowledge content communicated.

Table 26: Summary of the integrative manager and its influence on knowledge communication

Boundary-spanners
Structural characteristics
• Two individuals, low decision-making authority, high work integration, co-located and distributed location, cognitive convergence.
Knowledge communication effect
• High intensity, high richness and both explicit and tacit knowledge content communicated.

Table 27: Summary of the boundary-spanners and their influence on knowledge communication

Virtual network
Structural characteristics
• Approximately twenty people engaged, low decision-making authority, moderate work integration, distributed location, cognitive differences largely unchanged.
Knowledge communication effect
• Moderate intensity, low/moderate richness, explicit knowledge content communicated.

Table 28: Summary of the virtual network and its influence on knowledge communication

Transferred individuals
Structural characteristics
• Three persons were transferred to Far Partner, decision-making authority was low, work integration high, co-location, and cognitive convergence.
Knowledge communication effect
• High intensity, high richness, explicit and tacit knowledge content were communicated.

Table 29: Summary of the transferred individuals and their influence on knowledge communication

5.4.4 Final comments

As mentioned in the introduction to this chapter, it addresses the first and the second research aims defined in order to realise this study's purpose. The first aim concerns exploring different types of integration mechanisms, and the second how they influence knowledge communication between companies.

Having identified integration mechanisms influencing knowledge communication between companies, the first research aim is accomplished. The identification of different types of integration mechanisms adds new knowledge to research. Chapter 9.1.1 further discusses this contribution.

The eleven integration mechanisms identified cover a broad spectrum: from co-located to distributed, from senior management level to operational engineer level, from some twenty members to a single person, from high decision-making authority to none. The different integration mechanisms' structural characteristics are analysed – i.e. formal, location and cognitive structures. It is shown that the characteristics of these structures constitute major reasons for how people interact, for the development of informal relationships and for the extent to which they understand one another. The implication of this variation in structures is different capacity to communicate knowledge between collaborating companies.

In addition to exploring different types of integration mechanisms, this chapter also analyses how each of them influenced knowledge communication. Thereby, this chapter partly accomplishes the second research aim. However, in order to accomplish the second research aim fully, patterns in how integration mechanisms influence knowledge communication need to analysed. Therefore, the next chapter compares the integration mechanisms' influence on knowledge communication in a cross-case analysis.

6 Integration mechanisms' influence on knowledge communication

This chapter analyses integration mechanisms' influence on knowledge communication between companies in product development collaborations. It compares the identified integration mechanisms in a cross-case analysis. It finds that integration mechanisms' influence on knowledge communication can be explained by their degree of work integration, type of location structure, and degree of cognitive convergence.

The previous chapter analysed the studied cases. In total, it identified eleven different types of integration mechanisms. From that analysis, it is clear that there is a substantial variation in integration mechanisms' influence on knowledge communication between companies.

Chapter 5 accomplished the first research aim defined in section 1.5 and began to address the second research aim. This chapter builds on the analysis in Chapter 5 in order to realise the second and the third research aims:

- ➜ Analyse how the identified types of integration mechanisms influence knowledge communication in product development collaborations between companies.
- ➜ Explain why the identified types of integration mechanisms influence knowledge communication the way they do in product development collaborations between companies.

In order to accomplish these aims, a cross-case analysis compares the different types of integration mechanisms identified in Chapter 5. The cross-case analysis explores patterns regarding how integration mechanisms influence knowledge communication (Eisenhardt, 1989). The analysis uses literature from fields of research such as knowledge creation, knowledge transfer and product development in order to address several dimensions of the identified patterns. Thereby, this chapter develops explanations regarding why integration mechanisms influence knowledge communication the way they do.

This chapter has the following outline.

➜ First, it presents a table with the major results from the analysis in Chapter 5, concerning different types of integration mechanisms' characteristics and their influence on knowledge communication.

➜ Second, it discusses two characteristics of integration mechanisms that surprisingly do not influence knowledge communication.

➜ Third, the analysis focuses on the characteristics of integration mechanisms with direct influence on knowledge communication.

6.1 Cross-case analysis of integration mechanisms

The following table compares the identified integration mechanisms in order to seek patterns that can explain how they influence intensity, richness and types of knowledge content communicated.

Collaborations and integration mechanisms	**Explorer**		**Seeker**				**Mover**				
	HWPT	CIT	SMT	CMT	VPLT	VIT	SMMT	IM	BS	VN	TI
Integration mechanisms' characteristics											
Formal structure	D H WI H P 2	D M WI H P 20	D H WI L P 6	D L WI H (L) P 4	D M WI L P 2-4	D L WI L/M P 15(5)	D H WI L P 6	D H WI H P 1	D L WI H P 2	D L WI M P 20	D L WI H P3(1)
Location structure	CL	CL	DL	DL	DL	DL	DL	CL	CL & DL	DL	CL
Cognitive structure	CC	CC	CC L	CC (CC L)	CC L	CC L	CC L	CC	CC	CC L	CC
Knowledge communication indicators											
Intensity	H	H	L	H (L/M)	L	L	L/M	H	H	M	H
Richness	H	H	L/M	H (L/M)	L/M	L/M	L/M	H	H	L/M	H
Content types	E & T	E & T	E	E&T (E)	E	E	E	E & T	E & T	E	E & T

Table 30: Cross-case analysis of integration mechanisms' characteristics and their influence on knowledge communication[4].

4 The table defines the acronyms used in the cross-case analysis.

Table acronyms		
Acronyms of integration mechanisms	• HW PT (heavyweight project leader team) • CIT (co-located integrator team) • SMT (senior management team) • CMT (co-ordinator management team, indicating first characteristics and knowledge communication within team and parenthetically with other mechanisms)	• VPLT (virtual project leader team) • VIT (virtual integrator team) • SMMT (senior-middle management team) • IM (integrative manager) • BS (boundary-spanners) • VN (virtual network) • TI (transferred individuals)
Acronyms of factors analysed	• D (decision-making authority, high – low) • WI (work integration, high – low) • P (number of people) • CL (co-location) • DL (distributed location) • CC (cognitive convergence)	• CC L (cognitive convergence is limited) • H (high) • M (moderate) • L (low) • E (explicit knowledge) • T (tacit knowledge)

The cross-case analysis table uses acronyms in order to compress the data and thereby make an overview possible. The acronyms are explained in the footnote table on this page.

The table's upper row contains the names of each of the three collaborations studied. Each different integration mechanism is listed under the name of the collaboration where it was used. The left column contains a list of the factors analysed across the different integration mechanisms. The table contains two sections:

- ➜ The first section contains the central characteristics of different integration mechanisms' structures.
- ➜ The second section contains the indications of different integration mechanisms' influence on knowledge communication.

The reading of the table should be both horizontal and vertical. First, the cross-case analysis compares each structural category across the integration mechanisms. Thereby, it identifies differences and similarities in integration mechanisms' characteristics and knowledge communication effects. Thereafter, the analysis compares patterns in integration mechanisms' characteristics with patterns in indicators of knowledge communication effect. Based on this comparison, the analysis explores patterns regarding how integration mechanisms influence knowledge communication. This chapter will revolve around these patterns. However, first it will discuss expected patterns not found in the cross-case analysis.

6.2 Expected patterns not found in the cross-case analysis

The cross-case analysis indicates that (1) the number of people and (2) the decision-making authority did not have clear effects on integration mechanisms' influence on knowledge communication between companies. The following will comment upon these two expected patterns not found.

6.2.1 The role of the number of people in integration mechanisms

To begin with, there is no clear pattern indicating that the number of people has an impact on how integration mechanisms influence knowledge communication. In existing research, the number of people in integration mechanisms is one major characteristic – e.g. from single person to team (Galbraith, 1973). For instance, single person integration mechanism may more easily experience information overload than a team (Nadler and Tushman, 1987). Therefore, this study has investigated the number of people as a factor potentially influencing knowledge communication.

The integration mechanisms with capacity to communicate tacit knowledge include few persons, with the exception of one having approximately twenty individuals. Yet three integration mechanisms with low capacity to communicate knowledge also have few members. The large virtual integration mechanisms also have limited capacity to communicate knowledge.

Concerning explicit knowledge, it is reasonable that the number of people plays a more limited role. The reason is the potential to reach large numbers of people with the help of information systems (e.g. Evans and Wurster, 1997). That is, communication of knowledge expressed in e.g. documents largely has the same effects regardless of the numbers working in integration mechanisms.

The integration mechanism that includes some twenty persons had however, not evenly distributed capacity among the members. Instead, a large share of the knowledge communication took place in small work-teams with two to three members. Hence, it seems that high-level knowledge communication is related to a few personal relationships, meeting one another face-to-face (Daft and Lengel, 1984). This relates to Rogers' (1995) argument that informal relationships with people similar to oneself enhance communication. It also reflects the difficulty of having intensive face-to-face contacts with more than a few individuals. However, there are three integration mechanisms with a few members having knowledge communication capacity similar to the large virtual integration mechanisms. Hence, it is not entirely clear that the numbers can explain the level of knowledge communication realised. Therefore, this analysis implies that few individuals may be an important factor, but not sufficient for enabling high-level knowledge communication.

6.2.2 The role of decision-making authority in integration mechanisms

The analysis of Table 30 suggests that the decision-making authority in integration mechanisms does not influence knowledge communication. This is mentioned here because in existing research, managerial decision-making authority is one central quality of integration mechanisms. Nadler and Tushman (1987) discussed the fact that companies can use a managerial linking role in order to bring managerial authority to the integrative work. This role is similar to the heavyweight project leader role discussed by e.g. Clark and Wheelwright (1991). For instance, it could be assumed that decision-making authority in integration mechanisms should influence the types of knowledge communicated. As the following explains, that is not indicated by this study.

The analysis of the studied cases finds that the heavyweight project leader team and the integrative manager had high decision-making authority. Both these roles are associated with high capacity to communicate knowledge. The virtual project leader teams have moderate decision-making authority and low knowledge communication capacity. The two board integration mechanisms identified have high decision-making authority and low capacity to influence knowledge communication. Hence, results in this study indicate that the formal power in an integration mechanism does not directly influence the level of knowledge communication between companies.

Yet it can be noted that knowledge communication in the identified integration mechanisms largely takes place between people on similar hierarchic levels. In that sense, the results here are similar to those of Allen (1977) who found a pattern suggesting that communication mainly takes place between people on equal hierarchic level.

The discussion here has revolved around factors not indicated as directly influencing knowledge communication between companies. The following addresses the three different characteristics of integration mechanisms identified as influencing knowledge communication.

6.3 Characteristics of integration mechanisms that influence knowledge communication

The identified types of integration mechanisms had different influence on knowledge communication. The cross-case analysis of integration mechanisms' structures establishes that the key characteristics which influence knowledge communication are the degree of work integration, the type of location structure, and to what extent cognitive convergence takes place. The general patterns are that:

- ➜ Integration mechanisms with high capacity to communicate knowledge are characterised by high degree work integration, co-location and converging cognitive structures.
- ➜ Integration mechanisms with low capacity to communicate knowledge are characterised by low degree work integration, distributed location and little or no convergence of cognitive structures.

The following sections focus on how and why integration mechanisms' work integration, different location types and cognitive convergence influence knowledge communication. The analysis will first address the influence of work integration, thereafter location types and finally cognitive convergence. Based on the analysis, each section generates propositions.

6.3.1 The influence of work integration on knowledge communication

The cross-case analysis identified that integration mechanisms' work integration directly influences knowledge communication. The degree of work integration reflects to what extent the companies share work-tasks in integration mechanisms. Work integration is one of three characteristics of integration mechanisms' formal structure specifically investigated by the present study. The other two, as discussed previously in this chapter, did not indicate any clear influence on knowledge communication. In this section, the analysis revolves around how and why different levels of work integration influence knowledge communication between companies.

The cross-case analysis finds a clear pattern regarding the role of work integration for knowledge communication. The integration mechanisms with high work integration had high knowledge communication capacity. The integration mechanisms with low work integration had limited knowledge communication capacity. This role of work integration for knowledge communication is similar to results presented in existing research. For example, Clark and Fujimoto (1991) addressed the strong impact of overlapping work between functional units for communication intensity and richness. The major difference is that this study focuses on the influence of work integration on knowledge communication between companies.

One example of high degree of work integration is found in the co-located integrator team, in the Explorer collaboration. In that integration mechanism, engineers from Red Systems and Yellow Partner worked together on the same work packages. They had frequent meetings to discuss different technological issues, and often they shared ideas and experiences during informal conversations. The effect of working together was frequent communication of ideas, technical analysis and problems. Thus, the knowledge communication enabled was characterised by e.g. opportunities to engage in discussions with rapid feedback (Dennis and Kinney, 1998). This is one explanation why high knowledge communication intensity and richness were realised in integration mechanisms with high work integration.

One example of low work integration is the Seeker collaboration's virtual teams. In that integration mechanism, people from the collaborating companies shared few joint work tasks. Instead, the lion's share of work was performed within the companies' R&D departments. The integration mechanisms with low work integration reflected the fact that each company focused on its work packages and they did not have daily problem-solving activities. That is, work interdependence was pooled or sequential, in the terminology of Thompson (1967). Thereby, the need to interact was limited, which meant low (sometimes moderate) knowledge communication intensity. Furthermore, the few reasons to meet face-to-face also explain why knowledge communication richness is largely low in integration mechanisms with low work integration. In addition, opportunities for development of informal relationships were few. One implication was lack of knowledge regarding whom to contact in the partner company, in order to discuss issues during the development process. This further explains why low work integration contributes to low knowledge communication intensity.

High work integration enhances opportunities for people to express their tacit expert knowledge in action, e.g. illustrating complex analysis on a white board. This way to communicate tacit knowledge is similar to the discussion by Schön (1983) on expressing professional knowledge through action. This study shows how multiple languages enhance the capacity to communicate tacit knowledge. That is, high-level work integration creates continuous dialogue, extensive sharing of explicit knowledge, and opportunities to observe colleagues using knowledge. This relates to e.g. the discussion by Hedlund (1994) regarding how companies transfer tacit knowledge through dialogue and reflection. This combination of communication tools enhances the capacity to communicate complex tacit knowledge regarding e.g. product technology and the development process. In contrast, low work integration means that other tools for communication are used, which have less capacity to contain tacit knowledge. For instance, instead of face-to-face communication, one major means of communication is documents with e.g. technical analysis of interfaces between subsystems. Consequently, the content communicated is largely explicit knowledge.

Another explanation for high knowledge communication capacity is that integration mechanisms with high integration enhance development of knowledge redundancy between the companies. This is similar to Nonaka's (1990) discussion of overlapping division of work as a way to create information redundancy. The integrative manager in the Mover collaboration is an illustrative example. As he became involved in the work at Far Partner, knowledge redundancy in relation to colleagues increased. This further enhanced the quality of knowledge communication content since he could e.g. ask more nuanced questions and provide colleagues with better answers. Thus, development of knowledge redundancy enhances knowledge communication. The following elaborates this result.

People working together on the same tasks need access to the same technology in order to realise the joint development. Therefore, they need to develop knowledge redundancy. That increases the knowledge communication intensity, because people need to continuously share new knowledge in order to develop or maintain the redundancy necessary for accomplishing the joint work. In addition, in order to develop knowledge redundancy, people need to engage in discussions over e.g. the interpretation of blueprint. This enhances knowledge communication richness. The underlying reason is that redundant explicit knowledge is not enough. It is also necessary to share tacit knowledge in order to enable common interpretation of the explicit knowledge (e.g. Boisot, 1998). Therefore, focusing on the same knowledge over time also enhances communication of tacit knowledge. People discuss e.g. blueprint, work on modifications, raise questions and discuss them over again. This leads to development of common knowledge, which in turn enhances the capacity to interpret the knowledge communicated by colleagues from partner companies (Carlile, 2002). Hence, knowledge redundancy is both a reason for and an effect of knowledge communication. This discussion suggests that high work integration can generate a positive spiral between knowledge redundancy and knowledge communication.

