Product-Service Transformation in Product-Centric Firms

By

Benjamin Levitt

B.S. Industrial Engineering
Lehigh University, 2001

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Signature of Author: ____

Benjamin Levitt
System Design and Management Program

Certified by: ____

Eric Rebentisch
Thesis Advisor
Research Associate, Center for Sociotechnical Systems Research, MIT

Accepted by: ____

Patrick Hale
Senior Lecturer, Engineering Systems Division
Director, System Design and Management Program

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Abstract

In slow or no-growth economies, firms cannot rely solely on recurring business from large, core customers who often delay or cancel capital investments in belt-tightening times. To achieve growth, firms must lever domain knowledge to expand business markets to find new customers. A core method to accomplish this expansion is through service models that can provide recurring revenues without as much up-front investment for customers. However, in a product-centric firm, the process of transforming a product into a service can be complex, and is the motivation for this research. No other complete explanation of this process has been published to date. The goal of researching this process is to give direction to managers who are considering transforming a product into service. The research led to building a service model using the Collaborative Adaptive Sensing of the Atmosphere (CASA) Radar System as its subject. The CASA Radar System is an X-Band Phased-Array Radar used for weather forecasting and environmental warning, led by University of Massachusetts with the assistance from several universities and industry partners. The radar system provides capabilities that did not exist previously in larger and less price effective systems, but was only available to be acquired directly, for upwards of $600 million. The CASA model sought to show how transforming the radar system from a product to a service could create value for the UMASS led team by selling more systems in a new service model to new customers, including weather-sensing firms and non-profits that want access to the CASA Radar System and would even pay for it, but were unable to support its standard capital costs.

Thesis Supervisor: Eric Rebentisch
Research Associate, Center for Sociotechnical Systems Research, MIT

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Chapter 1: Introduction

1.1 Motivation

In slow or no-growth economies, firms cannot rely solely on recurring business from large, core customers who can delay or cancel capital investments in belt-tightening times. To achieve growth, firms must leverage domain knowledge to expand business markets to win more customers. One method to accomplish this expansion is by creating new business models for existing products to provide recurring revenues from different market segments. The service approach can be a mechanism to increase the life of products by reaching a second tier of customers who could not afford the initial capital costs of the product, but could be interested in paying for a service to meet the same needs. For expensive defense technologies, repurposing products that are no longer for military use to meet civilian needs can be a vehicle for growth.

1.2 Thesis Scope

The thesis presented in this research aims to understand if by transforming a radar system from a product to a service, the UMASS-led team could add value by meeting a greater number of customer's unmet needs, such as weather-sensing firms and non-profits that want access to the CASA Radar System but are unable to support its capital costs. The scope of this research is to understand that Product to Service Transformation for established products. The research outlines several examples, including an in-depth analysis of the CASA Radar System from a product to service perspective. The deliverable of this research is the Product-Service Transformation Process. The process guides a firm in transforming an established product into a service. This research describes the nuances involved when exercising this process on the CASA Radar System and details the resulting business case.

1.3 Thesis Structure

The thesis is structured to first discuss the motivation and reasoning for the research. Next, published literature on the subject is described. This is followed by a case study to verify the process. The thesis closes with recommendations and conclusions.

Chapter 2: Literature Review

This literature review examines previous research in the area of product to service innovation to build a framework for a product to service transformation. This section begins with an analysis of the definition of a service and how the product-service transformation relates to its key features: whole life cost analysis and the service development process. The review continues with an examination of Systems Architecture, a methodology to understand the structure and approach to accomplish the transformation. The literature review concludes with a summary of the main conclusions of existing research and the background for the creation of a new hypothesis.

This discussion presents a deductive method of understanding the process to transform a product into a service. This transformation is termed a Product-Service System. Since the product-service innovation process has yet to be well defined in existing literature, there is a need to map out that literature that partially informs the process.

2.1 Introduction to Services

Over 70% of the gross national product (GNP) for industrialized nations is earned through services [1]. The sale of services is a key strategy to maintain and grow a business. Cusumano argues that managers in the past often viewed services as a necessary evil to sell or support their product-driven approach. Cusumano explains that firms should focus on creating additional value from products through services in what Cusumano terms 'servitizing'-- servitizing products can create new-value opportunities and pricing models for a firm [1]. Examples of this practice include ongoing maintenance and subscription streams.

The definition of a service is an intangible value provided by a firm to a customer that does not result in ownership [2]. The value of a service is often difficult to store. This contrasts from the definition of a product. A product is an entity that is possessed by the consumer as an asset. Since a service is not stored, the value often needs to be consumed at the same time and location of the purchase. Products are storable and often produced in a standardized way with limited interference from the customer. Even though customization of products is becoming more popular, customers can typically choose from a defined set of options [2]. Firms should strive toward standardization of services to lower the amount of risk in terms of quality to a company [3].

In recent years, technology advances in information technology have expanded the role of services in many sectors of industry [2]. In the past, the value from services often needed to be produced and consumed at the same locations [2]. Improvements in information technology systems have changed this traditional picture. Companies such as Amazon and Google profit from their abilities to transfer services throughout the global market. The concept of software as a service (SaaS) has grown exponentially from this technology.

Another view is that of Ettlie and Rosenthal. Their research argues that it is difficult to capture value from service innovation because services are easy to imitate by competitors [4]. This view contends that the value passed to the customer can be easier understood and then duplicated with other technologies or base products.

The lack of consensus in this topic is due to the complexity and variation in the services industry, as well as the overall lack of publications in the area.

2.2 Service Models

The Product-Service System (PSS) is a service model built off of a product. Arnold Tukker, of TNO Institute of Strategy, Technology and Policy, points to three main models for product-service systems [5]. Tukker unpacks the three models into five subsequent models. This is illustrated in Figure 1 [5] and three main models are discussed below.

The first model is the Product Oriented PSS. This model describes a firm that transfers a product while supplying the customer continuing services, such as maintenance [5]. An example of this would be a defense company selling a complex radar system while also offering contracts to maintain and update the system.

Another product-service system is the Use Oriented PSS. This model describes a strategy where the firm retains the ownership of the product and offers only the services of their product [5]. An example of this model is the satellite service start-up company Skybox. Skybox offers high-resolution visualization images from their satellites to customers. Customers could use these images for numerous applications including determining the number of cars in a certain parking lot, the number of fuel tankers on particular roads in China, or the size of slag heaps outside gold mines in southern Africa [6].

The last model is the Result Oriented PSS. The Result Oriented PSS illustrates a strategy when a firm uses a service to replace a product [5]. An example of this model is service of voicemail replacing the answering machine [5].

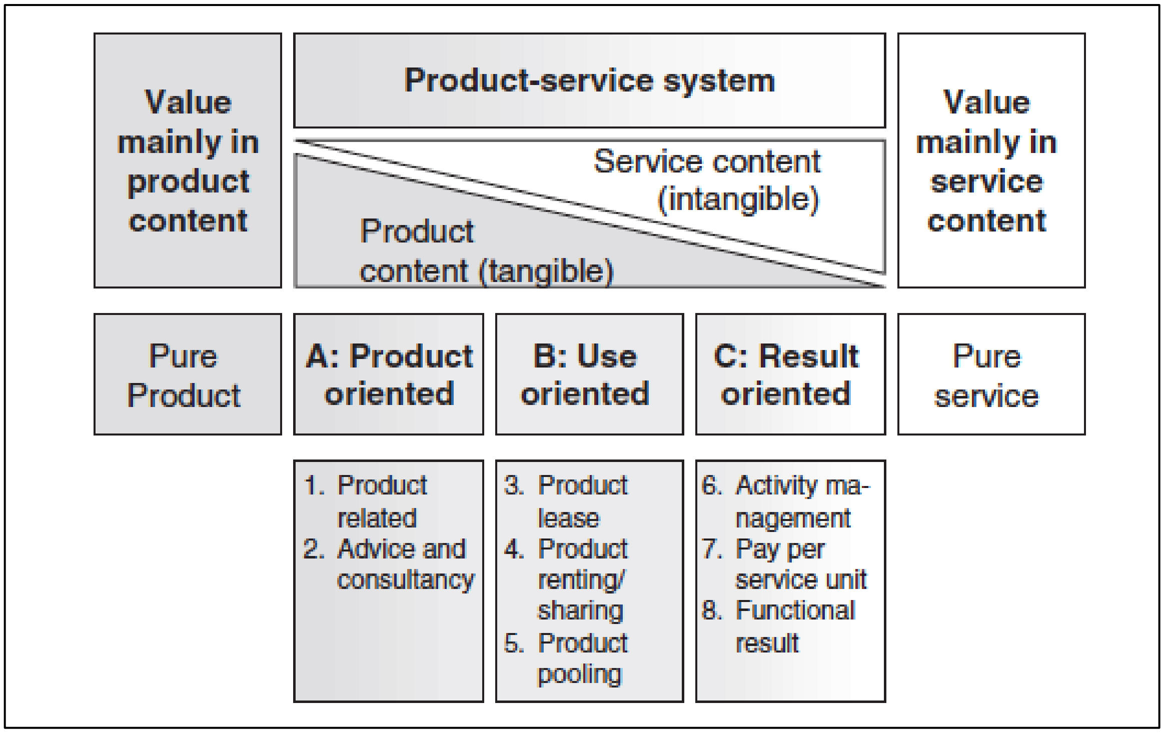

Figure 1: Main and subcategories of PSS

2.3 Trends in Service Literature

Published literature on the topic of product-service has increased in recent years. The growth is displayed in the plot in Figure 2 [7]. The data was computed using information from scopus.com. The data shows an exponential increase in the number of publications with product and service in the title or subject. Since practice often follows research, one can expect that industries will soon be focusing more attention on product-services. This phenomenon will most likely lead to more firms considering product-service transformation.

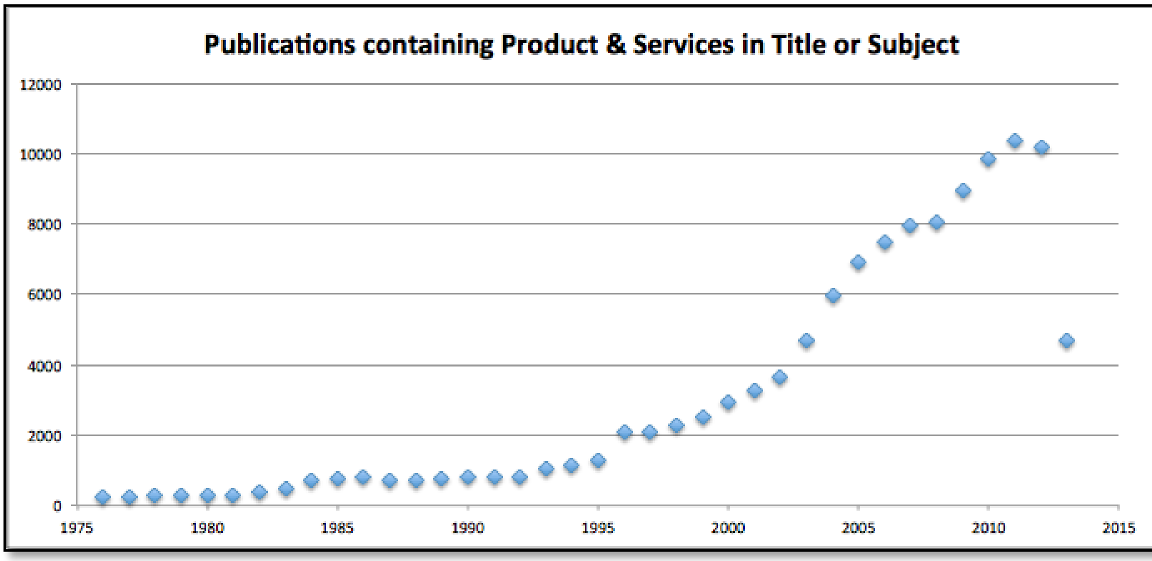

Figure 2: Publications containing both Product and Services in the title or subject

2.4 Service Motivations

The motivation to focus on a product-service model as opposed to a conventional product model is detailed in the following section. Various sets of research point to key benefits in the areas of the economic value, de-commoditization, and customer relationships.

2.4.1 Projection of Economic Value

The act of selling a service is a progression of a commodity's economic value [8]. As presented by MIT Professor Bruce Cameron, the progression of economic value begins by extracting commodities. Commodities then develop into goods. Goods are customized into services and delivered to the consumers. Services are what consumers now seek, leading to the over 70% GDP in industrial nations [8]. Services are commoditized to reduce the initial cost for the consumer [8]. An example of this is Zipcar, a service that delivers a transportation product, a car, to consumers in terms of a service that can be paid for hourly. Beyond products and services is staging experiences for the consumer. An experience is a customized service that delivers a personal experience in terms of a memory to the consumer [8]. The economic progression as discussed by Cameron is displayed in Figure 3 [8].

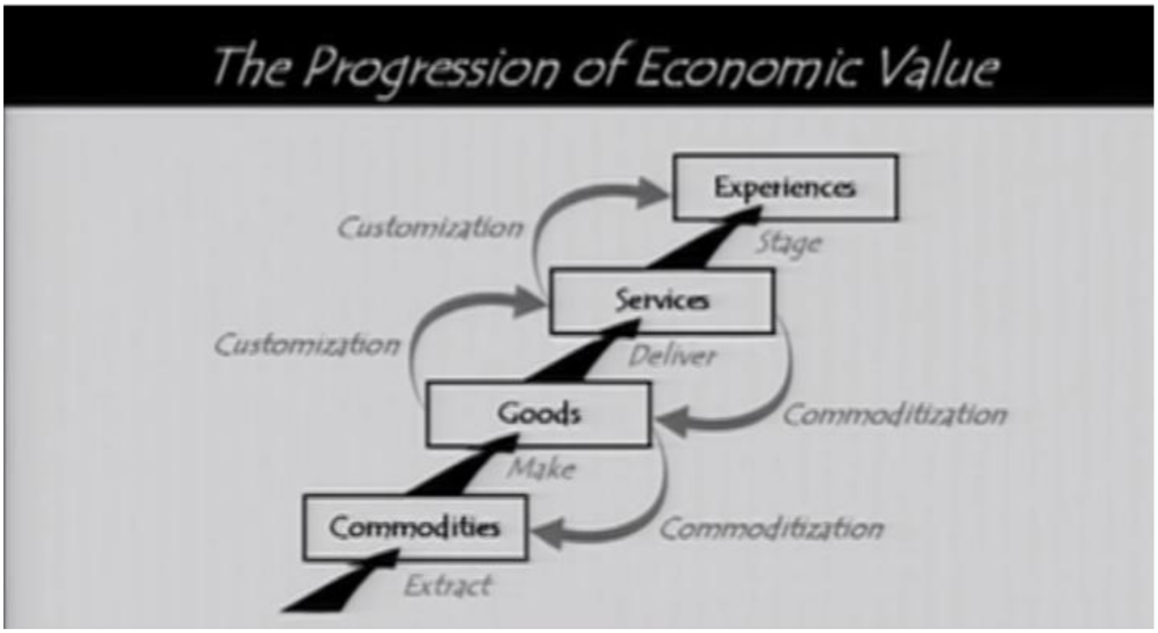

Figure 3: Progression of Economic Value

Differentiation motivates a firm to move up the economic value. Moving up the chain allows a firm to compete with more than just the value of their product. Often as a product matures and imitations are more prevalent in the market, the price and quality capabilities of a product become comparable. By moving up the chain, a firm can benefit from providing value to customers through customization in terms of services and experiences [8]. This is discussed further when the literature review hits on the works of Barras and Utterback.

2.4.2 De-Commoditization

An important incentive of the service model is de-commoditization [1]. Cusumano's research concludes that firms that offer standardized services in a form of a product should utilize service innovation to enhance and de-commoditize the actual product being sold [1]. Customer service is a simple example of a service de-commoditization. Customers are often willing to pay more for a product that is supplemented with excellent customer service than one without. De-commoditization also allows a product to be shared among customers in the form of a service. The sharing of the resource drives down the individual cost of the benefit that the product is offering.

2.4.3 Customer Relationship

The relationship that a service evokes with a customer is another valuable consideration for the product-service model [9]. Susman argues that service models help company establish “intimate and trusting” relationships with its customers. Susman’s research concludes that innovation in services typically results in increased customer satisfaction and loyalty, making the case that services can gain on products by transferring additional value and function gained than by just owning or leasing a product. Susman’s guidance is that the product to service transition must occur in phases that involve mastery of new skills and capabilities at each phase before graduating to the next one [9].

2.4.4 Other Advantages

Mansharamani further points out advantages for a service model in his research. Mansharamani emphasizes the importance of the customer as an active participant in the involvement of the service innovation [10]. Cusumano adds to this by also including that the customer can avoid a capital-intensive investment from purchasing the products [11]. This allows a firm to focus on their core competencies and outsource the general functions of the service. Richard Barras’ research concludes this section by pointing out that services reduce the delay in customer adaptation due to customization and relationship with customer [12].

2.5 Whole Life Analysis

This section focuses on whole life analysis (WLA). WLA, termed Life Cycle Analysis in some publications, is an important aspect of the product-service transformation. In a product model, a firm’s ownership of product concludes when the product is transferred to the consumer. On the other hand, a firm with a service model continues to transfer benefit to the customer throughout the life of the product. This difference points to the importance of understanding the whole life costs for a product-service.

2.5.1 Defined by the Department of Defense

The Defense Acquisition Guidebook provides an encompassing definition of the whole life cycle. The Department of Defense (DOD) defines life cycle cost as the research and development costs, investment costs, operating and support costs, and disposal costs over the entire life cycle. The guidebook includes not only the direct costs of the acquisition program but also indirect costs that would be logically attributed to the program. This ensures that all costs that would be logically attributed to the program are assigned to the program. The guidebook also comprises infrastructure or business process costs not normally attributed to the program [13].

2.6 Product Development for Products and Services

The next section investigates the research in the service development process. The section begins describing the typical literature in the traditional product development process and then reviews the publications that focus on the service development process.

A large amount of literature has been published on product development with a concentration on physical artifacts. Ulrich and Eppinger investigate such topics in *Product Design and Development*, 2000. Pugh also examines the topic in his work, *Total Design – integrated methods for successful product engineering*, 1999. Both of these publications treat service innovation as an after-thought, where physical products are the main focus of development [14][15]. Ulrich and Eppinger detail a development process focusing on the expected interactions among parts. The stages of development explained are of the following: concept development, system-level design, detailed design, testing and refinement, and production. Their process only notes customer involvement during the need findings event in the initial phases of the development [14]. This typical product development process is not compatible with service products.

James Utterback's research concludes that product innovation continues only until a dominant design has emerged. At this point, a firm must concentrate on process innovation until a prevailing service has surfaced. The model begins with product innovation in the fluid phase, and then moves to process innovation in the transitional phase before completing in the specific phase. The concept behind the Utterback model is that as a product (or innovation) matures, the number of entrants into the market follows a pattern. This pattern begins with many firms competing in product innovation to determine the dominant design. Once the dominant design is defined, the firms compete on process to gain market share instead of product innovation [16]. A graphical depiction of this comparison is plotted below in Figure 4 [16].

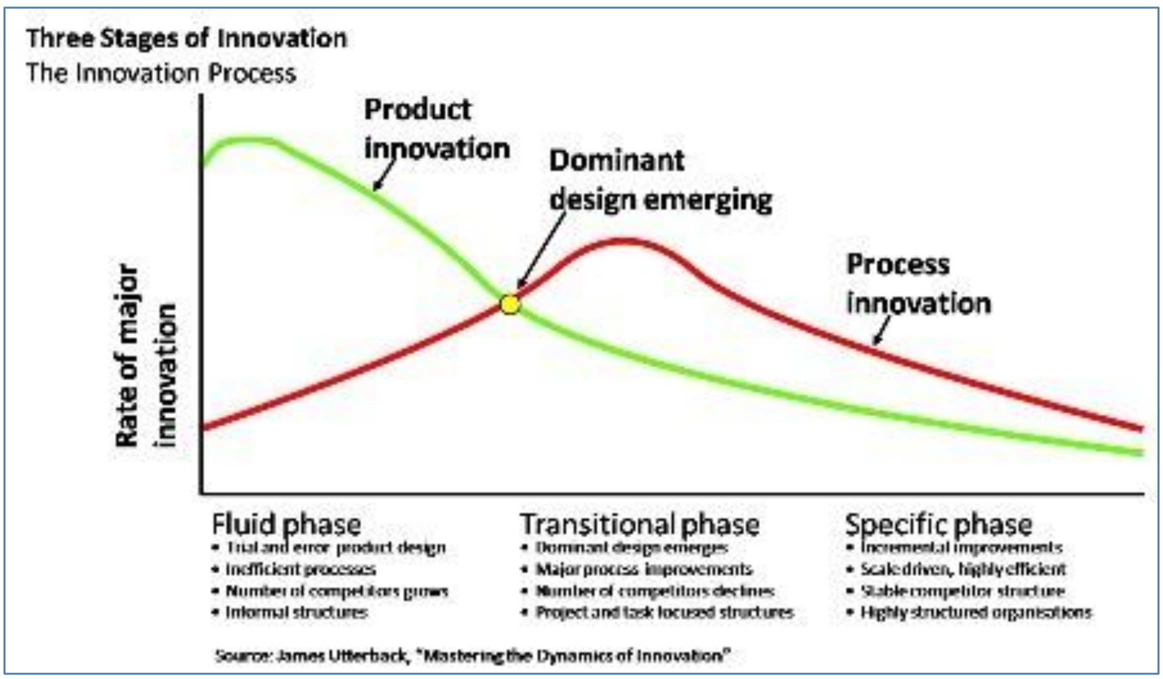

Figure 4: Dynamics of Product Innovation

In contrast, Barras' work, published in 1986, argued for the progression of services to processes [12]. He argued that service development should follow the reverse product lifecycle. This concept involves service improvements to increase efficiency of the existing services. This is followed by process innovation to improve quality, which, in turn, improves the quality of the service products [12]. This results in radically new forms of process. This is graphed in Figure 5 [12].