One major difference between the implications of high and low work integration for knowledge communication concerns the problem of stickiness. A high-level stickiness is a barrier constraining sharing of knowledge between organisations (von Hippel, 1994). The present study finds that a high degree of work integration partly reduces stickiness for knowledge communication. For instance, in integration mechanisms with high work integration, people develop the capacity of observing the knowledge used in colleagues' activities, its importance and contextual meaning. Thereby, people from collaborating companies develop an understanding of the partner's needs of knowledge, challenge in developing knowledge, and knowledge useful for the partner's own work. This makes it possible to focus communication on relevant issues and to conduct discussions revolving around tacit knowledge. Szulanski (1996) argued that knowledge is sticky because e.g. the recipient lacks absorptive capacity. This is a consequence of much knowledge being context-dependent (Spender, 1996). The implication of this analysis is thus that a shared work practice dismantles, at least partly, this hindrance to knowledge communication. Thus, high work integration constructs a common organisational context between companies, enhancing knowledge communication.

Low work integration, on the other hand, has the implication that little common organisational context is developed. Thereby, knowledge remains sticky regarding even trivial issues, such as who knows what in the partner organisation. Therefore, the tacit dimension of the partner company's knowledge remains largely unknown to people engaged in integration mechanisms. This is one explanation for the limited capacity to communicate tacit knowledge when work integration is low.

The analysis in this section has addressed the influence of different levels of work integration for integration mechanisms' knowledge communication. Based on the analysis, the following generates propositions regarding the influence of work integration on knowledge communication.

The influence of work integration on knowledge communication

In this section it was found that a high degree of work integration:
a) Provides frequent opportunities for face-to-face dialogue on both product technology and the development process – which contains both explicit and tacit knowledge
b) Creates frequent opportunities to express tacit knowledge through action
c) Enhances knowledge redundancy and thereby stimulates intensity, richness and communication of both explicit and tacit knowledge
d) Reduces the problem of stickiness, i.e. increases the capacity to locate and understand the partner company's tacit knowledge
Therefore, the proposition is:
P1. A high degree of work integration enhances communication of explicit and tacit knowledge, as well as intensity and richness of knowledge communication

Table 31: The influence of high degree of work integration on knowledge communication

In this section it was found that a low degree of work integration: a) Focuses knowledge communication to explicit knowledge such as blueprint b) Creates little incentive for people from different companies to communicate frequently and face-to-face c) Constrains development of informal relationships, which means few direct linkages for communication d) Faces the problem of stickiness and has little capacity to reduce its constraining impact on location and interpretation of the partner company's knowledge Therefore, the proposition is: **P2.** A low degree of work integration generates low (up to moderate) knowledge communication intensity and richness, and constrains communication of explicit and in particular tacit knowledge

Table 32: The influence of low degree of work integration on knowledge communication

6.3.2 The influence of location types on knowledge communication

This study finds that location structure is one of integration mechanisms' key characteristics, with direct influence on knowledge communication. In the studied cases, different types of location structures are found and their influence on knowledge communication has a clear pattern.

➜ Co-location refers to shared office space between people from different companies collaborating in integration mechanisms.

➜ Distributed location means that people, from different companies collaborating in integration mechanisms are geographically separated most of their time.

Integration mechanisms with co-location enhance knowledge communication of both explicit and tacit knowledge, and realise high intensity and richness. Distributed location means knowledge communication with low intensity and low richness, and containing mainly explicit knowledge.

Comparing the findings of this study with existing literature, the results are in line with research on the communication capacity of different location structures (e.g. Allen, 1977; De Meyer, 1991; Song et al., 2007). The major difference is, as will be elaborated in the following, that this study indicates the role of different location structures for integration mechanisms' influence on knowledge communication between companies.

As a point of departure for the analysis, the following table summarises data regarding the geographical separation between companies in the studied collaborations.

	The Explorer collaboration	The Seeker collaboration	The Mover collaboration
Geographical separation	• Located in different European countries • Distance approx. 2000 kilometres • Same time zone	• Located in different European countries • Distance approx. 200 and 700 kilometres • Same time zone	• Located on different continents • Approx. 20h travelling • Six hours time difference

Table 33: Geographical separation between companies in the studied cases

Table 33 shows that in all three collaborations studied the companies were located in different countries. There is no indication that the size of geographical distance between companies influences knowledge communication. The Seeker collaboration facing the shortest distance had the lowest level of knowledge communication (see Table 30). Instead, as elaborated in the following, the type of location structure in integration mechanisms influenced knowledge communication between companies. The main reason is the kind of interaction patterns generated in the different types of location structures.

As research shows, co-location of people enables informal discussions as well as frequent meetings – both *ad hoc* and planned (e.g. Allen, 1977; Leenders and Wierenga, 2002). For example, in the Explorer collaboration, the co-located integrator team organised people from the two companies around the same tables in order to support continuous daily interaction. In the Mover collaboration, the integrative manager was involved in the daily discussions concerning detailed technology issues on the joint office space. The analysis finds the same pattern in the other integration mechanisms with co-location. In contrast, in the distributed integration mechanisms, such as the virtual project leader teams, there was a low frequency of meetings. There were few opportunities to meet face-to-face. Moreover, there were few *ad hoc* informal contacts.

The kind of informal interaction enabled in the co-located integration mechanisms was important in the creation of conditions for addressing complex issues (Westling, 2002). For example, the members of the co-located integrator team experienced that working side by side with one another gave daily opportunities to discuss up-coming issues of e.g. product design. Thereby, the physical co-location enabled highly intensive knowledge communication.

Co-location also meant that people met face-to-face and received direct feedback to questions (Dennis and Kinney, 1998). This was the case in, for example, the heavyweight project leader team. The two project leaders had their office rooms next to one another, which meant that they could easily engage in discussions several times a day. They also developed an informal relationship, which contributed to enabling nuanced communication of complex and politically sensitive issues regarding e.g. the development work. Thus, co-location is one major explanation for the high knowledge communication richness realised.

The high intensity and the high richness enabled in the co-located integration mechanisms reflected the communication of complex product technology and process issues. The transferred individuals, for example, were able to engage in daily communication within their functional areas. This meant that they were exposed to the flows of explicit knowledge in the form of documents and artefacts. Through the intensive and rich communication they also managed to communicate tacit knowledge about both technology and development process. Hence, co-location is one explanation for integration mechanisms' capacity to communicate tacit knowledge.

Compared to the co-located integration mechanisms, those with a distributed location structure had low or moderate knowledge communication intensity. As argued by De Meyer (1991), geographical distribution of activities is one of the major challenges to communication in R&D. One important reason is that distance gives fewer opportunities for ad hoc meetings – e.g. at the coffee machine. Another reason is that people are likely to have fewer points of contact in other geographical locations (e.g. Rogers, 1995). This was, for example, the situation in the virtual network used in the Mover collaboration. People in both companies had few contacts in the partner's organisation. Therefore, they often hesitated to call colleagues at the other company. It also constrained communication about recent developments, in the partner organisation, of importance for the joint work. This includes the development of product technology as well as organisational changes. The lack of communication of knowledge was one reason why people working in Green Systems were frustrated during the collaboration with Far Partner. This analysis is similar to Hansen and Løvås (2004), who argued that lack of informal relationships is a factor explaining geographical separation's limiting effect on communication.

One major challenge is to create informal contacts in distributed location structures. Song et al. (2007) suggested that co-location in early project phases enhances communication in virtually distributed structures used in later phases. This kind of early phase co-location was not used in the integration mechanisms identified. This is a reason why there was a lack of informal relationships when the integration mechanisms with distributed location were set up. In the Mover collaboration's virtual network, a few informal relationships were gradually created between engineers in the two companies. This contributed to enhanced intensity in the knowledge communication – but the few personal contacts remained a limiting factor. Thus, the analysis here suggests that the combination of distance and few informal contacts is one explanation for the low to moderate communication intensity in the distributed location structures.

One implication of distrusted location is obviously limited opportunity to interact face-to-face. This is one additional explanation for the low to moderate richness achieved in the virtual integration mechanisms' communication (Daft and Lengel, 1984). The achieved face-to-face communication took place during formal meetings between members of the integration mechanisms. The virtual teams in the Seeker collaboration illustrate this. People working in those teams met during intensive meetings once every second month. The opportunities to discuss and to receive direct feedback at those meetings were small, since the schedules were tight and a large number of people were participating. Instead, written documents, with complementary use of occasional meetings and telephone, were the major means of communication in the integration mechanisms using a distributed location structure. Thereby, distributed location means largely communication of explicit knowledge.

As a response to knowledge communication difficulties, integration mechanisms with distributed location develop routines. The knowledge communication routines are common activities that people agreed to conduct regularly. For example, in the Mover collaboration, the virtual network used to have a weekly telephone conference as the major means of communication. Hence, the communication routines define the forms and frequency of meetings. Thereby, they create predictability regarding when and how to communicate with colleagues working on another location. This relates to the proposition made by Dyer and Singh (1998) regarding the importance of knowledge-sharing routines for collaboration capacity. The major difference is that this study points at the role of communication routines as means for integration mechanisms' handling of distributed location.

The analysis in this section has addressed how and why location structure influences knowledge communication between companies. Similar to existing research, the analysis points at the important role of location structures for interaction patterns and development of informal relationships (e.g. McDonough III et al., 2001). This has implications for the level of knowledge communication between companies. Co-location of development teams e.g. enables increased interactions and enhanced informal communication (Sharifi and Pawar, 2002). This contributes to a high knowledge communication capacity. Distributed location integrates dispersed development organisations. It enables contacts between large numbers of people, but has less communication capacity (De Meyer, 1991; Song et al., 2007). Based on the analysis, the following develops propositions regarding how and why location structures influence knowledge communication.

The influence of location on knowledge communication

In this section it was found that co-location: a) Enhances opportunities to meet face-to-face – both in formal meetings and informally – and thereby interaction enabling high-level knowledge communication b) Contributes to development of informal relationships, which become vehicles for high-level knowledge communication Therefore, the proposition is: **P3.** Co-location enhances communication of explicit and tacit knowledge, the intensity and richness of knowledge communication

Table 34: The influence of co-location on knowledge communication

In this section it was found that distributed location:
a) Enables few opportunities for people to meet face-to-face
b) Constrains development of informal relationships and thereby linkages important for raising questions, distributing knowledge and discussing current issues in the collaboration
e) Enables knowledge communication largely through common routines, which e.g. define the forms and frequency of meetings
Therefore, the proposition is:
P4. Distributed location allows substantial communication of explicit knowledge, low knowledge communication intensity and richness

Table 35: The influence of distributed location on knowledge communication

6.3.3 The influence of cognitive convergence on knowledge communication

This study has identified the fact that cognitive convergence is a central characteristic of integration mechanisms in product development collaborations between companies. Cognitive convergence is here a process through which integration mechanisms reduce differences in cognitive structures. Thereby, it creates new cognitive structures, which enable more advanced knowledge communication to take place between companies.

According to literature, common conceptions play an important role in collaboration on product development (Dougherty et al. 2000). One reason is that people need to be able to understand one another's points of views and behaviour, in order to communicate knowledge efficiently. Differences between their cognitive structures cause different interpretations of knowledge (e.g. Brown and Eisenhardt, 1995). Hence, difference in collaborating companies' cognitive structures is a factor making knowledge communication difficult.

This study finds that integration mechanisms that reduced differences in cognitive structures, through a convergence process, enhanced knowledge communication. This pattern is similar to the findings of e.g. Inkpen and Tsang (2005) who pointed out the important role of shared cognitive structures for knowledge transfer. The chief difference is that existing literature has not explicitly explained levels of change in integration mechanisms' cognitive structures, and linked them to the knowledge communication capacity realised between companies.

This section discusses the influence of cognitive convergence on knowledge communication. First, it focuses on the process of cognitive convergence in different types of integration mechanisms, as a background for discussing the influence of cognitive convergence on knowledge communication. Thereafter, the discussion addresses the effect of different levels of cognitive convergence on knowledge communication.

6.3.3.1 The process of cognitive convergence

In each of the studied product development collaborations, when integration mechanisms first were established, the cognitive structures were rather divergent.

These differences reflected the participating companies' different experiences and collective conceptualisations (Lyles and Schwenk, 1992).

The following table provides examples of background factors in the three collaborations studied. They indicate differences in cognitive structures between the companies in the studied cases, when integration mechanisms were established.

	The Explorer collaboration	**The Seeker collaboration**	**The Mover collaboration**
Background factors	• Same industry • Competitors on other products • Limited previous collaboration • Different national cultures • Similar technology level • Similar quality & cost values • Different work processes • Different technical terms • Different national languages	• Related industrial backgrounds • Not competitors • No previous collaboration • Related national cultures • Asymmetric technology levels • Different product quality & cost values • Different work processes • Different national languages	• Same industry – but different positions (OEM and supplier) • Not competitors • Major previous collaboration • Different national cultures • Complementing technology, asymmetric levels on key areas • Different product quality & cost values • Different work processes • Different national languages

Table 36: Major organisational differences between the companies in the collaborations studied

The data in Table 36 indicate that in all three cases cognitive structures were different between the companies. It is therefore interesting, as the following analysis shows, that some types of integration mechanisms indeed reduced major differences through cognitive convergence, while others did not.

In the Explorer collaboration's integration mechanisms, cognitive convergence enhanced the capacity to understand the colleagues from the partner company. The pattern is similar for the integrative manager, the boundary-spanners and the transferred individuals in the Mover collaboration. However, there is one important difference between integration mechanisms in the Explorer and the Mover collaboration. In the Explorer collaboration, people from both companies began to develop a new common cognitive structure, which was expressed through their shared vocabulary and ways of working together. This type of common cognitive structure development was not observed in the Mover collaboration. In that collaboration, cognitive convergence meant that people from each company extended their understanding of the other's organisation. For instance, the boundary-spanners from Green Systems extended their cognitive structures towards enhanced understanding of technology values underlying Far Partner's views on the Mover. This kind of gradual learning of the partner's perspective also took place within the Explorer collaboration's co-located integrator team, in addition to the development of common cognitive structure.

In other integration mechanisms, such as the virtual teams used by the Seeker collaboration, there was very little or no cognitive convergence. The consequence was that difficulties of understanding the partner company's perspectives regarding e.g. product technology quality remained a challenge largely unchanged during the collaboration.

The analysis shows that in the present study, there are two different types of cognitive convergence. It finds that people from different companies gradually develop similar conceptions or that they increasingly understand the partner's conceptions of e.g. the product technology. These two approaches are similar to what Boland and Tenkasi (1995) called, respectively, perspective-making and perspective-taking.

How did cognitive convergence take place in different integration mechanisms? To begin with, cognitive convergence seems to be a continuous process. In the Explorer collaboration, it took half a year to recognise that there were cognitive differences, which could explain major misunderstandings. Hence, the company's existing cognitive structures were experienced as dysfunctional in the new context. This insight initiated work on developing a common language, which contributed to the experience of cognitive convergence. Reduction of differences in product and process philosophies emerged over time through the daily work in the co-located integrator team. It contributed to the development of e.g. a fairly common view on the Explorer's technology. In the Mover collaboration, the integrative manager's cognitive convergence process follows the same pattern. By working together with colleagues from the partner company, differences were identified in interpretation and behavioural patterns, and gradually the partner's perspectives could be understood.