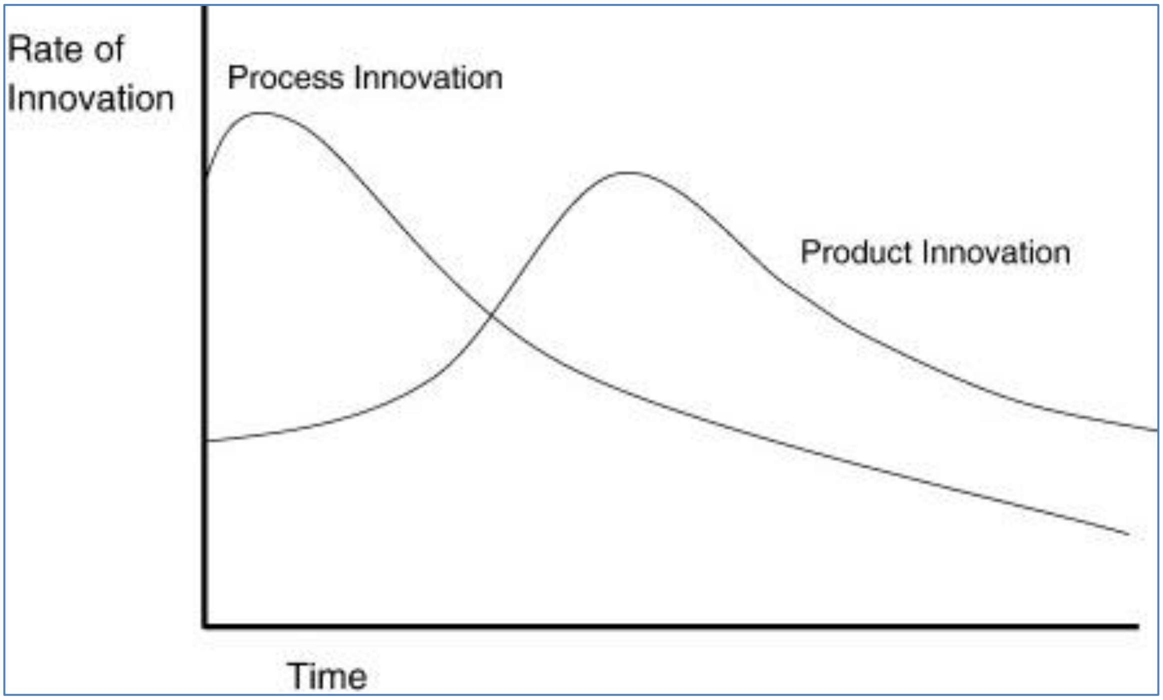

Figure 5: Dynamics of Service Innovation

An interesting perspective on the combination of the products and services is that of Ericson and Larsson. In their paper, *A Service Prospective on Product Development – Towards Functional Products*, Ericson and Larsson explore the use of functional products in the development of products and services in Swedish manufacturing firms [17]. Functional products are defined as a combination of hardware, software, and services. Their research concludes, "The function part in function products is understood as the customers' needs, while the product part can be understood as the result of the processes to meet those needs." The authors also found that function products as a concept is described differently from different perspectives [17]. While not a concise argument, the authors' idea of using function products to describe the roles of both product and service in a unique system.

2.7 System Architecture Methodology

The system architecture methodology, established by MIT Professor Crawley, is a method to connect a user's needs to a system's value [18]. As discussed previously, the customer and market differentiation for services differs significantly than that of a product. By following the system architecture methodology, stakeholders and goals lead to functions and realized sub-systems. This process is also a good exercise to analyze the needs required to add value. The following section dissects stakeholder interaction, prioritizing beneficial stakeholders and a need to goal approach and a method to discovery functionality and its effects on upstream and downstream activities [18]. This methodology was selected to provide the link between a service product and its value for the stakeholders.

2.7.1 Stakeholder Interaction

In Crawley's System Architecture lecture at the Massachusetts Institute of Technology, he describes the principles involved in the exchange model of beneficial stakeholder interaction. A key characteristic of Crawley's approach is that value is successfully delivered in an exchange with a benefiting stakeholder. This exchange occurs when the system's outputs meet the stakeholder needs or the stakeholder's outputs meet the system's needs. Any break in the loop implies that value is not delivered and the system will fail [18]. The diagram of this interaction is shown in Figure 6 [18].

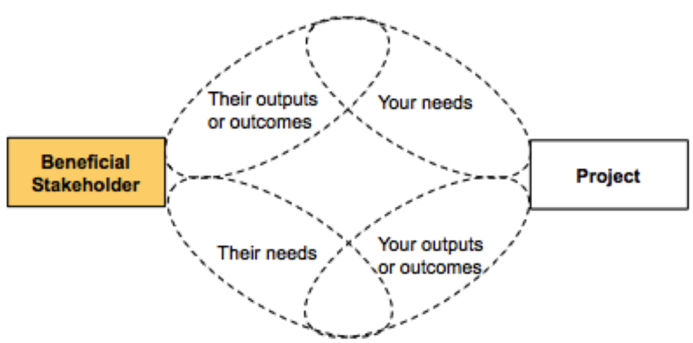

Figure 6: Exchange Model of Stakeholder Interaction

2.7.2 Prioritizing Beneficial Stakeholders

The next step is identifying the most beneficial stakeholders. Crawley divides these stakeholders into three hierarchy groups; primary, beneficial, and charitable. The basis of the hierarchy ranking is based on the value delivered to the firm. Primary stakeholders must be considered and their needs must be satisfied. Beneficial stakeholders must be considered and their needs should be satisfied. Charitable stakeholders should be considered and their needs might be satisfied. Crawley's reasoning is that a firm will benefit most by focusing their energies on the most important and most profitable stakeholders [18]. This is graphically displayed in Figure 7 [18]. A similar analysis should be conducted for the needs of the stakeholders.

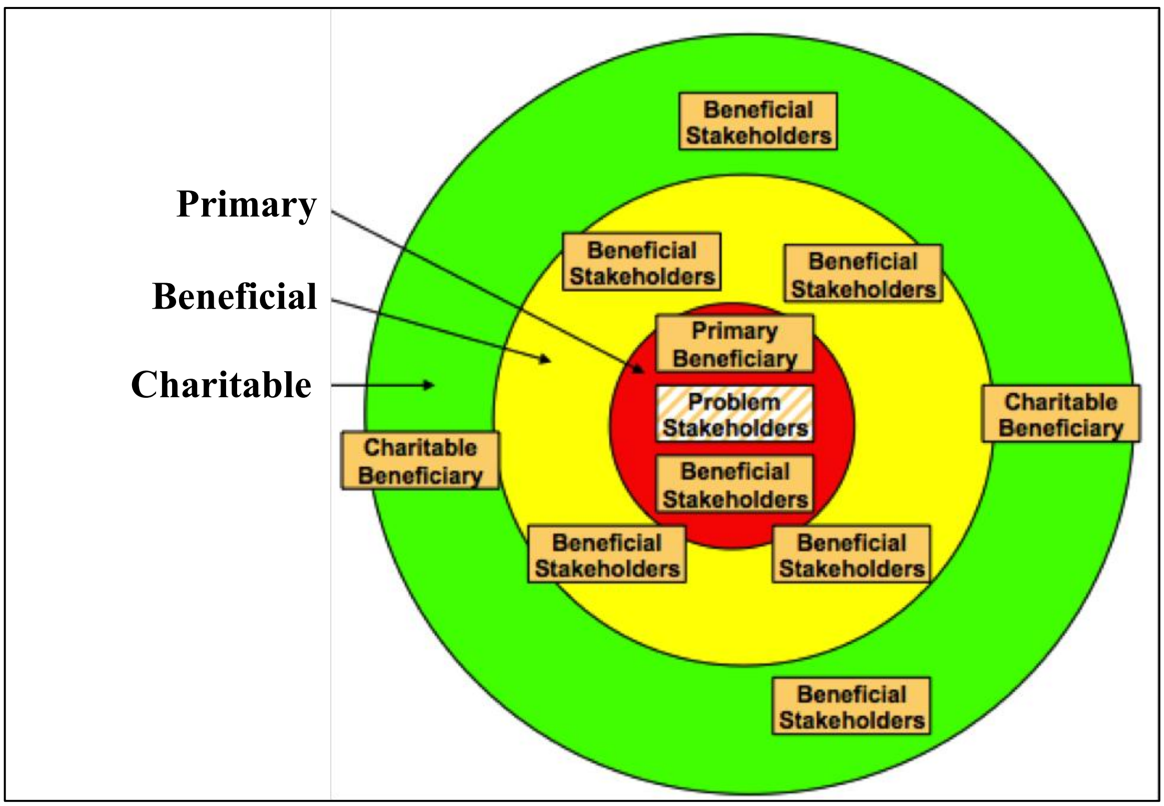

Figure 7: Tier of Stakeholders

2.7.3 Needs to Goals Approach

Once the stakeholders are identified and prioritized, user needs are required to satisfy the compelling problems of the stakeholders. Crawley finds a system's value in his System Architecture Framework using an expanded framework of the needs to goals approach [18]. The flow of value chain is evident in Figure 8 [18].

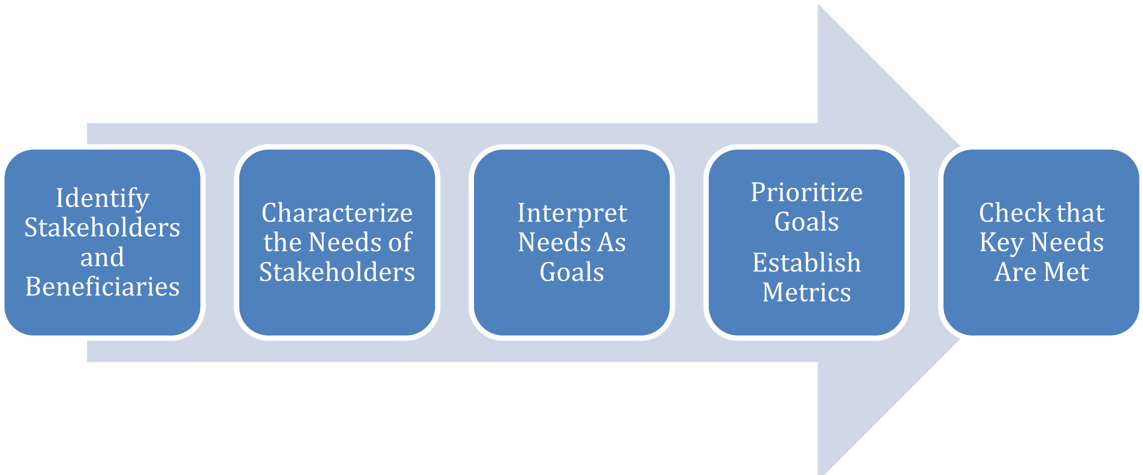

Figure 8: Iterative Needs to Goals Approach

The first step is to identify stakeholders and beneficiaries. As discussed previously, this includes a tiered system of stakeholders. This activity contains the identification of the needs of the stakeholder's interests and institutions. Grouping of the stakeholders may also be conducted in this initial step. These needs are found by inputs from beneficiaries, enterprise models, flows, or value exchange models [18].

The second step is to characterize the needs of the stakeholders. This comprises a characterization of the value flow of the stakeholder's needs. This value can be understood by analyzing simple value flows, chains and loops, and the importance in supply [18].

In the final steps, the needs on the project are mapped to the project model. The mission of this step is to deliver primary value to the prime stakeholder by formulating goals that focus on the system's problem statement. The final goals need to map to the internal and external functions, the interfaces, and the form of the system. By weighting stakeholders, a manager can prioritize the goals of a system. The goals should be linked to the metrics that will be used to evaluate the goals. These goals need to be checked to ensure that they are representative of the goals, complete, consistent, and most importantly attainable for the overall system [18].

2.7.4 Goal Decomposition

Another aspect of Crawley's process is the concept of goal decomposition. Crawley explains that once goals are defined, a system architect must conduct trade offs in terms of function and form with the intent of the system. Derived from methods explored by Coopman, Crawley envisions a 3-dimensional axis with form and function as the X and Y axes, while the intent of the system is represented as planes on the z-axis, represented the trade off space [18]. This is represented in Figure 9 [18].

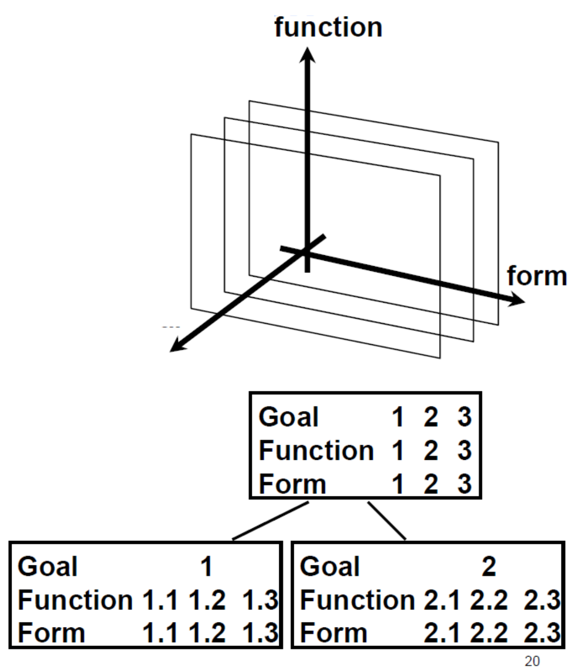

Figure 9: The Form, Function and Goal Tradeoff Space

2.8 Literature Review Conclusion

This section has provided a literature framework for the process to innovate a product-service transformation. The building blocks in the literature review are utilized in the following sections to build the Product-Service Transformation Process. The main takeaways from the review are the motivation behind service innovation, the use of service innovation in technical strategy, and the ability to understand products through the system architecture methodology. The Product-Service Transformation Process leans heavily on these building blocks to provide the structure and rigor of the process.

The literature review corroborates that services are needed in slow or no-growth economies where firms cannot rely solely on their typical core customer. Services can leverage off domain knowledge to produce new and business models for existing products. These service methods can be utilized to de-commoditize products and build customer relationships.

While most typical product development publications do not focus on service innovation, the importance and particulars of services should not be overlooked. The dynamics of product innovation point to the nuances that contribute to the discussion on product versus process innovation.

System architecture is a logical framework for understanding the value of a system. The methodology focuses on customer prioritization, customer needs, and system goal decomposition.

These building blocks are valuable in the following sections, as the Product-Service Transformation Process will demonstrate. The process utilizes the qualitative nature of the literature sited in this section and builds a method to build value through services.

Chapter 3: Methods

The Product-Service Transformation Process was developed utilizing a combination of the system architecture methodology, the principles of the product-service system, and best judgment. The system architecture methodology, which was modified to supplement the concepts of the product-service system, was used as the framework for the process. A holistic approach was then taken to recognize the functional boundaries and interfaces of the product-service system. The technical strategy methods developed by Utterback and Christensen are used to construct the appropriate service concept.

The system architecture methodology is used to provide the initial elements of the process. These steps comprise the customer prioritization, the customer needs, the functionality of the product, and the organizational goals. A system thinking approach was then taken to connect these elements into an arrangement that can be molded into a product-service model. These are documented in such a way to realize potential issues and provide advice for potential downstream effects. The architecture approach is then used again to discover the importance of the functional boundaries and system interfaces.

Throughout the process, the concept of feedback loops is discussed. While the process appears to be a one-way directional path, there is potential for downstream discovers to propel the user to re-think earlier steps. The final business plan step also includes a number of methods to measure the value delivered by the finalized product-service.

Chapter 4: Product-Service Transformation Process

4.1 Overview

The following process was based largely on the published information sited in the literature review with additional inputs from interviews with leaders in the radar and software industry. The Product-Service Transformation Process gives guidance to managers who are considering the product-service transformation and for managers that should be considering the transformation to services. Since this process is very dependent on the attributes of the product under consideration, the process contains an abundance of questions, followed by examples when necessary, that lead to different, and sometimes divergent, paths.

An overview of the process flow starts by extracting the stakeholders, beneficiaries, and the product's value to the system. Using a systems architecture approach, the stakeholder's needs, the competition environment and the organizational objectives and values are mapped together. Needs are then mapped to each value derived by the product, thus connecting the stakeholders, beneficiaries and organization. This mapping is utilized to understand the proper service concept that should be used for the product and its corresponding delivery method.

The service model concept is chosen to meet the stakeholder's unmet needs and to deliver value to the stakeholder and the product's provider. The concept is derived from a list of eight product-service systems possibilities. The best option is selected based on the one that best fits the product, its supporting sub-systems, and the corresponding business functions. After the concept is generated, the architecture of the system is defined. This is the key to manage the evolution of complexity when the concept of the product-service is introduced to its internal and external sub-systems.

Once the service model is selected, the architecture is structured by the remaining functional boundaries and interfaces. This includes operations, finance, product marketing and the branding strategy of the organization. The remaining facets of the process are both downstream impacts, as well as feedback inputs to the concept decision. Unexpected information discovered in these stages may cause feedback loops when sub-systems change the concept or objectives of the system.

An overview of the Product-Service Transformation Process is displayed below in Figure 10. The process describes the each activity in the figure. Each activity is detailed in a format that first explains the inputs and outputs of the individual activity. A definition of the activity is then examined, followed by the methodology to determine the outputs of the activity. Any questions that pertain to the activity but were not included in the methodology are then stated. The process uses a holistic view and identifies the effects to down-steam activities. The activity concludes with any additional discussion points and examples.

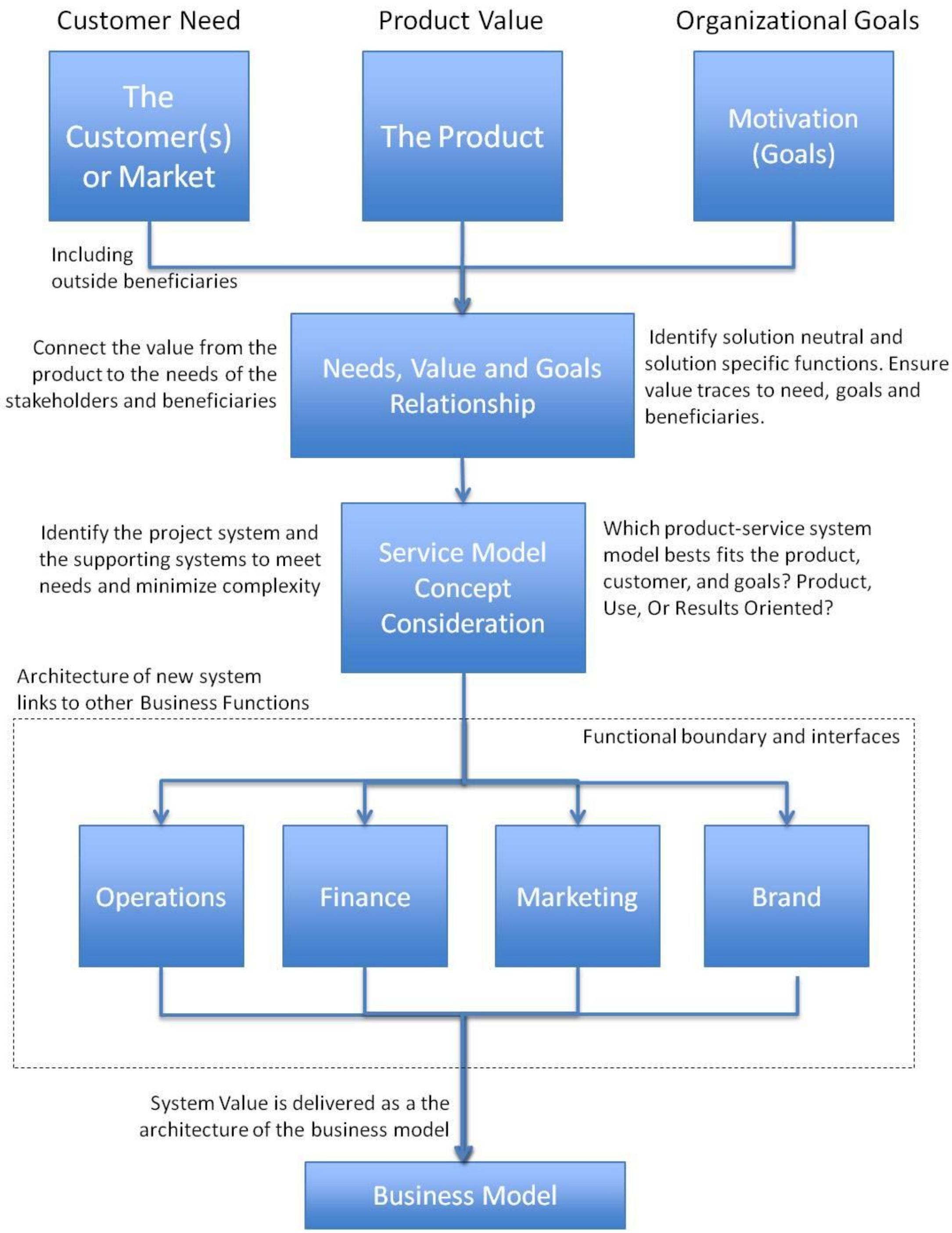

Figure 10: The Product-Service Transformation Process

4.2 Customer

4.2.1 Inputs: Customers, beneficiaries, and their respective needs
4.2.2 Output: Prioritized matrix of customers and beneficiaries

4.2.3 Definition: The customer needs are an essential aspect of the product-service system. The customer described in this section most likely is not a singular entity. It is more likely that the customer is a group of consumers or a target market. The customer's needs fit into two areas, un-met needs and latent needs. Un-met needs are current customer requirements, while latent needs are future customer requirements. The customer's needs are directly mapped to the functions of the product.

Stakeholders are defined as the customers, users and outside beneficiaries. Often incorrectly used interchangeably, the concept of stakeholders includes more than just the client with a spending budget, but also the users and the groups outside the system that benefit. An outside beneficiary is defined as person who receives benefit from the system but has little or no impact on it. A society benefit is an example of an outside beneficiary.

4.2.4 Method to determine customer needs:

1. Identify primary stakeholders, including product's market and new service market
    a. Identify the operator/user of the technology
    b. Identify the agent of the stakeholder (The stakeholder with a spending budget)
2. Identify secondary stakeholders and charitable stakeholders
3. Identify outside beneficiaries (community and society) that may benefit from fulfilling the needs
4. Understand the competitors in the market
5. Interpret needs

    a. Methods: Surveys, interviews, case studies, customer feedback, history, situational analysis
6. Discover latent needs
    a. Methods: Strategy, market research, forward thinking, simulations, prototype analysis
7. Characterize the stakeholders' needs and the specific value flows to the needs
8. Rank the stakeholders' needs based on benefit and value flow
9. Organize the results in a matrix with appropriate rankings based on the previous instructions

4.2.5 Questions to consider:

1. When examining the projected customer or market,
    a. Is the service stakeholder the same as the product?
        i. If so, does the service offering affect the relationship? Is there space for the customer to consider the product/service as an add-on, or is it a replacement for the product?
        ii. If not, what are the customer acquisition costs? The customer acquisition costs are the costs that an organization pays to gain a customer. This can include marketing, branding, and time.
        iii. What are the customer acquisition costs? Is the potential win worth the cost of the customer acquisition?
2. How does the relationship with the customer fit the acquisition team? What is the ability of the organization to shape the value stream of the project customers?
3. Does the service allow the user to concentrate on core-competencies instead of producing, purchasing, and integrating the needed product or experience?
4. Is there any extra incentive for the user to pay a premium to allow the organization to handle the repairs and maintenance of the product when deployed?
5. What level of reliability is required to fulfill the customer's needs? This is discussed further in the operations implementation.

4.2.6 Impacts to down-stream activities:

Interpreting customer needs is the most important activity in the product-service transformation process. Since the customer needs are mapped to the organizational goals and then defined as the functions of the product, each downstream activity in the product-service transformation process is impacted.

Example:

An example of the customer needs for a consumer product is displayed below [18].