Cognitive convergence can be seen as a process which can generate results similar to what Normann (2001) calls reinterpretation, and what Argyris and Schön (1974) refer to as double-loop learning. It is a process that changes the organisation's existing frames for thinking and acting. However, this does not mean complete elimination of cognitive differences or that it always makes it possible to understand the partner's perspectives.

At the centre of this process was the knowledge communication process through which people express past and current experiences. It recalls Weick's (1979) argument that communication can contribute to mutual understanding through development of a common frame of reference. This explains why integration mechanisms with intensive and rich communication in integration mechanisms gradually enabled reduction of cognitive differences. Hence, there is a reciprocal relationship between cognitive convergence and knowledge communication. The subsequent Chapter 8 further discusses this relationship.

The analysis here has so far discussed the process of cognitive convergence. The following will elaborate the role of cognitive structures for integration mechanisms' influence on knowledge communication.

6.3.3.2 Influence on knowledge communication

The focus of this section is the influence of different degrees of cognitive convergence on knowledge communication between companies. It finds that the degree of cognitive convergence is a key factor determining, in particular, the level of communication of tacit knowledge.

Integration mechanisms realising a high degree of cognitive convergence enhance the capacity to communicate tacit knowledge. The integration mechanisms with limited cognitive convergence develop substantially less capacity for communication of tacit knowledge. However, this study is not able to identify a difference in the influence on knowledge communication between the two types of high-degree cognitive convergence discussed in the previous section.

In the co-located integrator team, for example, when technical terms acquired a common meaning, it improved the understanding of the technical as well as the process knowledge expressed by colleagues from the partner organisation. In the Mover collaboration, the integrative manager and the boundary-spanners gradually began to understand how Far Partner was thinking about e.g. product quality. Thereby, it became possible to understand more of knowledge, e.g. underlying arguments about priorities between e.g. time-to-market and product design. Hence, cognitive convergence positively influences communication of knowledge, regarding both product technology and development process.

One reason why cognitive convergence enhances communication of tacit knowledge is that it contributes to development of increased absorptive capacity in integration mechanisms (e.g. Cohen and Levinthal, 1990; Lane and Lubatkin, 1998). Lavie and Rosenkopf (2006) argued that absorptive capacity enhances both efforts and capacity to seek and assimilate external knowledge. Hence, there is both a motivational and interpretive aspect in the role of absorptive capacity. This is central for the capacity to engage in communication of complex knowledge, which largely is specific for the partner's organisational context (Spender, 1996). The perspective here is that, through cognitive convergence, it becomes easier to appreciate the partner's view of knowledge and the role of the knowledge in its organisation. That is, the filter otherwise constraining interpretation of context-specific knowledge is increasingly possible to penetrate. Thereby, it is increasingly possible to understand the knowledge communicated by the partner.

The opposite example is integration mechanisms, such as the virtual teams, experiencing limited cognitive convergence. The implication was that it did not become much easier to understand the partner company's philosophies behind product technology and development processes as time passed. This is similar to Spender's (1996) view that knowledge is context-dependent. Without understanding the partner's organisational context, it is difficult to understand the knowledge they communicate. Hence, lack of cognitive convergence is a reason why the capacity to communicate tacit knowledge remains limited in integration mechanisms. It also explains misunderstandings in interpretations of explicit knowledge communicated.

Regarding the motivational effect of cognitive convergence Kogut and Zander (1996) provide a similar and interesting explanation. They argue that people perceive communication with those similar to themselves as meaningful, because the content makes sense to their existing knowledge categories. The implication is that people are motivated to engage in knowledge communication concerning product technology and development processes. For instance, in the Mover collaboration the integrative manager became increasingly engaged in knowledge communication regarding process-planning issues as he gained understanding about Far Partner's development process. Hence, cognitive convergence does not only reduce interpretive filters of knowledge – it also enhances efforts to communicate complex and largely tacit knowledge.

Another explanation in the identified types of integration mechanisms is that cognitive convergence contributes to development of trustful relationships. It means that people trust the partner company not to opportunistically exploit e.g. proprietary knowledge. This enhances the motivation to communicate knowledge with the partner company (Inkpen and Tsang, 2005; Becerra et al., 2008). People can also gain trust in the partner's competence as they gradually learn to understand one another's perspectives underlying technology preferences and actions during development work (Levin and Cross, 2004). This increases the willingness to communicate knowledge with the partner company, because its knowledge is perceived as trustworthy. Hence, trust that emerges with cognitive convergence is one important explanation for realisation of high-level knowledge communication.

Lack of cognitive convergence can have the opposite effect on development of trust and thereby constrain knowledge communication. The underlying reason is that not being able to understand the other side generates suspicion. In the integration mechanisms in the Seeker collaboration, there was lack of cognitive convergence. One consequence was frequent misunderstanding and conflicts regarding e.g. how to interpret blueprint, counteracting development of good personal relationships. This in turn reduced motivation to communicate knowledge. In addition, it increased concerns that the partners would exploit communicated knowledge outside the collaboration and potentially become competitors. The concerns for potential opportunistic exploitation of knowledge remained strong during the collaboration. This is one important explanation for constrained knowledge communication.

The analysis in this section finds that cognitive convergence enhances knowledge communication of tacit content – regarding both product and process knowledge. This creates a positive spiral. When people working in integration mechanisms communicate tacit knowledge, they also enhance the common understanding of knowledge. Increased understanding enhances the capacity to communicate tacit knowledge. In addition, trust that emerges with cognitive convergence increases the willingness to communicate knowledge. In contrast, a low degree of cognitive convergence means that major difficulties of knowledge communication remain obstacles in the collaboration. It is difficult to understand much explicit knowledge communicated, because its contextual background is hard to understand. Lack of understanding in the relationship makes it more difficult to develop trust in sharing the company's knowledge with colleagues from the partner company.

Based on the analysis in this section, the following develops propositions regarding the role of cognitive convergence for how and why integration mechanisms influence knowledge communication between companies.

The influence of cognitive convergence on knowledge communication

In this section it was found that a high degree of cognitive convergence:
a) Increases absorptive capacity of the partner company's product technology and development processes, which largely is tacit knowledge
b) Strengthens the perceived meaning of engaging in knowledge communication with colleagues from the partner company, concerning complex product technology and development processes
c) Contributes to development of personal and competence trust between people working in integration mechanisms, which enhances communication of knowledge
Therefore, the proposition is:
P5. A high degree of cognitive convergence in integration mechanisms enhances the capacity for communication of tacit knowledge

Table 37: The influence of high degree of cognitive convergence on knowledge communication

In this section it was found that a low degree of cognitive convergence:
a) Constrains development of understanding for one another's perspectives on product technology and development processes, which makes communication on tacit knowledge very difficult
b) Counteracts development of trust necessary for high-level knowledge communication between companies
Therefore, the proposition is:
P6. A low degree of cognitive convergence strongly constrains communication of tacit knowledge

Table 38: The influence of low degree of cognitive convergence on knowledge communication

6.4 Summary

In this chapter, the second and third research aims are addressed. Thereby, the chapter has generated knowledge regarding how and why different types of integration mechanisms influence knowledge communication.

The chapter began with examining patterns regarding how identified types of integration mechanisms influence knowledge communication. This was accomplished by comparing the identified integration mechanisms' structural characteristics with the knowledge communication indicators. It found that *work integration*, *location structures, and cognitive convergence* in integration mechanisms influence knowledge communication.

Work integration refers to the degree of shared work in integration mechanisms between collaborating companies. High work integration means that the collaborating companies share several work-tasks, e.g. working together on the design of the product architecture. This enhances knowledge communication intensity and richness, and includes both explicit and tacit content. Important reasons are the development of opportunities for face-to-face interaction, knowledge redundancy, and reduced knowledge stickiness. Low work integration means differentiated tasks, such as focus on different work packages, with little need for co-ordination of results. It constrains knowledge communication intensity, richness and explicitness, and in particular the tacit content. Major reasons are the limited opportunities and incentives for face-to-face interaction and little capacity to handle stickiness. Another reason is constrained development of informal relationships.

Location structures refer to spatial distribution of people within integration mechanisms. There are two principally different types of location in the identified integration mechanisms: co-location and distributed location. Co-location means that people working in integration mechanisms share the same office – which can be temporary or more permanent, such as for a couple of years. It enables intensive interaction face-to-face and thereby development of informal relationships. This enhances knowledge communication between collaborating companies. Distributed location refers to situations where people are located at the collaborating companies' home organisations – possibly separated by long distances. It creates conditions for interaction between distributed members of integration mechanisms. However, the intensity of face-to-face contacts is limited, and informal relationships are difficult to develop. Hence, the knowledge communication capacity is low.

Cognitive convergence is a process reducing differences in cognitive structures, i.e. patterns in thinking, which are expressed in language and actions among people working in integration mechanisms. In some types of integration mechanisms, cognitive structures converge between people coming from different companies. Integration mechanisms enabling a high degree of cognitive convergence enhance the capacity to communicate tacit knowledge. Important reasons are increased absorptive capacity and development of trust between people understanding one another. On the other hand, a low degree of cognitive convergence constrains understanding of the organisational context-specific dimensions of the knowledge communicated. It also counteracts development of trust for actively pursuing knowledge communication with colleagues from the partner company.

In this chapter, we have seen how and why the different types of integration mechanisms influence knowledge communication. In the following chapter, we will explore and analyse the moderation of integration mechanisms' influence on knowledge communication.

7 Moderation of integration mechanisms' influence on knowledge communication

This chapter explores factors potentially moderating integration mechanisms' influence on knowledge communication. It finds one such factor, strategic learning intention, which positively moderates integration mechanisms' influence on knowledge communication.

The theoretical discussions in Chapter 2 addressed central organisational factors in collaborations between companies. It focused on the company's strategic motives to collaborate on product development, different forms of collaboration, and the role of the product technology developed. This chapter addresses the potential moderating role of these organisational factors for integration mechanisms' influence on knowledge communication. Thereby, this chapter focuses the fourth research aim:

➜ Explore and analyse factors moderating identified types of integration mechanisms' influence on knowledge communication in product development collaborations between companies.

The factors addressed are broad theoretical categories containing factors that are more specific. This chapter therefore searches for patterns cutting across the studied cases in order to explore such specific factors and explain their moderating roles. Through this cross-case analysis, one factor is explored that has a positive moderating effect: the company's strategic learning intention.

The chapter is organised in the following way. The first section presents the cross-case analysis table and discusses the results explored. Second, section 7.2 discusses the pattern explored through the cross-case analysis, which generates a proposition. Third, sections 7.3 and 7.4 discuss each of the factors not found to have the expected moderating effect. In the final part, the chapter is summarised.

7.1 Cross-case analysis of organisational factors

This section compares theoretical categories across the studied cases in order to explore organisational factors moderating integration mechanisms' influence on knowledge communication. In order to accomplish this, the following table is used.

The table's left column contains a list of the theoretical categories investigated (Table 39). To the right, one column for each case study is listed with data related to the theoretical categories.

Case characteristics	**Explorer**	**Seeker**	**Mover**
	Organisational factors		
Strategic motives	• The companies aimed to take a technology leap • The task was to develop a new product architecture • Both companies wished to take a leading position on the changing market • Shared view on the relationship as a strategic partnership • The companies wished to develop collaboration skills • Both companies aimed to understand the whole system • Red Systems also wished to influence the operations management	• No shared strategic motives • Blue Systems' aimed to meet customer expectations and remain in business • Blue Systems' wished to develop a new product generation • Black Partner and White Partner wished to fill their order books & enhance competence • Blue Systems operational aim was to accomplish project requirements	• Both companies wished to take a technology leap • The collaboration was seen as a way to realise first mover advantage • Green Systems wished to reduce dependence of suppliers • Far Partner needed to share R&D costs • Green Systems' ambition was to understand the whole system (a view shared by Far Partner) • Green Systems wished to gain influence over operations management
Form of collaboration • Legal form & central contracts	• Contractual agreement – vertical relationship • Autonomous project structure – independent and co-located • Each company owned its contributions – intellectual property • Different levels of openness	• Joint venture (phase 1) • Shared project structure • Contractual agreement • Each company owned its contributions – intellectual property • Different levels of openness	• Contractual agreement • Operator project structure – supplier has lead • Shared ownership of intellectual property
Kind of product technology developed	• Architectural product technology	• Incremental product technology	• Modular (new subsystem architecture) product technology

Table 39: Cross-case analysis of factors that potentially moderate the influence of integration mechanisms on knowledge communication

The table should be read horizontally – each theoretical category across the three cases in order to explore patterns. In each category, (1) strategic motives, (2) form of collaboration, and (3) product technology, the analysis compares data from the studied cases.

1) Strategic motives refer to why a company engages in product development collaboration. Important reasons discussed in section 2.1.1 are learning, innovation potential and cost sharing.

2) The form of collaboration concerns the legal and organisational relationship between companies – for instance, whether they jointly own and control resources, and how they handle intellectual property.
3) Product technology refers to the primary object of the collaboration. There are different kinds of product technology, which e.g. have implications for the extent to which companies need to work integrated.

Based on the data generated by the presented study, the analysis finds the three theoretical categories too general. Instead, the analysis across the three cases identifies underlying factors, within the broad theoretical categories, that more accurately describe the patterns explored. The cross-case analysis explores two such underlying factors – *strategic learning intention* and *product technology uncertainty*. However, the form of collaboration used does not indicate any pattern between the cases, which could have been expected on the basis of previous research.

As the following will explain, strategic learning intention is a factor that positively moderates integration mechanisms' knowledge communication. Although product technology uncertainty does not have a moderating role, it is interpreted as playing a central role as background factor, which is discussed in section 7.3.

The following discusses how the patterns were explored through the cross-case analysis.

➜ The analysis of Table 39 establishes that, in two cases, companies have intentions to understand the whole product system and to influence collaboration management. The ambitions to understand the whole system are also related to another pattern, the aim of taking a technology leap through the collaboration. These intentions imply ambitions to learn from and together with the partner – i.e. they can be categorised as *strategic learning intention*. The two collaborations with high strategic learning intention have integration mechanisms with capacity to enable high-level knowledge communication. In contrast, the Seeker collaboration, where the companies' strategic learning intention was very limited, integration mechanisms have low knowledge communication capacity. Thus, there is a relationship between the level of strategic learning intention and integration mechanisms' influence on knowledge communication. Section 7.2 further elaborates this relationship and finds that strategic learning intention positively moderates integration mechanisms' knowledge communication.

➜ In Table 39, it can be observed that there is a difference between the studied cases regarding the kind of product technology developed. Building on existing research it is reasonable to assume that underlying the difference in product technology developed there is a difference in product technology uncertainty (Henderson and Clark, 1990; Tushman and Rosenkopf, 1992). The level of uncertainty is important because it can be assumed to influence the required communication capacity between companies (Stock and Tatikonda, 2004). In the studied cases, high *product technology uncertainty* is associated with architectural technology in particular, but also modular product technology. The two collaborations with high product technology uncertainty have integration mechanisms with capacity to enable high-level knowledge communication. In contrast, the Seeker collaboration faced relatively low uncertainty, because it was dealing with incremental product technology development. In this collaboration, the integration mechanisms had low capacity to enable knowledge communication. Hence, there is a relationship between the level of product technology uncertainty and integration mechanisms' influence on knowledge communication. Section 7.3 elaborates this observation and finds that product technology uncertainty does not directly moderate the influence of integration mechanisms on knowledge communication. Instead, as also indicated by existing research, e.g. Nadler and Tushman (1987), the level of product technology uncertainty may influence the type of integration mechanisms required for meeting knowledge communication needs.