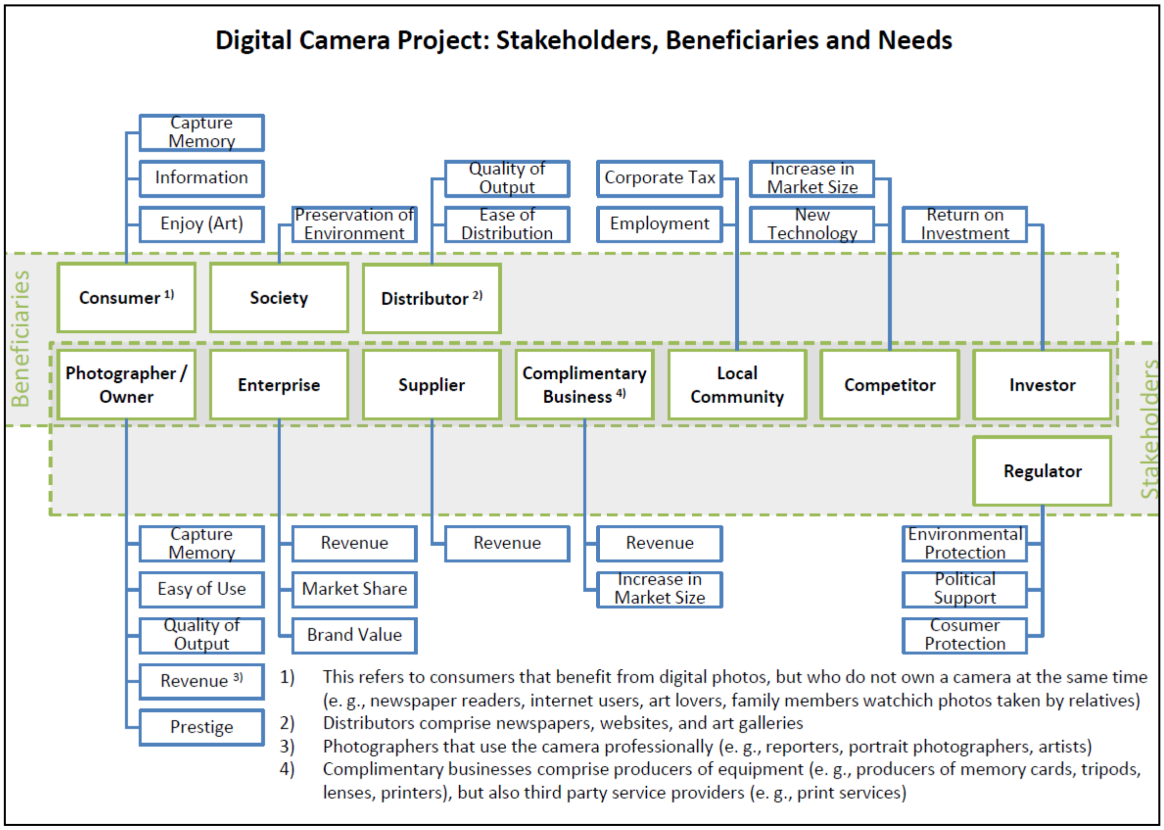

Figure 11: Stakeholders, Beneficiaries and Needs

4.2.7 Discussion:

Changing user behavior is another aspect of the product-service system that is worth considering in terms of outside beneficiaries. An example of this is the driving shifts caused by the implementation of the Zip Car service. Robin Chase, CEO of Zip Car, has said that the Zip Car service has reduced both fuel usage and carbon impacts by reducing the amount of car trips. Chase explains that Zip Car users will only drive the required amount to do errands and will also often take care of their entire car needs in a single use to reduce fees. This contrasts the normal behavior of a user who owns a car and, since the up-front costs have been already paid, has less incentive to make shorter, multi-tasking trips [19].

4.3 Product

4.3.1 Inputs: Product

4.3.2 Output: Product – Function Mapping

4.3.3 Definition: A product creates value for its user. Delivering function through services and experiences also generates value. In a traditional product, the value-added processes are designed with the customer's needs in mind. The product-service transformation process takes into consideration that the product or technology has already been designed as a traditional product and, instead, focuses on the value-added processes of the product instead of designing the product.

4.3.4 Method to determine product value:

1. Identify the intent of the product (The goal of the system)
2. Identify the solution specific functions (The functions that support the product's intent)
3. Identify the delivery methods available for the product (The methods through which value can be delivered to the customer. See Figure 1 in the Literature review for an outline of the different available service methods.)
    a. Example: Delivery methods impact the variety of choices for the service model decision.
        i. ie. Car – sell car (product), deliver car (service), deliver driver (service)
        ii. Satellite Imaging – Deliver satellites (product), deliver images (service), or deliver analysis of photos (experience)
4. Construct Product – Function Map for each intent or goal of the systems following the schematic in Figure 12. This mapping is built off Figure 9 with the exception to the z-axis. Since the form of a product-service system is conveyed as a delivery method, form, the z-axis, is substituted for delivery method in this activity.

a. Example:

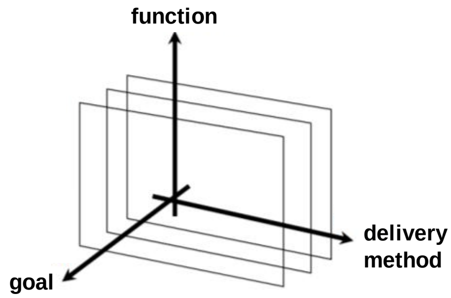

Figure 12: Product-Function Mapping

4.3.5 Questions to consider:

1. Is the product deployable to multiple customers?
   a. Through product pooling or sharing?
   b. Is there a need for a dedicated end-user? This could complicate combining services for security minded entities, such as certain commercial and government users.
2. What is the speed of the technology? The turnover in technology is a key to the decision-making process. Rolling out a technology service that will be obsolete in a short time may not be beneficial for producing a quick enough ROI.
3. Is there value in an open product model? An open model allows users to build their desired functions off a platform provided by product's producer. An example of this is the Android platform built by Google.
4. Does the product require infrastructure additions or modifications?
   a. Are additional employees needed?
      i. Is the organization built to accommodate more employees? Who would these new employees report to?
   b. Service Sites
   c. Suppliers for deployment and maintenance
5. Does the product require a learning curve? Operator ease?

4.3.6 Effects to down-stream activities:

The product has many effects to the down-stream activities. These effects are noted in the write-up for the remaining activities.

Example:

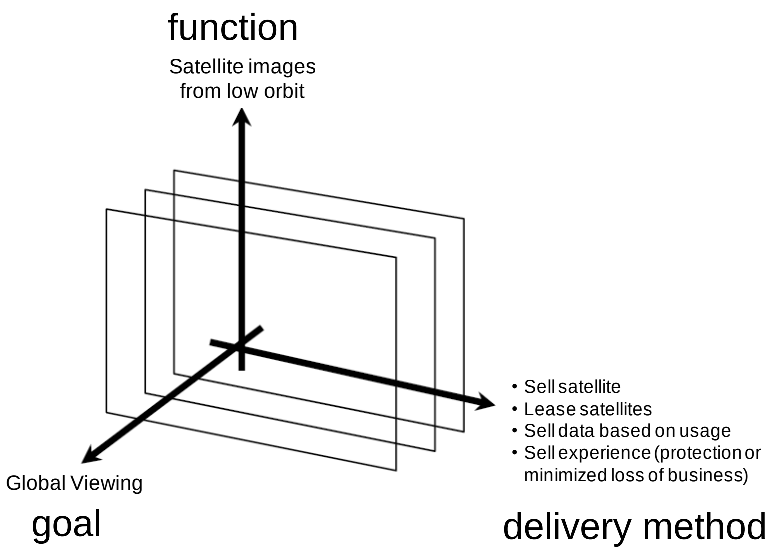

Figure 13: Product-Mapping example for satellite imaging

4.3.7 Discussion:

James Utterback's work on the Dynamics of Innovation provides an interesting viewpoint on the readiness of a product for services. As discussed in the literature review, this model compares the number of entrants in to the market and uses this to determine if a dominant design has been determined. If the market has not yet determined a dominant design, an organization inquires a significant risk that all service infrastructures may be obsolete once a dominant design has emerged [16]. Utterback's Mastering the Dynamics of Innovation provides additional analysis and insight on the topics of dominant design.

4.4 Organization Objectives

4.4.1 Inputs: Organization objectives and prioritized needs from the stakeholders
4.4.2 Output: Prioritized set of goals based on the Customer Needs and the Organizational Goals

4.4.3 Definition: Organization's objectives comprise a firm's current and long-term objectives and the view of the firm's intended business values. The objectives are defined by senior leadership and are communicated to the firm's employees. The organization's objectives are included in the entity that is called stakeholders needs. The organizational goals may adapt or add to the customer needs to build a complete picture of the needs for the product-service system.

4.4.4 Method to determine organizational objectives:
The organizational objectives are defined by the organization. This process assumes that the objectives have already been defined. Instead this section focuses on evaluating the customer needs in regards to the organizational goals. Needs that do not match the organization's vision and strategy should be minimized or withdrawn.

4.4.5 Questions to consider:
1. What customer needs best fit the future direction of the company?
2. How do the organizational goals affect the customer market and the priority of customer needs
3. How do the organization's goals affect the community and society in general?
    a. Downstream effects to branding?

4.4.6 Effects to down-stream activities:
1. Organization objectives may impact financial commitments
2. Long-term organizational goals may steer which functionalities are pursued
3. Organizational objectives may target certain markets, therefore re-arranging the stakeholder priorities

4. Branding may be highlighted as a key, therefore steering products to focus on community benefits
5. Operation ability to support life cycle costs and maintenance may be tied to the organizational objectives.

4.4.7 Discussion:

A product's success in meeting financial goals is only valuable to an organization that values the product in its near or future strategy. The success of a product or service depends heavily on the organization and management structure of the organization. Clay Christensen argues that new products or services cannot satisfy the near-term growth requirements of a firm with an existing successful platform. Christensen describes this failure by executives to understand that a disruptive innovation in an emerging market will not bring the immediate desired returns to meet its annual growth rates for a mature firm. Christensen states that disruptive product innovation should be designed with individual goals and even at a distant location. The Newton by Apple was considered a failure even though 140,000 units were sold. While this is a small number in relation to the Apple II, the Newton should have been a success due to the infancy of the product, not a flop as perceived by Apple executives [20].

Poor management and customer service can hamper even the best technology. Management pitfalls include pricing out valuable customers and not meeting an expected level of on-going service. An example of this pricing pitfall is the case of Iridium, the satellite phone company. Established in 1991, Iridium provided a state of the art satellite system with the ability to connect users all over the world. Iridium had supportive investors to supply the company with the $5 billion in capital needed to build the entire satellite network [21]. Iridium was even able to differentiate their service by meeting a global customer's need of both local and remote communications. Despite this, the cost structure of the service and the possibility of a future, less expensive substitute, specifically conventional cellphones, led Iridium to failure. While conventional mobile phones have still not met this global need, the high cost structure doomed the company.

The prices were as follows: $3,295 for a satellite phone, $695 for a pager, and airtime fees up to $7/minute [21].   By 1999, Iridium was in Chapter 11 bankruptcy and, only after being acquired for $25 million, was the firm able to provide a reasonable user price [21]. Today, the company survives by targeting military personnel positioned in remote areas of the earth. Iridium provides a cautionary tale of product-services that while needed, may be too expensive for a mass customer following.

Another similar example is the case of the Concorde Airliner. The Concorde, developed jointly by Aérospatiale and the British Aircraft Corporation in the 1960's, was a technical marvel and the leader in supersonic commercial transport. Representing a dream in travelling faster the speed of sound, the Concorde was launched with the expectation of revolutionizing commercial flights. Each plan could hold up to 100 passengers. In conjunction with the high speed was a high cost to passengers. The Concorde program cost approximately $1.5 billion to design and maintaining the fleet was also expensive [22]. The leaders of Concorde had planned on widespread acceptability to the firm to be profitable. Concorde did not realize this acceptability and operated at a loss for many years. Eventually the company was sold for a dramatic loss and the new management changed its approach to a small niche market of customers willing to pay the extremely high price for the service. This enabled Concorde to stay viable until their final flight in 2003 [23] .

These examples highlight the need for managers to understand their respective markets and pricing schemes. Iridium and Concorde were fortunate to have endured in their industries with initial approaches that did not match their intended markets.

4.5 Connection: Goals to Value

4.5.1 Inputs: Prioritized goals, products, and value added functions

4.5.2 Output: Stakeholder-Goals-Function Relationship

4.5.3 Definition: The Goals to Value activity characterizes the relationship between the customer needs, product values, and organizational goals. This relationship defines the path to be used to build the concept in the subsequent activity. This activity presents a framework to organize the data collected in the previous activities. The framework is then analyzed in the following activity: Service Model Concept Consideration.

4.5.4 Method to determine organizational goals:

1. Map the stakeholder and the corresponding goal to the value-added function by means of the form of the function (Value-added delivery method). This method is meant to provide a space to connect the stakeholder, their goals, the product's intended function, and a method to discriminate the product features to build value. This activity is thought provoking and can be difficult of inexperienced architects. Figure 14 outlines a useful method to accomplish this activity.

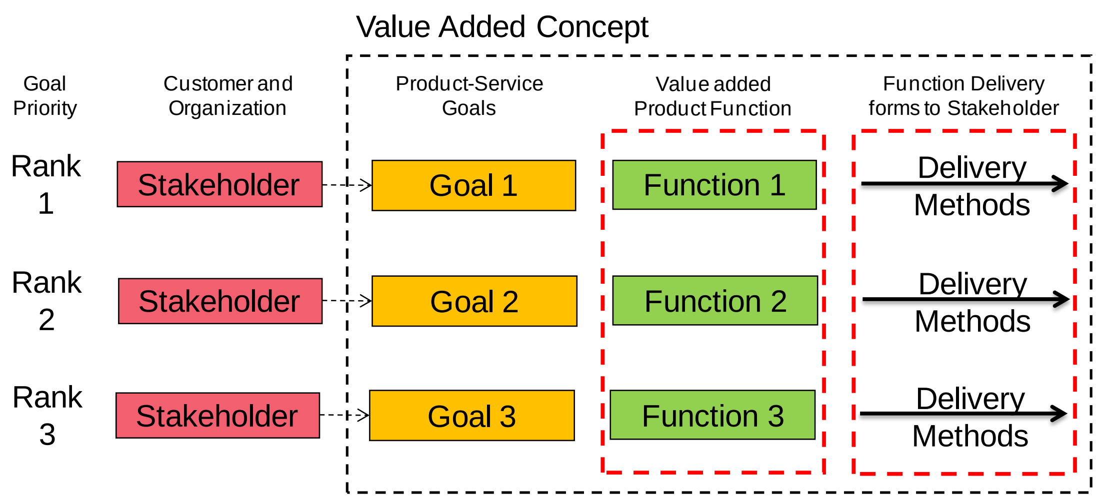

Figure 14: Stakeholder-Goals-Function Relationship

4.5.5 Questions to consider:

1. Does the priority given to each function via the goal fit the overall vision of the organization?

4.5.6 Effects to down-stream activities:

The Stakeholder-Goals-Function Relationship defines the approach of the following activity, Concept Generation.

4.5.7 Discussion:

Example:

Below is an example of the Goals to Value results for a satellite-imaging firm. Each stakeholder is listed with a product-service goal, which in turn is mapped to a value added function. The value added function is then transferred to the stakeholder by a delivery form.

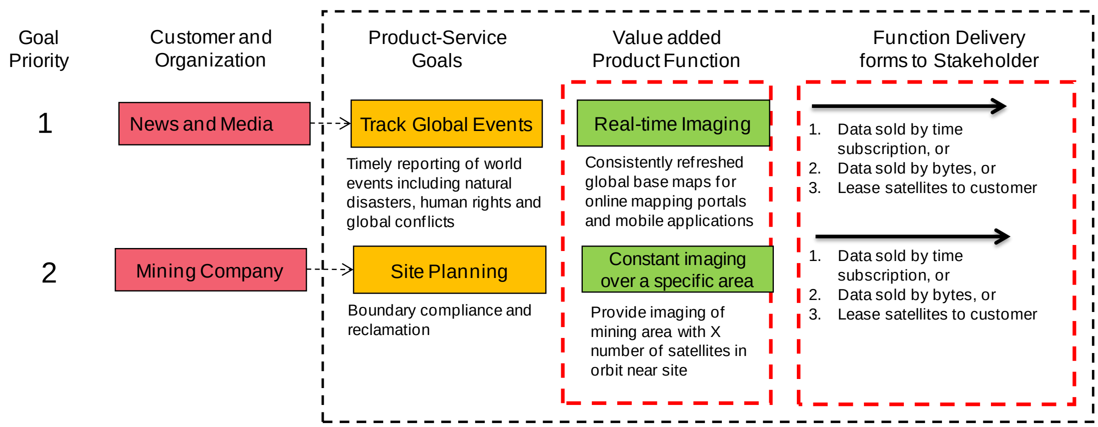

Figure 15: Stakeholder-Goal-Function relationship for a satellite-imaging firm

4.6 Service Model Concept Consideration

4.6.1 Inputs: Stakeholder-Goal-Function Relationship

4.6.2 Outputs: Selected service model

4.6.3 Definition: The Service Model Concept Consideration activity integrates the customer, the product, and the organizational objectives. The service concept described in this activity delivers the development plan for the remaining aspects of the system. This activity begins the analytical examination of the product-service system. The analysis is completed in the final activity of the process after the functional interfaces and boundaries are defined.

4.6.4 Method to determine organizational goals:

1. Map the characteristics of the Goals-Value structure to the appropriate Product-Service Model following the diagram in Figure 16 (Partially based on work by Tukker [5])

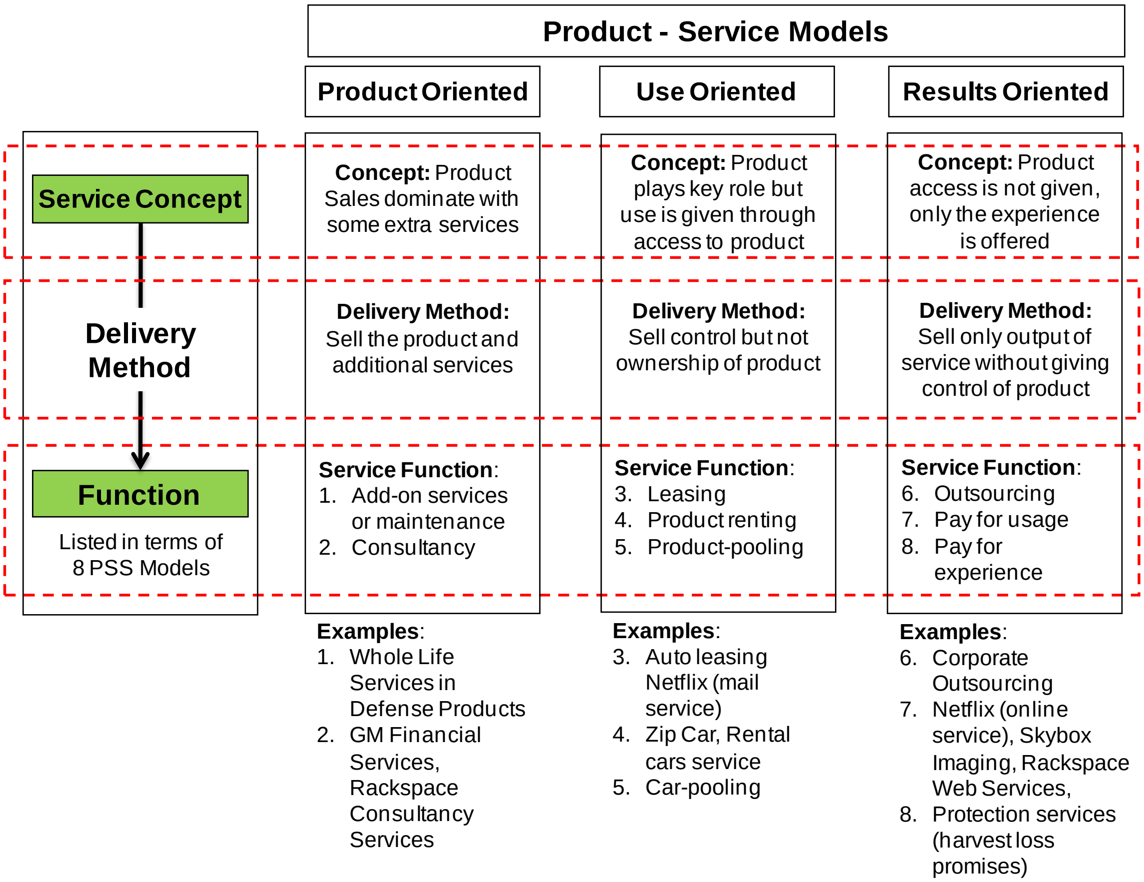

Figure 16: Product-Service Models

2. The eight models need to be weighed in terms of the following [5]**:**
   a. Tangible and intangible value for the user
   b. Tangible costs and risk premium for the provider
   c. Capital investments needs
   d. Firms position in the value chain and client relationships

3. Each model that provides a feasible solution for the product-service should be investigated.

4. The Risk-Value Relationship

   A significant difference between the service models is their abilities to take into account risk transformation. The major theme of the PSS is the trade off of risk from the consumer to the producer. Below is a notional description of the value added in relation to the added risk of each PSS. The number of the product-service model relates to the risk and potential benefit for each option. Number 1, product oriented with add-on services, offers the least amount of risk while providing the smallest potential gains. A graphical description of this relationship is displayed in the figure below. While the slope of the line is linear in the graphical depiction, the actual curvature of the line is dependent on the both the product and the organization's ability to conduct the respective service model.

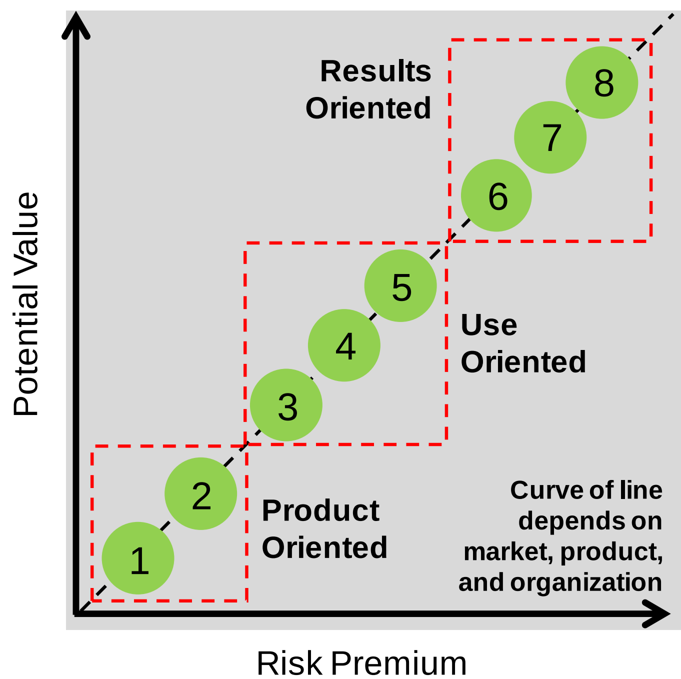

Figure 17: Theoretical Risk and Revenue Relationship

4.6.5 Questions to consider:

1. Which model offers the firm an opportunity for disruptive innovation through services?
2. Which model provides the most flexibility in relation to the potential value created?
3. Which model will help continued innovation of product and/or service value?

4. Which model allows for platform building in the future?
5. What is the market value of each PSS option? Tangible (product) versus intangible (experience). This is discussed further in the marketing activity.

4.6.6 Effects to down-stream activities:

This activity impacts the following step, the Service Model Concept Consideration.