The following section focuses upon the moderating effect of strategic learning intention on integration mechanisms' knowledge communication.

7.2 The moderating effect of strategic learning intention

The literature recognises learning as a major driver behind product development collaboration. One reason is that learning influences to what extent it is possible to combine internal and external knowledge, and thereby the capacity to innovate new products (e.g. Powell et al., 1996; Shenkar and Li, 1999; Hennert and Zeng, 2005). Another motive, Hamel (1991) argued, is that if knowledge is power, a company that wishes to have influence in collaboration is likely to strive for learning from its partner. The analysis of Table 39 explored a pattern suggesting that strategic learning intention is an organisational factor positively moderating integration mechanisms' influence on knowledge communication. The reason is that strategic learning intentions motivate people to pursue knowledge communication in integration mechanisms. This result is consistent with Pérez-Nordtvedt et al. (2008) who found learning intent to be positively associated with the comprehension and speed of knowledge transfer. The following examples illustrate the pattern observed in the present study.

Strategic learning intentions played major roles in the Explorer and the Mover collaborations, which the following elaborates. Both the Explorer and the Mover collaborations aimed at taking a technology leap (see Table 39). Since the companies worked close together with the partner company in the development of the new product, they had to learn about the new technology together as it was developed.

The data in Table 39 also show that in these collaborations companies had major intentions to understand the whole product system and to influence operations management in the project organisation. Although the cases are somewhat different, regarding to what extent these intentions are shared by both companies the effect is similar in terms of drive for learning through integration mechanisms. The intentions indicates strong ambitions to learn from, and together, with the partner company during the process of developing the new product. This kind of learning intention concerns more than the product knowledge. It also requires that the collaborating companies learn how to develop new knowledge together. That is, it also contains learning about how to work together (Zollo and Winter, 2002; Salk and Simonin, 2005).

In these collaborations, there was also learning related to the partner's existing knowledge. It concerned internalising knowledge from a partner company, tacitly embedded within its R&D organisation (Kale et al., 2000). For instance, Red Systems was interested in learning from Yellow Partner's experiences of testing technology similar to the Explorer. In the Mover collaboration, Green Systems was keen on making Far Partner understand the requirements of interfaces in order to enable integration with other product modules. Thus, in the studied cases there is a pattern indicating a relationship between high strategic learning intentions and high-level knowledge communication.

In contrast, in the Seeker collaboration there were limited intentions to learn from the partners. To a limited extent, the intention was that White Partner should learn some of Blue Systems' existing technology and experience. From the perspective of the different companies, there were no overall strategic ambitions e.g. to build competence through the collaboration as such, but from the internal work only. Hence, there was no explicit intention to learn together from the joint work. As Hamel (1991) argued, without clear strategic objectives it is difficult to motivate allocation of resources for learning. This was apparent, for instance, in the resistance in Blue Systems to transferring individuals to Black Partner. The limited efforts of White Partner to learn from Blue Systems do not indicate any major effect on the knowledge communication between the companies. Hence, limited strategic learning intention does not seem to moderate knowledge communication.

One reason for the positive moderating effect of strategic learning intention in the Mover collaboration was the direct engagement by Green Systems' and Far Partner's CEOs. An important signal about the project's importance was their two annual meetings. People working with the Mover collaboration experienced that this was a clear indication of the importance of their work. In addition, the management board members were very active and personally committed to the success of the collaboration. This management commitment was a sign of the collaboration's importance, where the ambition to understand the product technology and thereby influence the development was a central aspect. It also symbolically expressed trust between the companies. On operational levels, the managers' engagement enhanced motivation for knowledge communication.

In the Explorer collaboration, people from Red Systems understood the strategic importance of their efforts. It was clear to them that the management of the company considered it very important to access knowledge about the whole product architecture. The reason was the potential of the Explorer technology. It was central for building a competence platform, for the company's future products. This insight was one source of motivation for engineers to strive for knowledge communication, in the face of difficulties and misunderstandings. The project leaders' close collaboration was also a signal that the companies trusted one another – that they could be open with technology because they strove to accomplish something important together.

The analysis here suggests that companies' management strongly influenced the moderating effect of strategic learning intention. As Gioia and Chittipeddi (1991) argued, employees on lower organisational levels try to make sense of senior managers' visions and actions. According to Weick (1995), sense-making in organisations influences how people perceive different situations and how they choose to act. Managers' active engagement signals that the collaboration is important and it becomes a symbol of collaborative behaviour. To people engaged in integration mechanisms, this is one explanation of why strategic learning intention is important. Thereby, management commitment to strategic learning intention enhances operational levels' motivation to engage in knowledge communication (Harris and Nelson, 2008).

An additional reason for the positive moderating effect of strategic learning intention on knowledge communication is that it motivates development of trustful relationships. In this study, companies with strategic learning intentions do not conceal them from their partner companies. This is one reason for development of trust between collaborating companies' managers. Obviously, underlying the development of trust is a belief that the partner's strategic learning intention is important for the collaboration. Managers' trust in each other's intentions is expressed through their collaboration, which becomes a symbol enhancing knowledge communication efforts in operations. The reason is that people experience they can communicate with the partner company without having to be concerned with the risk of opportunistic exploitation. This is consistent with Dyer and Singh (1998) and Kale et al. (2000) regarding the important role of management trust for sharing of knowledge between companies.

The analysis here points at strategic learning intention as a driver of knowledge communication in integration mechanisms. However, its positive moderating effect is constrained by integration mechanisms' structures. For example, in the Mover collaboration's virtual network, people from Green Systems were motivated to enhance learning. It was possible to increase intensity of knowledge communication, but not richness and the tacit content. The reason is that, to the extent tacit knowledge needed to be communicated, people had to meet face-to-face. Hence, integration mechanisms such as the virtual network have more limited capacity to respond to strategic learning intention's positive effect on knowledge communication motivation. Instead, it takes integration mechanisms with high work integration, co-location and high degree of cognitive convergence in order to realise the positive moderating effect. Thus, in order to enable high-level knowledge communication, high motivation among operational level employees is not a substitute for integration mechanisms' structures.

Based on the analysis, this study can develop a proposition regarding the moderating role of strategic learning intention on integration mechanisms' knowledge communication.

In this section it was found that:
a) Strategic learning intention, supported by management commitment and trust, makes people in integration mechanisms motivated to communicate knowledge with colleagues from the partner company.
b) Strategic learning intention's positive moderating effect on knowledge communication richness and tacit content is constrained by low-degree work integration, distributed location and low-degree cognitive convergence.
Therefore, the proposition is:
P7. Strategic learning intention enhances integration mechanisms' influence on knowledge communication. However, the positive effect realisable depends on the characteristics of the structures of the integration mechanism.

Table 40: The influence of strategic learning intension on knowledge communication

7.3 The role of product technology uncertainty

The cross-case analysis identified that the uncertainty underlying different kinds of product technology is an organisational factor related to integration mechanisms' influence on knowledge communication. The following analysis elaborates this observation.

Stock and Tatikonda (2004) provided a useful definition of product technology uncertainty. They argued that uncertainty reflects technology's novelty, its complexity, and the tacitness of its knowledge. Novelty refers to the level of experience and change compared to existing product technology – i.e. what Roberts and Berry (1985) refer to as degree of familiarity with technology. The view on complexity is similar to the argument by Tushman and Rosenkopf (1992) that product technology complexity refers to the number of subsystems, interfaces and linking requirements between different parts in a product. Tacitness concerns the degree of tacit knowledge in relation to explicit knowledge. In brief, the newer the technology, the higher the complexity and the more tacit knowledge used, the more uncertain is the task of developing the product technology.

Product technology uncertainty is a reflection of the kind of innovation developed. As mentioned in section 2.1.3, Henderson and Clark (1990) argued that architectural product development implies change of established concepts concerning how different subsystems and components are related to each other. *Ex ante*, the development of a new architecture uncertainty is high, because it is hardly possible to know how subsystems will be combined and what consequences different combinations will have for product performance. This high-level complexity in collaboration contributes to high interdependence between the companies' different work-tasks (von Hippel, 1990). In comparison, an incremental product innovation takes place within an established architectural configuration. The product knowledge on an architectural level can be well known, which makes it possible to reduce much uncertainty concerning relationships between different subsystems through ex ante analysis. Hence, it is justified to organise the product development around differentiated work-tasks (Sanchez and Mahoney, 1996; Chesbrough and Kusunoki, 2001).

The Explorer and the Mover collaborations developed product technology with high uncertainty concerning whether e.g. architectural design and performance were possible to realise. The data show that both collaborations aimed to take a technology leap. Thus, the new product technology meant substantial development of new knowledge, and existing knowledge was not a sufficient reference and point of departure.

The reason why the development of the modular product technology, the Mover, required such high-level knowledge communication between the companies deserves a special comment. The OEM Green Systems and its supplier, Far Partner, were both engaged in the development operations. This kind of close collaboration on modular product technology development is different from the conventional view of more arm's-length relationships between the OEM company and suppliers (e.g. Clark and Fujimoto, 1991). The implication was a need to handle product technology uncertainty together, which required close operational-level interaction. Underlying this close collaboration was Green Systems' ambition to play an active role.

In the studied cases, the two collaborations facing high product technology uncertainty also had integration mechanisms influencing high-level knowledge communication. According to literature, high uncertainty is a driver for communication between organisations (e.g. Stock and Tatikonda, 2004). One reason is that high uncertainty requires high-level knowledge communication in order to enable necessary joint problem-solving and mutual adaptation during the development process (von Hippel, 1990). In fact, much of the companies' existing knowledge may be obsolete in the new development project (Sköld, 2007). The new architecture may e.g. have other geometrical principles, interfaces between subsystems and functional requirements of the product. Therefore, the collaborating companies need to create a new and common base of knowledge (e.g. Salk and Simonin, 2005), which requires knowledge communication. Therefore, a high-level product technology uncertainty requires integration mechanisms with capacity for high-level knowledge communication.

In the Seeker collaboration, which was concerned with developing an incremental new product technology, the integration mechanisms had low-level knowledge communication capacity. Notwithstanding the Seeker was a very advanced product with large uncertainties; it built on existing product architecture. Hence, the product technology uncertainty in relation to the other kinds of product innovation categories was low. The collaboration used the principle suggesting that product modularity enables organizational modularity (e.g. Sanchez and Mahoney, 1996; Grant, 1996). It is, however, indicated that the real product technology uncertainty was underestimated in the collaboration because of the companies' different pre-understanding of the technology. That is, the differences in knowledge meant that it was very difficult to define in advance e.g. interfaces between subsystems. Persson (2004) makes a similar analysis and argues that more of integration may be necessary than product modularisation indicates. This suggests that it is a major challenge to estimate the level of product technology uncertainty in collaborations between companies. The mere fact that companies share the same blueprint does not say much about the product technology they have in common. One important reason is tacit product knowledge, which largely is sticky and hence difficult or impossible to appreciate (Szulanski, 1996). Hence, it is very difficult or impossible to estimate product technology uncertainty embedded in companies' different understanding of the technology. Therefore, communication revolving around explicit knowledge entails the risk of overestimating common knowledge, and thereby underestimating product technology uncertainty.

The effect of perceived low product technology uncertainty was knowledge communication with focus on interface design and how their different work-tasks should be co-ordinated. This was explicit knowledge largely expressed in documents. Yet misunderstandings due to differences in the interpretation of the communicated explicit knowledge created a need of more extensive knowledge communication. However, to the extent that there were efforts to communicate more knowledge, not least with tacit content it was difficult or impossible to achieve. This is similar to knowledge communication efforts in the Mover collaborations' virtual network. In this integration mechanism, the explicit knowledge communicated was not enough to meet Green Systems' requirements. Therefore, people strove to communicate more tacit elements, which was very difficult due to constraints of e.g. distributed location.

The analysis in this section points at product technology uncertainty as a factor important for the level of knowledge communication required of integration mechanisms. The result is similar to research by e.g. Nadler and Tushman (1987) who regarded uncertainty as a determining factor for the kind of integration mechanisms sufficient to use. This study finds that high product technology uncertainty makes it important to communicate advanced knowledge in order to realise the joint product development work. A low-level product technology means that the knowledge communication required is limited. However, the analysis here does not indicate that product technology uncertainty should have any direct moderating influence over integration mechanisms' knowledge communication. Hence, from the perspective of this study, product technology is not a factor explaining how and why integration mechanisms influence knowledge communication. Instead, it is a background factor determining the level of knowledge communication capacity required of integration mechanisms.

7.4 The lacking role of collaboration form

The cross-case analysis suggests that organisational form is not important for integration mechanisms' influence on knowledge communication. This study expected that the formal form of collaboration used could have a moderating effect. Previous research has given attention to the fact that collaboration forms influence knowledge flows between companies (Harrigan, 1986; Osborne and Baughn, 1990; Mowery et al., 1996). For instance, it could have been expected that the collaboration form would influence e.g. development of trust and management commitment and thereby on the functioning of integration mechanisms.

That this study does not indicate such a pattern differs from a view common in the literature. Osborne and Baughn (1990) and Mowery et al. (1996) argued that joint ventures in general have more capacity to transfer knowledge, which indicates knowledge communication, than other forms of collaboration. Relating these results to the present study, the Seeker collaboration, which used a joint venture, should have achieved high-level knowledge communication, which it did not.

There are different potential reasons for the difference in the results found by the present study and existing research. For instance, the study by Mowery et al. (1996) is a survey which identifies relationships between different collaboration forms and knowledge transfer. It does not explain factors underlying the observed relationships – e.g. the role of different types of integration mechanisms. Hence, it is not clear whether their results reflect the functioning of different types of integration mechanisms. It is thus possible that other factors than integration mechanisms strongly influence knowledge communication between companies. Alternatively, it may be the case that the form of collaboration plays a lesser role than indicated by Osborne and Baughn (1990) and Mowery et al. (1996).

It is possible that a larger number of cases would have indicated that the form of collaboration has a moderating effect on integration mechanisms' influence on knowledge communication. Hence, further research would be valuable concerning this unexpected result regarding the role of collaboration form.

7.5 Summary

This chapter has accomplished the fourth research aim in order to realise the purpose of this study. It has explored, across the studied cases, organisational factors that potentially moderate integration mechanisms' influence on knowledge communication. The findings indicate that strategic learning intention is a moderator.

Strategic learning intention has a positive moderating effect on knowledge communication between companies. The effect is realised through management commitment to the collaboration. The reason is that people working under the challenging circumstances in collaborations need to make sense of why they should strive for learning – and therefore knowledge communication. Managers who personally are engaged in the collaboration enhance such sense-making, which increases people's motivation to engage in knowledge communication.

In addition, how managers handle their company's strategic learning intention influences the development of trust in the collaboration. Explicitly expressed intentions, reasonable from the perspective of accomplishing the collaboration, enhance trust. This signals to people in operations that they can engage in open knowledge communication, without being concerned with the risks of opportunistic exploitation of technology. However, the positive moderating effect is constrained in integration mechanisms characterised by low work integration, distributed location and different cognitive structures.

This chapter also discussed the fact that product technology uncertainty is one important background factor, influencing the level of knowledge communication capacity required of integration mechanisms. In the final section, it was briefly mentioned that the form of collaboration does not seem to moderate integration mechanisms' influence on knowledge communication.

The following chapter will build on the results from this chapter and the propositions presented in Chapter 6. Thereby, it develops this study's model of integration mechanisms' enabling of knowledge communication between companies.

8 Enabling knowledge communication

This chapter develops a comprehensive model concerning integration mechanisms' enabling of knowledge communication. The model synthesises the results from the analysis in Chapters 5–7. It emphasises that the combination of different factors creates conditions enabling knowledge communication between companies.

The analysis of the studied cases found that the influence of integration mechanisms on knowledge communication between companies is built up by the characteristics of different structures. In addition, it was found that strategic learning intention can positively moderate the influence of integration mechanisms on knowledge communication. This chapter integrates the results from the analysis in the previous chapters into a comprehensive model.

This chapter accomplishes the synthesis by linking the results regarding integration mechanisms' structures and the results regarding the moderating effects. Thereby, the model constructs a cohesive view of the factors and relationships enabling integration mechanisms' knowledge communication. Based on the model, the discussion in this chapter extends the results from the previous chapters, which focus on the single factors' influences. The principles discussed here constitute the background for the development of knowledge communication strategies, presented in section 9.3.2.

The outline of this chapter is as follows. First, it introduces the model and discusses its major characteristics. Thereafter, it elaborates the model's different factors and relationships in different sub-chapters. Finally, this chapter discusses the major conclusions generated.

8.1 A model of the study's results

This section introduces the model that synthesises the study's results. It integrates the principal relationships of different factors regarding integration mechanisms' enabling of knowledge communication between companies. Existing research is used in this chapter in order to enhance the generalisation of the principal relationships discussed.

The model focuses on the causal relationships that this study has identified. It is important to point out that this chapter extends the results from previous chapters, by offering a more dynamic view on how and why integration mechanisms enable knowledge communication between companies. Therefore, the discussions in this chapter address the relationships between the factors presented in the model.

The following model presents the study's principal results regarding integration mechanisms' enabling of knowledge communication between companies.

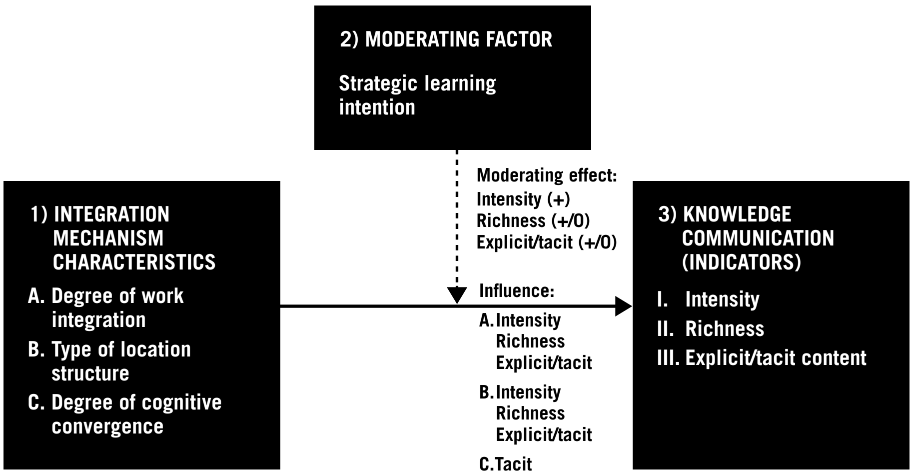

Figure 21: How and why integration mechanisms enable knowledge communication between companies

This study identifies four different factors, which together explain integration mechanisms' enabling of knowledge communication. Three of these factors are integration mechanisms' characteristics: (A) degree of work integration, (B) type of location structure and (C) degree of cognitive convergence. Strategic learning intention is the fourth factor, and it positively moderates integration mechanisms' enabling of knowledge communication.

1) In the model, the horizontal arrow indicates the influence of integration mechanism characteristics, A, B and C.
   A. Degree of work integration defines to what extent people from collaborating companies share work-tasks. The model (Figure 21) illustrates that the degree of work integration influences knowledge communication intensity, richness and content. High degree of work integration enhances intensity and richness of knowledge communication and the capacity for communication of both explicit and tacit knowledge. Low degree of work integration allows rather constrained knowledge communication, which largely means low intensity, low richness and mainly explicit knowledge.

B. The type of location structure shapes conditions for interaction between people from collaborating companies. As illustrated in the model (Figure 21), location structure influences knowledge communication intensity, richness and content. Co-location has a strong influence on all three knowledge communication indicators. The influence of distributed location is limited, in particular regarding richness and communication of tacit knowledge.

C. Degree of cognitive convergence concerns to what extent people from different companies increase the understanding of one another's conceptions of e.g. product technology and development processes. It also concerns to what extent they develop common conceptions. The role of cognitive convergence is different from work integration and location structure, because it only influences the content of knowledge communication. It takes high-degree cognitive convergence in order to enable enhanced communication of tacit knowledge.

Together these characteristics of integration mechanisms shape conditions for activities enabling knowledge communication. Integration mechanisms influencing high-level knowledge communication are characterised by high-degree work integration, co-location and high-degree cognitive convergence. The integration mechanisms enabling low-level knowledge communication have low-degree work integration, distributed location structure, and low-degree cognitive convergence.

2) In the model, the vertical arrow illustrates the moderating effect of strategic learning intention. Strategic learning intention enhances integration mechanisms' capacity to enable knowledge communication. The moderating effect is realised through management commitment and trust, which make operational levels motivated to share knowledge in integration mechanisms. Strategic learning intention has a positive effect on knowledge communication intensity. It can enhance richness and the tacit knowledge of the content communicated. Whether strategic learning intention enhances knowledge communication richness and the tacit dimension of the content depends on the characteristics of integration mechanism structures. It is required that the integration mechanism have high-degree work integration, co-location and high-degree cognitive convergence in order to realise the positive moderating effect, regarding richness and communication of tacit knowledge.

3) The right box in the model (Figure 21) contains the knowledge communication indicators. Recalling from section 2.4, this study uses the following definitions of knowledge communication indicators:

I. Intensity refers to how often knowledge communication takes place – daily, weekly or less than weekly.
II. Richness refers to the capacity of different media to allow e.g. direct feedback, use of multiple languages and individualisation of messages. Face-to-face communication indicates high richness, e.g. telephone indicates moderate richness and e-mail indicates low richness.
III. Content of knowledge communication refers to explicit and tacit knowledge. Communication of explicit knowledge is indicated by e.g. documents. Communication of tacit knowledge is indicated by dialogues and experienced change in understanding of the knowledge in focus for the joint work.

One of the key points made through the model (Figure 21) is that the combination of integration mechanisms' different structural characteristics (A, B and C) and the level of strategic learning intention is what enables knowledge communication. However, each of the different elements in the model needs to be discussed separately in order to explain their different roles.

In what follows, the discussion further elaborates the model. The first part focuses on the role of integration mechanisms' characteristics. The second part discusses the moderating effect of strategic learning intention integration on mechanisms' knowledge communication.

8.2 Three characteristics of integration mechanisms that enable knowledge communication

Integration mechanisms enable knowledge communication through the combination of three types of structural characteristics: degree of work integration, type of location structure and degree of cognitive convergence. The differences in characteristics of these three structures are explanations for different types of integration mechanisms' influence on knowledge communication between companies.

In this sub-chapter, it is discussed how and why different types of integration mechanisms enable knowledge communication. It builds on the analysis in Chapters 5 and 6. However, it develops those results by focusing on the relationships between the three characteristics of integration mechanisms – i.e. degree of work integration, type of location structure and degree of cognitive convergence. The key argument made is that integration mechanisms enable knowledge communication through the combination of the three characteristics.

The following will first focus on the role of work integration; thereafter the focus turns to location structures and finally cognitive convergence. The discussion in each section will briefly recapitulate the major results from Chapter 6, before focusing on the relationships between the different characteristics.

8.2.1 The role of work integration for enabling of knowledge communication

The degree of work integration in integration mechanisms concerns to what extent collaborating companies share work-tasks. It generates activities influencing the kind of interaction taking place between companies. Thereby, the degree of work integration has a strong impact on how and why integration mechanisms enable knowledge communication. Work integration also enables knowledge communication indirectly through its impact on location structures and convergence of cognitive structures. The following first recapitulates the results from Chapter 6 and thereafter the discussion elaborates these roles for different degrees of work integration.

Obviously, there is a continuum of different degrees of work integration. However important these nuances, it is useful to outline the principles for enabling of knowledge communication. Therefore, the discussion here addresses two degrees of work integration: high work integration and low work integration.

The degree of work integration influences to what extent people from collaborating companies need to work together on problem-solving during the development process. This relationship between the degree of work integration and joint problem-solving is similar to the discussion by von Hippel (1990) regarding the level of task partitioning between organisations as a regulator of cross-boundary problem-solving. The major difference is that this study focuses on the role of work integration within integration mechanisms. In particular, the present study is different because it focuses on the role of work integration for different types of integration mechanisms' knowledge communication.

Chapter 6 discussed different explanations for why the different degrees of work integration influence knowledge communication. For example, it found that high-degree work integration enhances knowledge redundancy. This is similar to Nonaka's (1990) argument that overlapping tasks enhances information redundancy. However, in comparison the present study specifically points at the role of high-degree work integration as a factor enabling knowledge communication, because of e.g. development of knowledge redundancy. This study also finds that low-degree work integration means limited development of knowledge redundancy, which is one reason for low knowledge communication capacity.

This difference in the functioning of work integration has implications for integration mechanisms' location structures and cognitive convergence. The following develops this role of work integration for enabling of knowledge communication.

8.2.1.1 The influence of work integration on location structures and cognitive convergence

This section extends the results from Chapter 6 by arguing that work integration also enables knowledge communication through its impact on location structures and cognitive convergence.

High work integration creates a drive for people to interact on e.g. a joint office floor. The underlying reason is that meeting face-to-face enhances knowledge communication richness (e.g. Daft and Lengel, 1986), and thereby increases the potential to communicate tacit knowledge. In comparison, in a situation with high-degree work integration and distributed location, it is difficult to communicate tacit knowledge. The consequence is limited joint problem-solving capacity. Hence, high work integration drives people to interact face-to-face, which enhances the importance and use of co-location for knowledge communication.

In contrast, low work integration creates little drive for face-to-face communication. This is similar to e.g. von Hippel's (1990) argument that low problem-solving interdependence means little need for interaction between organisations. One reason is that it makes little sense to make the investments, such as co-location of teams, in order to enable more knowledge communication (e.g. Grant, 1996). It also means that even though people are co-located they communicate less when work integration is low.

High degree of work integration also puts focus on the cognitive structures in integration mechanisms. The reason is that different conceptions of e.g. the product are filters hindering communication of tacit knowledge. Thereby, in order to realise the level of knowledge communication motivated from the perspective of high work integration, cognitive convergence becomes necessary to accomplish. Failing to achieve cognitive convergence constrains knowledge communication, and thereby causes problems in the joint work. The solution is largely related to the level of work integration. A high degree of work integration functions as a catalyst of cognitive convergence. The reason is that work integration constitutes a formal structure for interaction that generates activities and discussions that contributes to change of collective conceptions (Löwstedt, 1989).

Collaborations with low degree of work integration can experience that differences in cognitive structures may cause problems for knowledge communication. However, the consequences are less apparent in the day-to-day work, compared to situations with high work integration. Therefore, this kind of situation generates less effort to realise cognitive convergence. For example, it makes less sense to take on the different conceptions of the technology developed. In addition, with low degree of work integration there are limited opportunities for the kind of interaction necessary for setting a process of cognitive convergence in motion. Thereby, low-degree work integration also indirectly contributes to low-level knowledge communication.

The discussion here specifically points at how the degree of work integration indirectly, through its impact on location structures and cognitive convergence, enables integration mechanisms' knowledge communication. The following addresses the direct and indirect role of different types of location structures for knowledge communication between companies.

8.2.2 The role of location structures for enabling of knowledge communication

This study finds that location structures play a major role for integration mechanisms' enabling of knowledge communication. The study has explored a variety of location structures, enabling different levels of knowledge communication. The following will first recapitulate the results from Chapter 6 and thereafter elaborate on the indirect effects of integration mechanisms' location structures.

The continuum of location structures spans from co-located teams, over transferred individuals and boundary-spanners, to geographically distributed location between the members of integration mechanisms. In practice, the location structures used in product development collaboration may contain a mix of these different location structures. The location structure may also change over time as the collaboration enters new phases. In focus here is, however, the principal influence of two different types of location structures on knowledge communication between companies – co-located and distributed location.

To begin with, the location structure of an integration mechanism has important implications for the development of informal relationships between people from different companies. It also influences to what extent spontaneous meetings take place. These effects of the type of location structure influence the intensity and richness in knowledge communication, as well as the type of knowledge communicated.

Like Rogers (1995), this study recognises the enhancing role of co-location for informal contacts. It also points at the important role of co-location for spontaneous meetings (Westling, 2002). Similar to Daft and Lengel (1984) this study finds that co-location enhances face-to-face interaction and thereby communication richness.

This study also finds, similarly to arguments by e.g. De Meyer (1991), that distributed location is a major challenge to communicating knowledge. The integration mechanisms using distributed location obviously had limited opportunities for face-to-face communication and development of informal relationships. Consequently, the socialisation process that Ghoshal and Bartlett (1987) found important for communication between different locations was constrained.

Thus, the overall findings of this study regarding the role of location structures in knowledge communication are similar to existing research. However, the findings of this study are complementary, because they specifically focus on the role of location structures for integration mechanisms' influence on knowledge communication. This study is also able to argue that location structures indirectly enable knowledge communication through work integration and cognitive convergence. The following further elaborates this role.

8.2.2.1 The influence of location structures on work integration and cognitive convergence

In the following, it is discussed that location structures play a major role for work integration and the process of cognitive convergence between companies. Thus, a point made here is that location structure influences knowledge communication also indirectly.

This study finds that distributed location contributes to knowledge communication with low intensity and richness, and largely explicit knowledge content. This enhances or maintains low work integration and differences in cognitive structures. Distributed location is an effective barrier for people to interact and thereby develop opportunities for joint work to emerge. Obviously, this is not a problem in collaborations requiring little work integration. However, in collaborations requiring high work integration, distributed location can make it difficult to realise. Distributed location also constrains cognitive convergence, largely because of the limited opportunities for people to interact face-to-face. These effects of distributed location are consistent with existing literature. For instance, McDonough III et al. (2001) found that it is difficult to facilitate effective personal relationships and communication in globally distributed teams.

In contrast, as mentioned, co-location enhances knowledge communication intensity, richness and capacity for tacit and explicit knowledge. It thereby supports high work integration, and it creates conditions for cognitive convergence to take place. As Orlikowski (2002) argued, work practice is generated through everyday action. Co-location offers the physical preconditions for integrated work. Cognitive convergence is enhanced by the on-going interaction face-to-face with colleagues from the partner company. Thus in the terminology of Tsai and Ghoshal (1998) it contributes to development of social interaction, which enhances knowledge communication.

The discussion here points at the important role of location structure for the balance between the integration mechanism's structural characteristics. In contrast, co-location and low work integration, or distributed location and high work integration, do not create complementary and mutually supportive structures. The effect of imbalance is difficulty in achieving efficient knowledge communication. The following continues the discussion of the interdependence between the characteristics of integration mechanisms, and the effects on knowledge communication between companies.

8.2.3 The role of cognitive convergence for enabling of knowledge communication

This section elaborates the role of different degrees of cognitive conference for knowledge communication. First, it recapitulates results from Chapter 6. Thereafter the discussion elaborates the influence of cognitive convergence on work integration and location structures.

In the field of research on integration mechanisms, Griffin and Hauser (1996) discussed the capacity of different integration mechanisms to reduce what they call difference in "thought worlds". The current study is complementary since it specifically points at the role of work integration and co-location for the process of cognitive convergence. It thereby underlines the fact that cognitive convergence is an ongoing process in some integration mechanisms. It also finds that cognitive convergence is limited in integration mechanisms with low-degree work integration and distributed location.