4.7 Operations

4.7.1 Inputs: Concept and product
4.7.2 Outputs: Operations management plan

4.7.3 Definition: The operations management plan oversees the design, implementation, and control of the production and repair of the product and service infrastructure.

4.7.4 Method to determine operations strategy and impacts:

1. Examine the life cycle costs of the product including standard deviations of cost and schedule projections
    a. Understand the flexibility of the current infrastructure's ability to deliver the service model
    b. Understand the growth capabilities in the infrastructure
2. Determine the level of service expected by the user
3. Contrast the level of service needed with the level of support and infrastructure that exists
    a. Understand the ROI impact on the operations cost projection
    b. Stay up to date on speed of technology that may increase due to service offering
4. Ensure that the design of the product-service is built to handle technical upgrades
    a. In traditional products, great effort is often made to control multiple software releases. The correct software infrastructure with a single platform should be able to do simultaneous upgrades across customers.

4.7.5 Questions to consider:

1. What additional service employees will be on the ground? To whom will this team report in the organization?
2. What are the switching costs associated with retiring old or damaged equipment to install new or renovated equipment?

a. (In some cases, switching costs can be as high as the original capital costs. e.g., re-launching satellites, or switching out liquid-metal batteries that lack modularity, etc.)

3. How can unexpected costs due to careless use of the service by the user be estimated?

4.7.6 Effects to down-stream activities:

The activity can affect the overall financial viability of the service. For example, operational activities that are not planned accordingly can create a scenario where the organization is may lose a competitive advantage by being forced to raise prices or lower service levels due to unexpected operational costs. Lower than expected service levels may in turn affect the organization's ability to keep existing customers. The organization's branding may also suffer for this lapse in quality. As discussed in the branding activity, this circumstance may have further downstream effects.

4.7.7 Discussion:

Understanding the level of service expected by the user is an important concept to understand. While this should also be understood when selecting the correct service concept, the impact is enough to also note in this section. Based on statistical defect processes, the difference between 90%, 95%, or 99% reliability may be significant enough to drastically impact costs and the overall user experience.

4.8 Finance

4.8.1 Inputs: Concept, product, and operations

4.8.2 Outputs: Finance estimates and projections

4.8.3 Definition: Management of the costs and risk for the product-service system. In many cases, to receive leadership support for a product or service, the expected ROI needs to be verified and the amount of risk must be acceptable to management.

4.8.4 Method to determine finance strategy and impacts:

1. Define financial plans and ability to support capital costs
2. Define the amount of risk and verify if it is acceptable
3. Define the spending structure for time, i.e., The time to see a return on investment
4. Diversity of investments
    a. Definition of risk premiums per concept and delivery method
    b. Length of expenditures
        i. Short term ROI versus Long-Term ROI
    c. Potential for growth service and the ability to raise more capital

4.8.5 Questions to consider:

1. What is the annuity payment our company would pay on the capital costs for the lifetime of the product? What is the present value of annuities?
2. Is the financial plan flexible enough to handle the risk?

4.9 Marketing

4.9.1 Inputs: Product, stakeholders, and concept

4.9.2 Outputs: Marketing plan, and feedback from users

4.9.3 Definition: The plan to communicate the value of the service to customers, present and future

4.9.4 Importance: The ability to capture value past the value chain, now and into the future, is the key the longevity of the product-service system.

4.9.5 Method to determine marketing strategy and impacts:

1. Understand the strategic position in the network of the value chain
2. Ensure low entry barriers to enable lower customer acquisition costs and increased loyalty
3. Understand the need for platform to 'lock' customer into the product-service
    a. Continue dialog with customer to understand new un-met needs and needs that are no longer necessary

4.9.6 Effects to down-stream activities:

The marketing activity impacts the branding activities. There is also feedback to the customer, relationships and concept selection based on customer research done after deployment of the product-service system.

4.9.7 Discussion:

A firm's ability to conduct customer research has increased with recent technology advancements in big data. Many companies are now able to analyze their customers buying and searching tendencies to determine trends that will help future designs and marketing approaches. Using a service strategy allows an organization to recognize trends across many diverse customer groups. This activity may also point to the possibility of complimentary assets that can assist in building a product-service platform.

4.10 Brand

4.10.1 Inputs: Product, customers needs, concept, and marketing

4.10.2 Outputs: Product branding plan

4.10.3 Definition: Branding is the communication of an organization's reputation to the market and general public. Branding is a key aspect to attract new employees and new opportunities.

4.10.4 Method to determine brand:

1. Understand the organization's current stance on branding in the organization
2. Determine the impact on the brand by the process product-service system
    a. For example, transforming a military or government product into a commercial product may help or possibly hurt an organization's reputation
    b. Focus on attracting new markets for service opportunities
    c. Focus on attracting new employees

4.10.5 Questions to consider:

1. What are implications to our brand? Will this require new branding, visual elements, for a new type of customer?

4.10.6 Effects to down-stream activities

1. Customer attractiveness
2. Employee attractiveness and retention

4.11 Business Model Composition

The business model activity is the final activity in the Product-Service Transformation Process. The purpose of this activity is to synchronize the information obtained in the previous activities. The Product-Service Transformation Process is designed to be evaluated by managers prior to an organization's standard business development tasks leading to a proposal.

An analytical model comprising of information computed in the previous activities are now evaluated. Value and forecasting tools such as Net Present Value (NPV) and payback period calculations are computed. A comparison between service models is made to provide the organization with the best model for the respective product. Definitions of the previously mentioned value and forecasting tools are substituted for similar tools that an organization may prefer.

Pricing and the competition are evaluated based on expectations and projected market penetration. Another important aspect is factoring in uncertainty. Uncertainty is based off past performance and market studies.

Not to be forgotten is the recognition of any feedback that is necessary to alter upstream activities. While the process appears linear, the information gained through the progression may have impacts in previously completed activities.

4.12 Conclusion

The Product-Service Transformation Process is a means of developing an existing product into a product-service system. The previous 10 activities serve as building blocks to guide managers who are considering the product-service strategy. Understanding the customer needs, the product, and the organizational objectives are critical to this process and should be fully realized before executing this process.

In the following section, the Product-Service Transformation Process will be applied to the CASA Radar System, an X-Band Phased-Array Radar used for weather forecasting and environmental warning, designed by a team from the University of Massachusetts and several industry partners. The goal of the application is to understand if by transforming the radar system from a product to a service, the UMASS-industry team can create more value by serving a wider range of customers, such as weather-sensing firms and not-for-profits that could utilize the system but is unable to support its upfront capital costs.

Chapter 5: Validation Case Study: Product-Service Transformation of the CASA Radar System

5.1 Introduction

The Product-Service Transformation Process was validated by means of a case study demonstration. The following section discusses the motivation and implications involved in transforming an established radar product into a radar service.

This research builds a service model using the Collaborative Adaptive Sensing of the Atmosphere (CASA) Radar as the established product. The CASA Radar System is an X-Band Phased-Array Radar used for weather forecasting and environmental warning. It was designed by a team lead by the University of Massachusetts and encompassing several academic institution as well as several industry partners [24]. The case study details the nuances of transforming the radar system from a product into a service and explains that the resulting product-service can increase the product's commercial value by meeting a greater number of customers' unmet needs. The additional customers come from a valuable eco-system that is unable to support the radar's capital costs, such as weather-sensing firms and non-profit institutions, but which would pay for the radar as part of a service.

5.2 Background

Weather radar was first introduced after World War II when military radar operators realized that the technology also could help predict weather behavior, such as rain and snow. Since then, weather radar has become an important system for forecasting and storm warnings. The current weather surveillance radar system in the United States is derived from a network of system named the Weather Surveillance Radar – 1988 Doppler or WSR-88D or NEXRAD [25]. This system is a network of 160 high-resolution S-band Doppler radars, scattered throughout the United States. The WSR-88D system was a major leap in technology when it was first introduced in 1988 [25]. The high-resolution and multi-parameter tracking capability enabled observers to identify mesocyclones and tornadic vortex signatures [25]. This improvement led to an increase in tornado warning lead times from 7 to 10 minutes [25]. Further upgrades have moved the warning time to 13 minutes. As a result, deaths and injuries from tornadoes have also decreased by approximately 40%. The WSR-88D uses a 10 cm wavelength S-band radar capable of a complete scan every 4.5 to 10 minutes [22]. The deployment of the WSR-88D radar system is displayed in Figure 18, courtesy of NOAA [26].

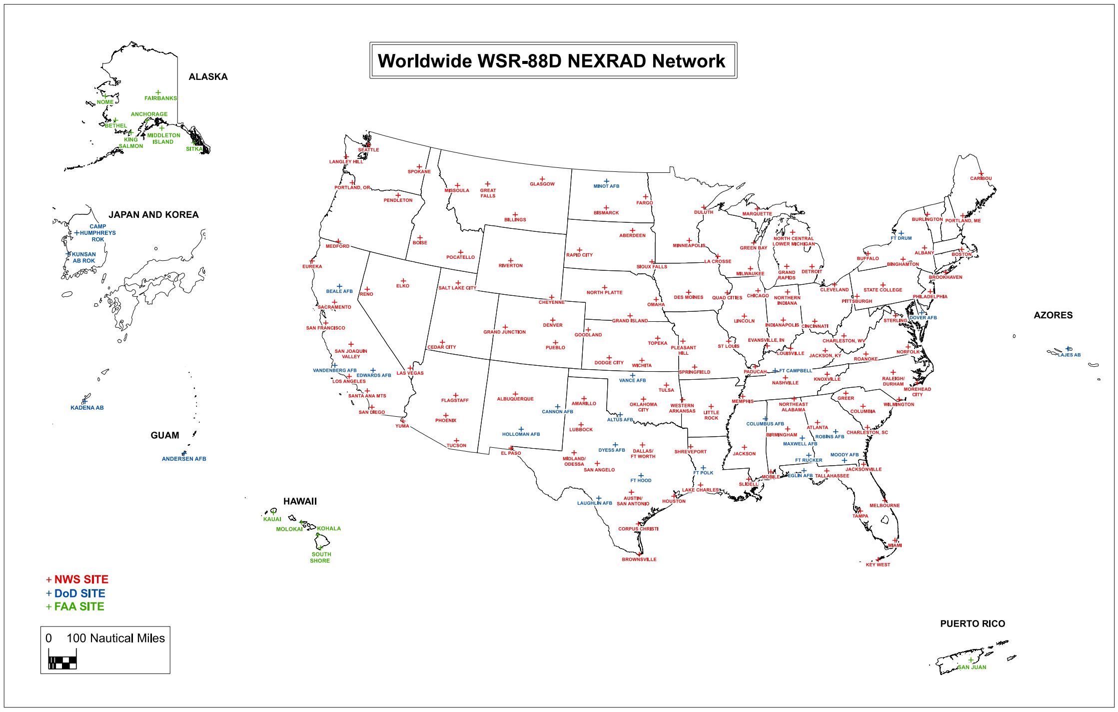

Figure 18: WSR-88D Deployment in the United States

While the WSR-88D system has widely improved the weather reporting and warning systems across the United States, the system is not without problems. The needs of the system vary from region to region and climate to climate. These needs depend on the depth of precipitating cloud systems and local topography as well as the need for rapid update cycle and improved data quality [27]. The WSR-88D system uses high-power, long-range radars to sense weather trends.

The downside of this long-range design is the coverage loss due to the curvature of the Earth's surface. This gap prevents the WSR-88D system from detection the full vertical rotation of most tornados [25]. An example of this is displayed in Figure 19 [28].