The discussions in Chapter 6 identified on two types of cognitive convergence between people from different companies. One type concerns development of common conceptions concerning both product technology and development processes. That is, a new cognitive structure is developed among people from different companies that work together. The second type concerns people learning to understand one another's different points of views without necessarily developing a common cognitive structure.

These two types of cognitive convergence are similar to what Boland and Tenkasi (1995) called perspective-making and perspective-taking. They argued that both perspective-making and perspective-taking play central roles for enabling communication between organisations. Inkpen and Tsang (2005) discussed cognitive structures as one major factor influencing knowledge transfer between companies. This is similar to the results generated by this study. However, this study specifically elaborates explanations for the role of the degree of cognitive convergence in communication of tacit knowledge. One example, discussed in Chapter 6, is the effect of a high degree of cognitive convergence on development of absorptive capacity between companies. The effect is enhanced capacity for understanding one another's knowledge. In contrast, a low degree of cognitive convergence means that differences in cognitive convergence remain unchanged between people from collaborating companies. The implication is constrained capacity to communicate tacit knowledge.

As the following outlines, this study is also able to argue that cognitive convergence indirectly enables integration mechanisms' knowledge communication, through its influence on work integration and location structures.

8.2.3.1 The influence of cognitive convergence on work integration and location structures

In the following, the indirect influence of cognitive convergence on knowledge communication is discussed. The focus is on how cognitive convergence influences integration mechanisms' work integration and location structures.

One important effect of cognitive convergence is enhanced capacity to work together on joint problem-solving activities, when e.g. designing the product technology architecture. The reason is that, as cognitive convergence enhances mutual understanding, people more easily develop a common way of interacting with one another. It means e.g. that people from different companies become used to one another's approaches to specific problems. It can also mean that people e.g. develop a new common work process for reviewing blueprint. Hence, cognitive convergence influences not only how people perceive one another's activities and language, but also how they interact in integration mechanisms. Thereby, cognitive convergence indirectly enables knowledge communication by enhancing the capacity to collaborate on joint work-tasks. The implication is that cognitive convergence contributes to realising high work integration. This is similar to Orlikowski's (2002) view that one characteristic of effective global product development is common ways of thinking, because they provide a common ground for working together. Thus, this study specifically points at the role of enhanced understanding for the development of such collaborative capacity, and thereby for enabling knowledge communication.

It can also be argued that one potential effect of cognitive convergence is shared understanding, regarding how to use the integration mechanism's location structure for communication of knowledge. For instance, it can contribute to a shared practice regarding how to walk over to colleagues and interrupt their work with questions. Another example is development of common ways to perform dialogues between different hierarchic levels. This influences, for instance, the perceptions of whether and how managers should spend time in the office landscape talking with engineers about technology. One effect of cognitive convergence, mentioned by Dougherty et al. (2000), is increased common sense-making of roles and routines between people from collaborating companies. The discussion here is similar. However, it specifically argues that cognitive convergence contributes to development of common ways of communicating knowledge in shared office-spaces.

The previous discussions in this chapter on work integration and location structures focused on how these structures influence cognitive convergence. The discussion here suggests that the relationship is reciprocal. That is, through cognitive convergence people from different companies develop an increased capacity to use the other structures of integration mechanisms in order to enable knowledge communication.

8.3 The moderating role of strategic learning intention

Integration mechanisms influence knowledge communication partly because of the moderating effect of strategic learning intention. Two different types of strategic learning intention are discussed – co-learning and learning from a partner. The former type is a driver of continuous knowledge communication, while the latter type may have a temporary moderating effect.

This study shows that strategic learning intention moderates integration mechanisms' influence on knowledge communication. It functions as a driver of knowledge communication between companies. The following elaborates the model presented in Figure 21, regarding the moderating role of strategic learning intention.

Strategic learning intention is one important factor positively moderating knowledge communication between companies. The enhancing role of strategic learning intention finds support from e.g. Simonin (2004), who concluded that learning intention is a major driver of knowledge transfer between companies. This study identifies two different types of strategic learning intention that positively moderate knowledge communication: (1) co-learning and (2) learning from a partner's existing knowledge. March (1991) makes a similar distinction between learning as exploration and as exploitation. Exploration refers to learning by crossing existing frames of thinking and acting. Exploitation, on the other hand, refers to learning within the existing frames of the organisation. This study points at the difference between co-learning as the collaboration develops and learning from a partner's existing knowledge. The type of strategic learning intention has implications for the moderating effect on integration mechanisms knowledge communication.

Co-learning is a strategic learning intention related, not least, to how to work together through the accumulation of collaboration experience (Zollo and Winter, 2002) – that is, learning how to collaborate in order to accomplish the joint product development. Co-learning is particularly relevant in situations facing high product technology uncertainty. The reason is that it is important to learn how to work together in order to realise the advanced process of developing e.g. a new product architecture. It is also important to be frequently updated by the partner's progress and to be able to learn together in order to work on joint problem-solving. This high-level strategic learning intention is a driver of continuous knowledge communication during the development process – possibly more in the beginning.

Strategic learning intention to learn from a partner's existing knowledge is driven by a wish or need to access what the partner knows. For instance, Hamel (1991) discussed such learning intention as a way to build a new competitive position. It includes strategies to out-learn the partner and thereby reduce its competitive advantage. The present study does not indicate such learning intentions. Instead, learning existing knowledge from a partner is a way to access technology necessary in order to participate in the collaboration, by e.g. learning interface requirements. This creates at least a temporary incentive for knowledge communication in the collaboration.

As mentioned in the introduction of the synthesis model, the moderating effect of strategic learning intention is channelled by management commitment enhancing people's motivation to communicate knowledge. The reason is that, in order to take on the challenges associated with complex knowledge communication between companies, people need to feel emotionally and intellectually motivated. This includes being willing and confident in sharing proprietary knowledge. Managers who are committed to the accomplishment of knowledge communication, as a necessary means in the collaboration, can contribute to such motivation, because it helps people working in integration mechanisms to make sense of their personal efforts in order to realise knowledge communication (Inkpen, 1996).

This moderating effect, however, is constrained by the capacity of integration mechanisms to enable high richness and communication on tacit content. Hence, it takes integration mechanisms with high-degree work integration, co-location and high-degree cognitive convergence in order to realise the positive moderating effect.

The discussion here points at the important role of strategic learning intention as one moderating factor of integration mechanisms' influence on knowledge communication. It is also the last part of the discussion on the factors constituting the model (Figure 21) on integration mechanisms' enabling of knowledge communication. The next section will build on these discussions and generate major conclusions from this chapter.

8.4 Concluding discussion on enabling of knowledge communication

This chapter began with introducing a comprehensive model on how and why integration mechanisms enable knowledge communication between companies. The implication of the model is an integrated view of the factors which together enable knowledge communication between companies. Thereby, this study generates cohesive explanations regarding how and why integration mechanisms enable knowledge communication between companies.

The discussions in this chapter have argued that integration mechanisms enable knowledge communication, through the combination of the degree of work integration, the type of location structure and the degree of cognitive convergence. In addition, the single company's strategic learning intention is a factor that can positively moderate the knowledge communication capacity of integration mechanisms. These factors are organisational building blocks. To what extent the factors contribute to enabling of knowledge communication reflects managerial competence to use each of them and combine them so that they support each other.

This chapter argues that integration mechanisms enable knowledge communication largely through their dynamics. The dynamics realised is a consequence of the degree of work integration, the kind of location and the degree of cognitive convergence. A highly dynamic relationship is created through high-degree work integration, co-location and high-degree cognitive convergence. The effect is enhanced knowledge communication. In contrast, low-degree work integration, distributed location and low-degree cognitive convergence generate a fundamentally constrained dynamics. Thereby, such integration mechanisms enable low knowledge communication capacity.

Based on the discussions in this chapter it can be proposed that integration mechanisms generate patterns of activities, which may merge into a specific kind of inter-organisational knowledge communication capacity (Zollo et al., 2002; Winter, 2003). The knowledge communication capacity varies between different types of integration mechanisms, because of their different characteristics. In all types of integration mechanisms, however, the capacity is expressed in how people e.g. update blueprint, conduct meetings together and discuss interpretations of one another's knowledge – that is, how people from different companies interact with one another in integration mechanisms in order to communicate knowledge. Thus, the managerial skill to utilise structures of integration mechanisms for creating such patterns of activities enables the knowledge communication capacity. This capacity is one explanation for how companies achieve competitive product development in collaborations.

9 Contributions, limitations and managerial implications

First, this chapter presents the study's major contributions. Thereafter, it addresses limitations of the study. Third, it presents normative recommendations to managers. Finally, the chapter gives some proposals for future research.

The study has addressed an issue of strategic importance when companies engage in product development collaboration. The point of departure is the current phenomenon of organisationally and geographically dispersed product development operations. For many companies, this means daily efforts to communicate knowledge between different organisations around the world. The challenge addressed is how and why integration mechanisms, which function as organisational interfaces, enable knowledge communication between companies. This is an operational-level challenge with implications for the single company's strategic development.

This study has found explanations for how and why different types of integration mechanisms influence communication of knowledge between companies. The results imply that the single company's boundaries to other organisations, e.g. geographical separation, value and language differences, can be handled in order to enable knowledge communication. This provides a perspective on how knowledge embedded within the company can be communicated to other companies. In a wider sense, this study offers a way to understand how product development between companies is realised.

This chapter has the following outline. First, it presents the contributions from the study. Second, it discusses the limits of the present study. Third, managerial implications are outlined – i.e. issues that can be recommended to be considered when managing product development between companies. Finally, directions for future research are proposed.

9.1 Contributions

The present study generates insight into different types of integration mechanisms and their roles as tools for knowledge communication between companies. This insight contributes to the intersection of three lines of research. First, it adds to the research on formal integration mechanisms (e.g. Nadler and Tushman, 1987). Second, it complements research on distributed product development (e.g. Song et al. 2007); and third, it complements the research on knowledge transfer in collaborations between companies (e.g. Simonin, 2004). Based on the results of its analyses, the study yields numerous conclusions regarding the enabling of knowledge communication.

This chapter presents the major contributions in three sections:

1. Types of integration mechanisms that influence knowledge communication.
2. Integration mechanisms' influence on knowledge communication.
3. Moderation of integration mechanisms' knowledge communication.

9.1.1 Types of integration mechanisms that influence knowledge communication

➜ *Eleven different types of integration mechanisms are identified, which influence knowledge communication in product development collaborations between companies.*

This study identifies eleven different types of integration mechanism that influence knowledge communication in product development collaborations between companies (see the summary in section 5.5 for a complete list).

First, compared to existing literature (e.g. Nadler and Tushman, 1987) this study identifies different types of integration mechanisms influencing knowledge communication in product development collaborations between companies. Previous research that has generated broad categorisations of integration mechanisms has had an intra-organisational perspective (e.g. Nadler and Tushman, 1987; Griffin and Hauser, 1996).

Second, although there are many similarities between existing categorisations and those identified by this study, five of those identified here are distinctly different from those discussed in previous research on integration mechanisms (e.g. Galbraith, 1973; Nadler and Tushman, 1987; Griffin and Hauser, 1996). The types of integration mechanisms are: (1) the heavyweight project leader team; (2) the co-located integrator team; (3) the co-ordinator management team; (4) the virtual project leader team; and (5) the integrative manager.

Third, this study describes in detail the characteristics of the eleven different types of integration mechanism. It concerns several structural characteristics, e.g. the number of people working in integration mechanisms, decision-making authority, and the work integration and location structure used. Thereby, this study develops more detailed integration mechanism categories than those discussed by Galbraith (1973), Nadler and Tushman (1987) and Griffin and Hauser (1996). In previous research, integration mechanisms are categorised largely after their formal characteristics and functional roles. This study's perspective of integration mechanisms as a combination of different structures is more similar to the concept of space, as means for knowledge transfer (Nonaka et al., 2006). However, in comparison, the characteristics of the integration mechanisms identified here are more nuanced regarding their construction and function. Specifically the analysis in the present study focuses in detail upon the different structural characteristics of the eleven types of integration mechanisms.

The implication of having identified eleven types of integration mechanisms is a categorisation of a spectrum of managerial tools, with different knowledge communication capacity. Together, the different types of integration mechanisms constitute a managerial toolbox for enabling of knowledge communication.

9.1.2 The influence of integration mechanisms on knowledge communication

➜ *Integration mechanisms influence knowledge communication through the degree of work integration, type of location structure and degree of cognitive convergence.*

This study has addressed how and why integration mechanisms influence knowledge communication between companies. Through the analysis in Chapter 6, it was possible to identify three structural characteristics that can explain how and why integration mechanisms of different types influence knowledge communication: (1) degree of work integration, (2) type of location structure, and (3) degree of cognitive convergence. This result complements research concerned with integration mechanisms, distributed product development and knowledge transfer.

The integration mechanisms discussed in the literature largely have an information-processing perspective (e.g. Nadler and Tushman, 1987). In comparison, this study provides empirically grounded explanations for different types of integration mechanisms' influence on knowledge communication between companies. In particular, this study complements research on integration mechanisms by focusing also on communication of tacit knowledge between companies. .

A range of authors, such as De Meyer (1991) and Song et al. (2007), have recognised challenges that here are associated with knowledge communication in distributed product development. It is emphasised by these cited authors that geographical separation is a major hindering factor, which companies need to deal with by e.g. using boundary-spanners and co-locating people. Song et al. (2007) are able to show the communication capacity of different location structures and the complementary role of different structures, including IT systems, for what they call knowledge dissemination. In comparison, this study specifically focuses on location structures within integration mechanisms. Thereby, it is able to explain in greater detail the influence of different location structures for knowledge communication between companies. It also complements existing research with results regarding the role of other integration mechanism structures – work integration and cognitive structures – in combination with different location structures.

This study also differs from existing research addressing knowledge transfer and exchange (e.g. Simonin, 1999; 2004). To begin with, the study focuses on knowledge communication as a process enabling transfer and exchange. Research discusses a broad range of factors that can influence knowledge transfer in collaborations (e.g. Inkpen, 1996; Simonin, 1999; Inkpen and Tsang, 2005). Important factors discussed by these authors are e.g. knowledge ambiguity, tacitness and management commitment. However, there is a lack of explanations for how and why companies transfer and exchange knowledge. Inkpen and Dinur (1998) argued that interaction between people is important for transfer of explicit, and particularly for tacit, knowledge in collaborations. However, it is not explained how this effect was accomplished. Focusing on knowledge communication, this study generates new explanations for how companies realise knowledge transfer and exchange in product development collaborations. The publications identified as closest to this study regarding the view of knowledge communication as a means for knowledge transfer, are Bresman et al. (1999), and Murray and Peyrefitte (2007). These studies found that communication facilitates knowledge transfer. More broadly, e.g. Hedlund (1994) and Nonaka and Takeuchi discussed communication and the related term 'dialogue' as means for transfer. However, the authors mentioned here do not explain how knowledge communication is accomplished. This study is thus complementary because it is able to propose how and why, for instance, high work integration in integration mechanism enhances knowledge communication, through knowledge redundancy and reduced stickiness.

This study also shows how integration mechanisms can enable cognitive convergence between companies, and thereby enhance capacity to communicate tacit knowledge regarding both products and processes. It is related to Carlile's (2004) contribution regarding how domain-specific knowledge is shared between organisations through a transformation and iteration processes. In comparison, this study points at the role of different types of characteristics of integration mechanisms for realising communication of tacit knowledge. Boland and Tenkasi (1995) discussed e.g. the importance of perspective-taking in order to overcome differences in interpretation of e.g. technology. They argued that enhancing the understanding of one another's perspectives plays a central role for communication between organisations. This study reaches a similar conclusion. However, it specifically addresses how different degrees of cognitive convergence are realised in integration mechanisms, and how the degree realised influences knowledge communication. Generally, this result relates to Inkpen and Tsang (2005) who discussed how social capital enhances knowledge transfer in collaborations. However, this study is able to specifically point at the role of cognitive convergence for how and why integration mechanisms influence communication of tacit knowledge between companies.

The results in this study also add knowledge regarding the dynamics between the characteristics of integration mechanisms and knowledge communication. Surveys have addressed relationships between different factors that influence knowledge transfer between companies (e.g. Simonin, 1999). This study is able to propose how the relationships between different characteristics of integration mechanisms influence each other in the making of knowledge communication capacity. For instance, cognitive convergence is a result of the kind of interaction between people, generated by work integration and location structures. In turn, cognitive convergence has implications for the development of work integration, because it enhances the capacity to communicate tacit knowledge and thereby achieve e.g. integrated problem-solving. Hence, this study offers a dynamic view on how and why integration mechanisms influence knowledge communication between companies.

9.1.3 Moderation of integration mechanisms' knowledge communication

➜ *Integration mechanisms' influence on knowledge communication can be moderated positively by strategic learning intention.*

This study has found that strategic learning intention moderates integration mechanisms' influence on knowledge communication. The moderating effect of this factor for integration mechanisms' influence on knowledge communication has not been analysed in previous research.

This study finds that one major reason why strategic learning intention has a positive moderating effect is that it enhances the motivation for knowledge communication. This positive effect is constrained by the capacity of integration mechanisms to influence knowledge communication richness and tacit content. It takes integration mechanisms with high degree of work integration, co-location and cognitive convergence in order to realise the positive moderating effect.

Research on knowledge transfer has recognised the importance of learning intention in collaborations between companies (e.g. Hamel, 1991; Simonin, 2004; Pérez-Nordtvedt et al., 2008). They showed that intentions to learn in collaborations enhance knowledge transfer. However, they do not explain the moderating role of strategic learning intention for integration mechanisms' influence on knowledge communication. Hence, this study adds complementary knowledge concerning the moderating effect of strategic learning intention on knowledge communication in product development collaborations between companies.

9.2 Limitations of the study

There are, of course, aspects that are outside the scope of this study, which may have important implications for the functioning of integration mechanisms as tools for knowledge communication. This section will discuss some limitations of the present study.

One limitation is that this study focuses on collaborations between manufacturing companies of similar size and related industrial backgrounds. Companies of different size may have different bargaining power, which possibly can influence their attitudes toward one another. The small company may wish to learn from the larger one, while the larger may wish to exploit the small one's knowledge. Clearly, such differences in attitude can be expected to influence knowledge communication. It is also possible that knowledge communication in integration mechanisms between companies of rather different industrial backgrounds – e.g. the service sector and manufacturing – is more difficult to accomplish. The understanding of e.g. technology and views on customers may be rather different and function as a barrier to knowledge communication. The present study is limited concerning the functioning of integration mechanisms for knowledge communication in such cross-industry collaborations.

The results of this study are generated through case studies of collaborations between large companies, with focus on the end-products or major subsystems. It is possible that more different value chain positions could influence the functioning of integration mechanisms. It can be imagined that difference in perspectives on what is the end-product influences knowledge communication. This study has not addressed such relationships – e.g. component technology perspectives vs. functional level perspectives. It is possible that such differences existing in supply chain collaborations lead to different use of integration mechanisms and knowledge communication.

Another aspect that potentially is important for the functioning of integration mechanisms is the members' different national backgrounds. This study has not addressed whether experiences of cognitive differences as well as cognitive convergence can be explained by national cultural origin of the integration mechanism members. It is possible, for instance, that cognitive convergence in integration mechanisms is easier or more difficult to accomplish depending on the difference between national cultures. Hence, it is not clear whether certain differences in national culture have implications for integration mechanisms' influence on knowledge communication.

Concerning the people working in integration mechanisms, this study is limited as regards how influence is exerted e.g. by previous experiences from working in integration mechanisms, by recruitment criteria and by personal incentives. For example, it is possible that whether people working in one integration mechanism have experience from other collaborations influences the knowledge communication. The profile of people recruited to integration mechanisms may be one important factor for the integration mechanism's capacity to handle e.g. cognitive differences. It can be assumed that open-minded people interested in e.g. foreign cultures are more likely to handle differences. However, this is outside the scope of the present study. Personal incentives in the form of e.g. career opportunities or financial rewards may also influence the behaviour of people in integration mechanisms. If, for instance, working in integration mechanisms is associated with status in the home company, that may positively influence the motivation to overcome knowledge communication barriers. This aspect is, however, not addressed by this study. It is also possible that the combination of people with different hierarchic positions and competence seniority in integration mechanisms influence interaction patterns and hence knowledge communication between companies. This aspect is not included in the present study.

Another limitation concerns the role of different types of leadership. It is possible that the type of leadership used influences the functioning of integration mechanisms. Is it possible to identify different leader types as more or less suitable for different integration mechanisms? For instance, it is reasonable to ask whether more administrative leadership is useful in virtual integration mechanisms while more competence-based leadership is useful for integrated teams. Project time is also a factor that possibly can influence integration mechanisms' knowledge communication. For instance, it takes time to develop personal relationships and reduce cognitive differences. This study does not address e.g. whether the notion of a long-term collaboration enhances efforts to develop personal relationships and cognitive convergence.

9.3 Managerial implications

The scope of the present study is the challenge of communicating knowledge with partner companies during the development of complex products. This is a challenge because important knowledge applied in product development is largely local and embedded in the single company's R&D department. This study has explored and explained how companies can handle these challenges in order to enable knowledge communication in product development collaborations. The following will elaborate the managerial implications of these results.

The background to this study is that today few companies can afford to develop internally all new technology and products that are necessary to remain competitive. Competitive forces drive this change – for example, shorter technology cycle times, increasing product variation, growing costs and more sophisticated customer demand. Consequently, many companies face the challenge to reduce development costs and simultaneously enhance innovativeness. In order to manage these two different challenges, product development collaborations increasingly play a central role in companies' strategy to create competitive advantage.

Essentially, product development collaborations are attractive because they enable companies to share costs and to combine specialised knowledge into new products. For example, in order to meet the increasing demand for "green" technology, companies in different industries face the combined challenge and opportunity to use collaborations in development of new products. To many companies this means that they will combine their existing technology with other companies' specialised technology.

The combinative potential may be great. However, in order to realise innovations it is necessary to build efficient organisational interfaces, here called integration mechanisms, with other companies. One of the key characteristics of an efficient product development organisation is the capability to manage knowledge communication. It is this author's belief that the results from this study can contribute to collaboration, both within and between companies.

Based on the results from this study, the following highlights key issues that managers are advised to consider. It will focus on how managers can think about integration mechanisms in order to enable knowledge communication. First, it addresses aspects of importance when designing integration mechanisms. Thereafter, the discussion elaborates four different knowledge communication strategies. Third, the chapter presents a checklist with a broad set of issues of importance for enabling knowledge communication. The final section summarises the managerial implications.

9.3.1 Designing organisational integration mechanisms enabling knowledge communication

This section will propose issues for design of effective integration mechanisms, which function as interfaces between companies. It will focus on the characteristics identified in this study as major explanations for enabling of knowledge communication.

When designing integration mechanisms, it is important to have the perspective that product development collaboration is a commitment for perhaps several years. This means that much will happen over time as the collaboration encounters new challenges and enters new development phases. The organisation established to initiate the collaboration may eventually have to change in order to adapt to new circumstances. The integration mechanisms designed when the collaboration begins may thus not be suitable during the whole development process.

Nevertheless, it is important to create the right mix of integration mechanisms that matches the knowledge communication requirements at the start. Otherwise, the collaboration is likely to experience major difficulties in co-ordinating activities, solving problems together and learning from one another.

This study has identified three characteristics of integration mechanisms, which explains their knowledge communication capacity: (1) degree of work integration, (2) type of location, and (3) degree of cognitive convergence (reduction of difference between the companies' thought-worlds or mind-sets). The following discusses implications for managers. The three major points of advice are:

- ➜ To use work integration as an engine for knowledge communication.
- ➜ To select location for sufficient knowledge communication.
- ➜ To manage differences between companies for efficient knowledge communication.

In order to make integration mechanisms enable the required knowledge communication, managers need to work with each of these three factors. The following discusses how managers can develop integration mechanisms enabling knowledge communication in product development collaborations.

9.3.1.1 Using work integration as an engine for knowledge communication

Work integration in integration mechanisms, e.g. design teams or virtual teams, has direct effects on the level of knowledge communication enabled between companies. The reason is that work integration influences to what extent people from collaborating companies are working together on shared tasks. It defines the scope of knowledge that people need to communicate in integration mechanisms. Thereby, it enhances the drive to realise knowledge communication. It enables knowledge communication through e.g. interaction patterns between people, the level of overlapping access to knowledge such as blueprint, and the capacity to access sources of knowledge within each other's organisations. The principle is that, the higher the level of work integration, the more knowledge communication capacity is enabled.

One factor determining the suitable level of work integration is product technology uncertainty in the collaboration. In collaborations where the companies need to handle a high product technology uncertainty, it is central to work together. One major reason is that it requires continuous high-level knowledge communication in order to deal with the complex problem-solving. Over time, as people working in collaboration learn more about the product architecture or face unexpected challenges, the required knowledge communication changes. Therefore, it is important being able to adapt work integration as the collaboration enters phases and faces new situations.

The implications for managers are:

- ➜ Manage work integration as an engine for knowledge communication. It defines the scope of knowledge communication and creates interaction patterns enabling communication capacity.
- ➜ The principles are:
  - A high degree of work integration is necessary in order to enable high-level knowledge communication capacity, e.g. when dealing with high product technology uncertainty.
  - A low degree of work integration is sufficient when low-level knowledge communication capacity is required, e.g. when dealing with low product technology uncertainty.
- ➜ Make work integration a permanent issue on the project management agenda in order to avoid an unexpected increase of knowledge communication inefficiency.

9.3.1.2 Selecting location for sufficient knowledge communication

Location is a powerful managerial means of creating opportunities for meetings between people, and thereby capacity to enable required knowledge communication between companies. It directly influences intensity, richness and content of knowledge communication – i.e. the effect variables addressed by this study. The polar types of the location spectrum are co-location and distributed location. Between these two types there are several kinds of temporary location alternatives – e.g. working for short periods on each of the collaborating companies' sites.

Co-location is necessary in order to enable communication of knowledge that is tacit. The reason is that communication of tacit knowledge requires that people meet in face-to-face dialogues. On the other hand, when knowledge is possible to articulate, it is easy to communicate through e.g. e-mail. In situations like this, distributed location is sufficient for enabling required knowledge communication. It could be worth mentioning that efficient means of communication of e.g. blueprints may cause managers to underestimate the level of tacit knowledge necessary to communicate in order to make sense of the blueprints. Therefore, an integration mechanism with distributed location structure may need complements such as boundary-spanners between the companies.

Consequently, companies should reconsider the original location design as the collaboration develops. It may for instance be necessary to add complementary integration mechanisms containing more co-location. One example of such a situation is when the companies realise they need to develop more common knowledge in order to be able to integrate results from their different work packages.

The implications for managers are:

➜ Design location structures in order to create conditions for the kind of interactions between people that are necessary in order to enable the required knowledge communication – for instance, in order to handle the collaboration's product technology uncertainty.

➜ The principles are:
- Co-location should be used in order to achieve high-level knowledge communication capacity, in particular conditions for communication of tacit knowledge.
- Distributed location is useful when low-level knowledge communication is sufficient.

➜ Consider that co-location alternatives may take time to establish since they often mean that people need to move – therefore start planning for different location alternatives early during discussions on starting up product development collaboration.

➜ Make realistic cost analyses of different location alternatives. Include e.g. costs of moving and co-locating people in the project's budget.

9.3.1.3 Managing differences between companies for efficient knowledge communication

Differences in companies' routines, language and product technology are major factors hindering efficient knowledge communication. These differences create boundaries between companies that are necessary to reduce in order to develop advanced new products together. Therefore, managing differences between companies is a critical tool for enhancing knowledge communication. The process for managing such differences is called cognitive convergence in this study.

In order to start managing cognitive differences, companies need to begin working together. Consequently, the level of work integration and the kind of location directly influence to what extent cognitive convergence takes place. Generally, working together on the same work-tasks and being co-located creates the conditions with best chances of starting a process of reducing cognitive differences between companies. For instance, being able to define different technical terms and to understand product and process philosophies does not come without determined efforts and interaction – largely face-to-face.

To managers, cognitive convergence is a twofold challenge. Early in the collaboration, it is difficult to know the extent of cognitive differences. Since cognitive difference, compared to geographical separation, is difficult to define, it is also easy to ignore. Second, even though cognitive differences are recognised it takes time and effort to manage them in order to enable efficient knowledge communication.

It is therefore important that the company have the management commitment necessary. Managers must be prepared to explain the reasons for engaging in the collaboration, in order to motivate people to make the necessary efforts for taking on the challenges of knowledge communication. It is also important to be prepared to actively support work in integration mechanisms, e.g. creating a process for development of common terminology, handling conflicts, and providing enough resources for travelling.

The implications for managers are:

- ➜ Try to identify and tackle cognitive differences early in the collaboration. Assume early in the collaboration that there are greater differences between the companies than first observable – in order to avoid negative surprises that may cause frustration and unnecessary conflicts.
- ➜ Prepare the organisation for the fact that managing differences between the companies may become the greatest challenges to the collaboration. In order to handle consequences of differences in constructive ways, employees need to be emotionally, intellectually and strategically committed. Therefore, in order to support this it is important that managers continuously motivate employees to tackle the challenges.

- ➜ Expect extra and yet unavoidable costs – e.g. due to higher work integration, more travelling to meetings, and extra time in order to handle misunderstandings and conflicts. Expecting extra costs may help to avoid some of the frustration that otherwise is likely to emerge.
- ➜ Actively use work integration and location as means for cognitive convergence.
- ➜ The principles are:
  - A high degree of work integration and co-location enables high-degree cognitive convergence. Thereby, the capacity is enhanced for high-level knowledge communication capacity.
  - A low degree of work integration and distributed location is sufficient when cognitive convergence is of little importance in order to achieve the required knowledge communication.

In brief, in order to manage knowledge communication in changing product development collaborations, managers need to focus on continuously redesigning integration mechanisms. This section has suggested a toolbox that managers can use in order to enhance the capacity to realise product development collaborations. The following elaborates on different situations where this toolbox is useful in order to realise sufficient knowledge communication.

9.3.2 Strategies for enabling knowledge communication

The previous section discussed principal aspects of designing integration mechanisms for enabling of knowledge communication. The aim here is to take the discussion a step further and propose strategies for enabling knowledge communication. Therefore, this section builds on the results generated by the present study, in particular Chapter 8, and discusses how managers in different situations can think in order to develop integration mechanisms with sufficient knowledge communication capacity.

To begin with, it is necessary to understand the dimensions shaping the requirements of knowledge communication in product development collaboration. Based on the present study it is possible to argue that two major dimensions shape the requirements of knowledge communication: (1) organisational gap and (2) interdependence.

First, organisational gap refers to differences between companies that constrain their knowledge communication. This study has come across several such factors, e.g. the companies' values, language, and knowledge level. The combination of these factors creates an organisational gap between collaborating companies. It means that they have different perspectives on e.g. product technology. The magnitude of the organisational gap reflects the diversity of the companies' backgrounds, their experience of collaborating and the difference in their competences. In order to handle the organisational gap, collaborating companies need to integrate their perspectives.

This means that they develop shared views on e.g. product technology or enhanced understanding of each other's points of view. The term 'perspective integration' is here seen as a broader term than cognitive convergence. The reason is that it includes not only reduction of cognitive differences, but also the overcoming of knowledge asymmetries. The reason for using this broader term here is that the organisational gap facing companies is often constituted by both cognitive and knowledge differences.

Second, interdependence concerns the level of mutual need of input between collaborating companies. Here a high-level interdependence means that the companies share work-tasks and thereby frequently need to share e.g. technology. One example is companies collaborating on development of new product architecture – i.e. a situation facing high uncertainty. In contrast, here a low-level interdependence means that the companies share few work-tasks, and hence require little input from one another. One example is a supply chain relationship where the supplier produces on the basis of blueprints and clear specifications.

The level of knowledge communication needed largely reflects the degree of organisational gap and interdependence between collaborating companies. In principle, the greater the organisational gap, and the higher the interdependence, the more knowledge communication capacity is required. The problem for managers is to match the need of knowledge communication with adequate integration mechanisms.

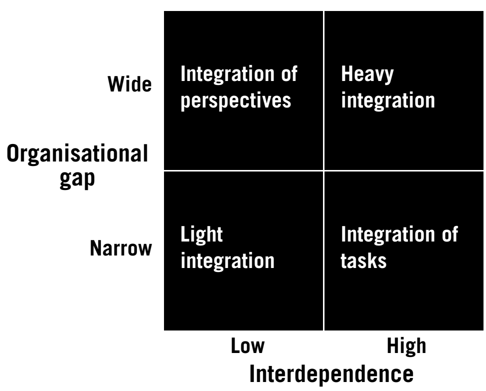

Figure 22: Strategies for enabling knowledge communication

This matrix outlines four different approaches in order to enable sufficient knowledge communication capacity, given different combinations of organisational gap and interdependence. A wide gap means major differences between the companies, e.g. values and langugages. A narrow gap refers to rather limited differences. High interdependence means more or less daily and mutual needs of input. Low interdependence refers to situations charaterised by little joint work.

Heavy integration is a response to a very complex situation. The organisation gap is wide because companies are different in terms of e.g. competence, and typically have little experience of collaborating with one another. At the same time, they are interdependent for the realisation of the collaboration's task. Therefore, they need to be able to communicate knowledge regarding not only the product and the development process, but also their different principles for e.g. the technology design. This means it is necessary to create a joint and permanent organisation, until the project is finalised. It should be characterised by e.g. close collaboration on a day-to-day basis.

Integration of perspectives is a way to handle collaboration between companies which are rather different, e.g. with backgrounds in different industries, but which have limited work-task interdependence. This means that each company focuses on its tasks without much interaction with the partner's work. Hence, the companies' need to communicate knowledge is limited concerning e.g. problem-solving. At the same time, since the companies set out to accomplish development of a new product together, they need to understand one another. This means they need to have a common view on e.g. what they should accomplish, what will characterise the product, and its value for customers. Otherwise, their knowledge communication will struggle with misinterpretations. They also need to understand each other's different management and communication styles in order to avoid unnecessary conflicts. Failing to handle the organisational gap is likely to generate difficulties in realising the product development. Therefore, the companies need to integrate their perspectives. One solution is e.g. to exchange managers between the companies. Exchanged managers become ambassadors in the partner organisation and they develop understanding of the partner's perspectives in their own company. They can facilitate much of the knowledge communication necessary, by personally integrating the companies' different perspectives.

Light integration is applicable in a collaboration characterised by narrow organisational gap between the companies and low interdependence. This means that the companies have much knowledge in common, understand each other's organisations and know how to collaborate. The companies have differentiated work-tasks, and accomplishing the product development requires little knowledge communication. This may be the case in e.g. a supply chain relationship during the modification of an existing product. This means that the interfaces and the requirements of the technology development are well known. Therefore, managers can handle much of the knowledge communication between the companies, e.g. through telephone talks and occasional meetings. On operational levels, virtual teams or networks can enable the knowledge communication.

Integration of tasks is a response to a situation where companies that are experienced at collaborating together join forces in a new complex product development endeavour. The product technology uncertainty is high and it is not possible to make a clear-cut division of work. Instead, the companies are highly engaged in one another's development work. Hence, the knowledge communication requirements are high. However, there is little need to be able to discuss different perspectives on technology or to enhance the partner's competence level. The reason is the low degree of organisational gap between the companies. Therefore, knowledge communication can focus on handling product-related tasks, which obviously change over time. This means that as the joint development tasks change, the integration mechanism used can also change in order to match the new knowledge communication requirements. Situations requiring integration of tasks can use e.g. co-located teams in order to solve complex problems together during a shorter period. Another example of integration of tasks is boundary-spanners who frequently visit the partner organisation in order to co-ordinate the development work. Thereby, they can focus knowledge communication between companies on specific tasks.

To summarise, the degree of organisational gap and interdependence between companies shapes the requirements of knowledge communication. Companies can use different knowledge communication strategies in order to create integration mechanisms with capacities sufficient for the requirements of the collaboration.

- ➜ Heavy integration is a strategy for collaborations requiring capacity to communicate complex knowledge regarding the product and the development process.
- ➜ Integration of perspectives is a strategy suitable for collaborations with little shared work, but a need to be able to communicate knowledge regarding e.g. product performance principles.
- ➜ Light integration is a strategy for collaborations between companies that understand one another and share few or no work packages, and thereby require limited knowledge communication capacity.
- ➜ Integration of tasks is viable for collaborations between long-term partners, who need to be able to communicate complex product knowledge.

9.3.3 Checklist for management of knowledge communication

In the following, a checklist is presented with issues that managers are advised to consider in order to achieve the knowledge communication necessary in product development collaboration. The recommendations presented complement the previous discussions on managerial implications. Hence, the checklist concerns additional managerial issues that have implications for the capacity to communicate knowledge in collaborations. The checklist builds on observations made during this study, although not all refer to results presented.

Strategic motives for collaborating
- Make your company's strategic motives explicit and share them within your partner company
- Identify the partner company's strategies – including what they expect from your company
- Make sure the companies in the collaboration understand one another's strategic motives
- Give special attention to differences in the companies' strategic learning intentions – because these directly influence knowledge communication
- Try to define common strategic aims with the collaboration

Management commitment
- Investigate managers' attitude toward the collaboration
- Focus on creating enough commitment in order to tackle knowledge communication requirements (and collaboration challenges at large)

Product characteristics
- Begin with creating a shared product vision
- Make up-front investments on defining product functions

Product technology uncertainty
- Analyse to what extent the new product architecture is different from the existing
- Map known component relationships and interfaces

Organisational differences
- Focus early in the collaboration (or before getting started) on major differences in the companies' terminology, product quality and cost philosophies
- Expect differences to be greater and more important than first appreciated

Knowledge asymmetries
- Appreciate major differences between your company's product knowledge and the partner company's knowledge, which largely is tacitly embedded in each company's organisation
- Analyse how the differences in product and process knowledge can influence the division of work and the potential of working together

Geographical separation
- Estimate implications of travelling hours and costs – have implications for use of boundary-spanners
- Analyse how different time zones (if any) can influence communication

Intellectual property
- Analyse what knowledge can be shared between your companies
- Estimate the strategic and economic value of protecting certain knowledge
- Consider the risk of, and implications of, opportunistic exploitation of your intellectual property
- Expect intellectual property to be a challenging issue, but necessary to handle

Knowledge to be shared
- Estimate the type of knowledge that needs to be shared between your companies
- Analyse the level of interdependence between knowledge developed in the different companies

Table 41: Checklist for managers

9.3.4 Final comments on managerial implications

The managerial implications presented here emphasise that one critical task for managers responsible for integration mechanisms is to create positive circles of knowledge communication between the collaborating companies. Failing to do that enhances risks of e.g. misunderstandings, distrust and fear of opportunistic exploitation of intellectual assets.

Developing and using appropriate integration mechanisms may not be easy, but it is possible. Managers should make careful analyses of knowledge communication requirements. Investing up front in integration mechanisms' knowledge communication capacity is important in order to hedge for unexpected difficulties – there are likely to be plenty in any normal product development collaboration. Finally, experience is a critical factor. Managers that become skilled using integration mechanisms for knowledge communication have a potential to enhance their company's competitive product development.

Managing knowledge communication is a way to harness the company's product development capability. The reason is that it increases the potential for meeting performance criteria such as time to market, cost efficiency and product quality. This makes managing knowledge communication a strategic issue, because product development capability is a key factor behind the company's profitability and growth.

9.4 Proposals for future research

As the discussion of this study's limitations showed, several additional issues are important to address in order to extend our knowledge about the relationship between integration mechanisms and knowledge communication. Therefore, this section presents a few possible directions for future research.

One interesting approach would be to conduct clinical research on the management of integration mechanisms used for knowledge communication over time. Such an approach could enhance knowledge on the dynamics within and between different integration mechanisms. It could for example provide valuable insights concerning challenges of adapting integration mechanisms to changing knowledge communication requirements and obstacles. One critical issue interesting to address with such an approach is how knowledge communication is influenced when companies change integration mechanism from co-located to distributed location.

A second approach would be to replicate this study in cross-industry collaborations, e.g. between OEM and service company. A similar kind of replication would be to address collaborations between product development organisation and manufacturing across company boundaries. Replications like these would possibly identify other types of integration mechanisms and explanations for how knowledge communication is realised.

A third direction would be to extend this study's results concerning integration mechanisms as means for creating common knowledge between companies. This could provide valuable insights concerning how it is possible to realise product development in industrial networks. Furthermore, this approach is interesting because it ultimately has implications concerning to what extent the company can utilise external knowledge. Several case studies could be a useful method in order to uncover patterns of how companies create common knowledge.

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List of illustrations

List of tables

Appendix 1.
Case study protocol

The aim with the case studies was to collect data about them in order to accomplish the purpose of this study. This appendix presents the case study protocol that was used in order to support the collection of empirical data during the case studies.

In order to accomplish the purpose, the case studies addressed the following major theoretical investigation dimensions:

➜ Motives for collaboration
➜ Form of collaboration
➜ Kind of product technology
➜ Role of management in collaboration
➜ Organisational structure
➜ Integration mechanisms
➜ Communication

Investigation dimension: Motives for collaboration	**Unit of study**	**Major questions**	**Data gathering procedures**
Background to collaboration	Collaboration project	What is the companies' main business? Which are previous experiences of product development collaboration? Is there any previous relationship to the collaboration partner? What constitutes the strategic background to the current product development collaboration?	Interviews Documents (Contracts) Data feedback workshops
Strategic aims	Collaboration project	What does the company aim to achieve with the current product development collaboration? What does the company perceive to be the partner's strategic aims with the collaboration?	Interviews Documents (contracts) Data feedback workshops

Investigation dimension: Form of collaboration	Unit of study	Major questions	Data gathering procedures
Legal form	Collaboration project	Which is the collaboration's legal form? • Joint venture (equity or non-equity) • Contractual agreement (lateral) • Contractual agreement (vertical) • Informal agreement	Interviews Documents (Contracts) Data feedback workshops
Central contracts	Collaboration project	Which are the central contractual agreements regulating the collaboration? • Intellectual property rights agreements • Technology transfer agreements • Sharing of rents/costs • Resource contribution to the collaboration	Interviews Documents (contracts) Data feedback workshops
Time frame	Collaboration project	Which is the time horizon for the collaboration? • Limited to current collaboration • Long-term (future collaborative projects yet unknown)	Interviews Documents (contracts, plans) Data feedback workshops

Investigation dimension: Kind of product technology	Unit of study	Major questions	Data gathering procedures
Major characteristics	Collaboration project	What is the intended function of the product technology? What is the perceived product technology complexity? How does the product technology relate to the companies' existing experience and technology?	Interviews Data feedback workshops

Investigation dimension: Role of management	Unit of study	Major questions	Data gathering procedures
Management levels	Collaboration project	Which management levels are involved in the collaboration? How are they involved?	Interviews Documents (e.g. management plan) Data feedback workshops
Management commitment	Collaboration project	How can the management commitment to the collaboration be described?	Interviews Written reflections (Green Systems) Data feedback workshops

Investigation dimension: Organisational structure	**Unit of study**	**Major questions**	**Data gathering procedures**
Division of labour/work	Collaboration project	How is the work divided between the companies in the collaboration? • Within work packages • Between work packages • *Ad hoc*	Interviews Documents Data feedback workshops
Distribution of decision-making authority	Collaboration project	How is decision-making authority distributed? • Centralised • Decentralised	Interviews Respondents personal illustrations Documents Data feedback workshops
Distribution of responsibility	Collaboration project	How is responsibility being distributed between the companies in the collaboration? • After division of work • Across division of work • Unclear/vague	Interviews Documents Data feedback workshops
Departmental-isation	Collaboration project	Which are the central organisational units in the collaboration? What is their role for the collaboration? How are the organisational units being geographically distributed?	Interviews Data feedback workshops

Investigation dimension: Integration mechanisms	Unit of study	Major questions	Data gathering procedures
Work interdependence	Collaboration project	What characterises the interdependence between work-tasks in the collaboration? • Pooled interdependence • Sequential interdependence • Reciprocal interdependence	Interviews Data feedback workshops
Hierarchy	Collaboration project	What is the role of hierarchy in co-ordination of work in the collaboration?	Interviews Data feedback workshops
Lateral roles	Collaboration project	Which lateral roles are used for co-ordination? • Liaison roles • Direct contact • Integrated teams • Integrating role • Linking managerial role • Matrix structure How are different lateral roles being used?	Interviews Data feedback workshops
Management means	Collaboration project	What management means for co-ordination is used in the collaboration? • Rewards • Routines • Rules • Strategy	Interviews Data feedback workshops

Investigation dimension: Communication	**Unit of study**	**Major questions**	**Data gathering procedures**
Forms	Collaboration project	Who communicates with whom in the collaboration? • Between peers on equal hierarchic level • Across hierarchic level Which are organisational structures for communication? • Within formal structures • Within interpersonal (informal) networks	Interviews Data feedback workshops
Means of communication	Collaboration project	Which are the means of communication? • Transport (e.g. artefacts) • CAD/CAM • E-mail • Telephone • Face-to-face communication	Interviews Data feedback workshops
Content in communication	Collaboration project	What kind technology is communicated/ transferred? • High (complex) • Low (low complexity) What other issues are being communicated? • Administrative – e.g. plans, schedules • Organisational – structure, processes, sources What is the complexity level of the technology being communicated/transferred? • Scale 1–5 (low to high)	Interviews Data feedback workshops Questionnaire (Blue Systems)
Time/frequency of communication	Collaboration project	What is the frequency in communication/ transfer? • Daily • Few times a week • Weekly • Other	Interviews Questionnaire (Blue Systems) Data feedback workshops
Volume communicated	Collaboration project	What volumes of technology are communicated? • Scale 1–5 (low to high)	Interviews Questionnaire (Blue Systems) Data feedback workshops
Language commonality	Collaboration project	What is the language used in the collaboration? What is the level of language commonality between the focal company and its partner?	Interviews Data feedback workshops
Openness in communication	Collaboration project	How does the company perceive the partner's openness to share its knowledge on technology and processes? • Open – experience access • Restricted openness – limited access • Closed – no access How does the company perceive the own company's openness in relation to partner(s)?	Interviews Data feedback workshops
Perceived effect	Collaboration project	How does the company perceive the value of knowledge communication?	Interviews Data feedback workshops

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