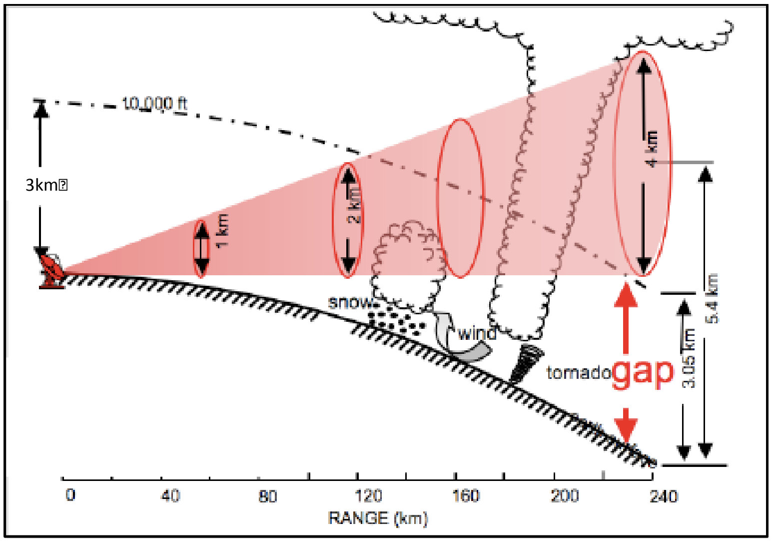

Figure 19: Radar gap due to curvature of Earth's surface

To help mitigate the atmospheric sensing gaps from the long-range radars, localized weather systems also exist to supplement the WSR-88D. The Terminal Doppler Weather Radar (TDWR) and the Airport Surveillance Radar (ASR) support more localized sensing, but both are limited in capability. The TDWR uses a 5 cm wavelength, which doubles the range resolution when compared to the WSR-88D. Unfortunately, this wavelength dimension can mask heavy rainfall in some situations including during heavy storms [29] [30].

The ASR is the system currently used at airports to detect aircraft position. The ASR is a mechanically rotating radar that operates in the range of 2700 to 2900 MHz [31]. This radar system was first introduced in 1995. While the ASR does support the airport mission, it is not designed to detect storms and cannot be used in conjunction with wind farms [32].

The United States Government essentially provides the weather sensing data to the public free of charge through the National Weather Service (NWS). The US Government, by way of the Federal Aviation Administration (FAA), funds the design, manufacture, and deployment of the TDWR. The FAA, in conjunction with the Department of Defense (DoD), funds the ASR. The WSR-88D radar data is available on the NWS website. Broadcasters and online weather reporting firms use this free data to provide weather reports and forecasts to the public. Many of these firms charge a fee via television or site subscription for this service.

5.3 CASA Radar Overview

The CASA Radar System was developed to be a comprehensive radar network with an emphasis on the lower atmosphere, thus minding the atmospheric gap of long-ranged radars, while delivering equivalent data quality. Funded by a National Science Foundation (NSF) grant and a consortium of industry leaders, the CASA program has relied on $40 million in funding over the past 10 years. The design of the system has been led by a team based at the Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere at the University of Massachusetts in Amherst, Massachusetts. CASA Radars have been tested against tornados in Oklahoma, the flash floods in the Dallas Fort Worth Megaplex, and wind shifts causing spreading fires in Australia.

The Collaborative Adaptive Sensing of the Atmosphere (CASA) Radar is designed to alleviate the capability issues of the current atmospheric radar system of the United States. The CASA Radar system is designed to operate as an array of X-band phased array short-range radars. The system is a low-cost enhancement to compliment and/or replace the WSR-88D, TDWR and ASR radars. Beyond the cost, the attractiveness of the CASA system is the size and mobility of the system. The radars are only 3 feet by 3 feet and can be mounted on cell phone towers and the sides of buildings. By separating the radars by 10-20km, the sensing gap derived from the earth's surface can be eliminated. This also provides for a concentration of radars when the need is high and a lower concentration in other areas. Another benefit of the CASA radar technology is its ability to track multiple objects simultaneously. The CASA radar and the WSR-88D are compared in technical detail at the end of the paper in Table 15.

The CASA Radar has benefitted from radar technologies improvements enhanced by modern advances in military technology, including the telecommunications boom in the 1990s, which changed the economics of this previously extremely expensive technology.

X-band and phased array technologies have been used in many military applications including the AN/SPY-1A radar [33]. The AN/SPY-1A is a major element on the AEGIS weapon system. Originally ground based, the AN/SPY-1A is often used on ships such as the Arleigh Burke-class destroyer. The radar is a phased array radar capable of tracking multiple objects and revisiting objects much quicker than that of a S-Band Radar, such as the WSR-88D Doppler radar [33]. The phased array radars have been used for early detection warning, which is often the most life-critical mission of weather radar. The AN/SPY-1A has been tested for weather sensing at the National Severe Storms Laboratory in Norman, Oklahoma since March 2003.

The radar system has received endorsements from the director of the NOAA National Weather Service Office of Science and Technology, Jack Hayes. Hayes describes the project explaining “CASA’s sensors would capture crucial boundary layer information, better define weather activity, and contribute to a more accurate forecast [25].”

While the advantages of the CASA capability have been proven in testing, the financial merit of the radar network outside of solely government funding has not. Utilizing the process defined previously in this paper, i.e., the CASA system as a service, will be explored beginning with its projected customers and markets and product goals. The result of the study will examine if there is a sufficient market opportunity to sell improved radar sensing to customers who for the most part, currently receive free albeit inconstant and often inaccurate information.

5.4 The Customer

The market for the CASA Radar System can be understood in seven principle industries; aviation, broadcasting, national weather safety, general public including non-weather related businesses, agriculture, off-shore drilling and utility services. The analysis for each market is detailed below and summarized in the table in this section: Table 1 (Customer Defined), Table 2 (Customer Needs), Table 3 (Prioritized), Table 4 (Segmented), and Table 5 (Need Frequency). Note the word 'customer' is used interchangeably to describe a single customer, a customer group or an entire commercial market.

Aviation Industry

The needs of the aviation industry are defined as airline safety on takeoffs and landing and in general, tracking airplanes. Radar tracking accuracy is important for forecasting future delays and staffing needs [34]. Since the aviation industry is one of the largest commercial industries in the world and has an enormous budget, this customer cannot be ignored. The potential to build a radar network based primarily at airports is a realistic possibility for this technology. The projected users of the radar technology are the airport's meteorologists, the airline's weather analysts, and the air traffic controllers. The primary paying customer is the FAA [31]. The FAA is responsible for airport radar sensing stations and airplane tracking. The airline passengers act as charitable stakeholders since they do not have any influence on the system but would benefit from safety improvements.

Technology advances in aviation radar are frequent. The existences of rival or alternative technologies and or services are accounted for in the terms of the product's ability to penetrate the market. This reinforces the benefit of a service meeting more than one core customer and is an important advantage to a possible product-service. This is further discussed in the Business Model Composition activity.

An additional need of this market is a radar that can track multiple objects simultaneously. In theory, this would be a radar that can perform weather sensing and tracking planes while maintaining accuracy and speed to meet both missions' requirements.

Commercial Weather Industry

The second market is the commercial weather industry. There are local and national components to this market. Local TV stations and their meteorologists have a strong presence in the daily lives of the local population. Accurate and timely reports on storms, tornados, and other harmful weather trends are key to keeping the population safe. The local population relies on broadcasters and their meteorologists to provide this support.

The WSR-88D Doppler radar provides the data that a majority of broadcasters utilize. Due to the radar gap, many tornadoes go un-reported. From 2000 to 2004, the NWS or local meteorologists did not report 26% of tornadoes [35]. These tornados often occurred at night when the ramifications are often worse. According to an analysis of four states, TX, OK, MA, and CT, only about 25-30% of weather stations owned their own radars [34]. Since a majority of broadcasters cannot afford their own radars, any solution where a broadcaster will need to pay for their weather data will need to be affordable.

The Weather Channel and the channel's various competitors such as AccuWeather and Weather Underground represent the national component. These firms rely on the WSR-88D Doppler radar to provide storm reporting throughout the country [36]. Recently, the Weather Channel has tightened its focus by concentrating reporting on local weather trends [37]. This reinforces the need and desire for local reporting.

An un-met need in the commercial weather industry, local and national, is an optimal method for delivering information to the public. Facebook and Twitter have become almost irresistible tools for much of the population in the US. Meteorologists have also fallen suit. Recent research found that meteorologists often use social media tools to discover and communicate with other meteorologists. The research found that 95% of meteorologists use NWSChat, a chat service provided by the NWS, and 40% use Twitter.

Safety Weather Industry

Every year, adverse weather affects many economic sectors, which amounts to thousands of lives and injuries as well as billions of dollars in damages. For this reason, the federal government, in particularly, the National Oceanic and Atmospheric Administration (NOAA), primarily conducts the overall logistics of weather safety. NOAA manages the National Weather Service, whose responsibilities include operating the WSR-88D Doppler Radar and providing data to meteorologists and researchers. Most of the data and products provided by the NWS are in the public domain and available free of charge.

The NOAA published six goals with four that directly connect to enhance radar technology. These four goals listed below require more accurate, timely and manageable data.

Goals of the National Weather Service are as follows [38]:

1. Improve weather decision services for events that threaten lives and livelihoods
2. Deliver a broad suite of improved water forecasting services to support management of the country's water supply
3. Enhance climate services to help communities, businesses, and governments understand and adapt to climate-related risks
4. Improve sector-relevant information in support of economic productivity

General Public and Storm Chasers

There are a large number of regular people who are interested in weather [37]. This category represents the people who are interested in weather and the 'Storm Chasers' who follow and report on storms and tornados in person. There have been IMAX and reality TV shows on the storm chaser phenomenon. It is very unlikely that an individual or a storm chaser could afford to purchase the radar, but the prospect of paying for only data may be attractive. An additional need for this group is for easily accessible data and the ability to access the data in an open software environment [39].

Urban Weather Management

The study of hydrology has contributed to city management's ability to manage water flows and reduce flooding. With improved abilities to predict precipitation and flash floods, meteorologists and the city works managers are able to decrease flooding by funneling water to reservoirs and opening and closing dams. Timely data for flooding cannot be overstated since 40% of deaths from flooding occur when unsuspecting people are trapped in their cars and 75% of all fatalities occurring in the evening or overnight hours [40]. This is a relatively new field, but timely, accurate data, would benefit cities at flood risk.

Agriculture

Timely and precise weather data is important for the agriculture industry. Accurate reports can help farmers mitigate losses from damaged crops due to the impact of unexpected weather. Forecasting techniques can also assist in enhancing the irrigation performance and the correct use of herbicides and pesticides. International firms currently dominate this market. This may be due to the large amount of software sold to supplement the WSR-88D Doppler radar. If a new radar system were implemented, this would be an advantageous market to explore [34].

Offshore Drilling

Offshore weather patterns are unpredictable. Drilling companies can mitigate loss of lives and drilling time by better predicting storms. This is an un-met need because the WSR-88D Doppler does not accurately cover sea-based platforms due to range limitations.

Wind-energy

Utility firms that specialize in wind energy provide another potential market. While predicting winds may be helpful to gauge return on investments, the ability to farm wind at airports is a lucrative pursuit. Currently, the radars used at airports are unable to perform when there is a windmill nearby. The blades of the windmill mask most radar returns. Since the CASA Radar operates an X-band signal, the CASA can still receive radar returns in this scenario [32].

Table 1: Service Customers and Charitable Stakeholders of the CASA Radar

Ref #	Customer / Market	User	Purchasing Agent
1	Aviation Industry	Airport Weather Analyst, Air Traffic Controller	FAA
2	Weather Broadcasting Industry	Commercial Meteorologists and Broadcasters	Broadcasting Leadership
3	National Weather Safety Industry	Research Meteorologists	NOA and NWS
4	Urban Weather Management and Safety	Department of Public Works (DPW)	City or State Leadership
5	Off-shore drilling industry	Meteorologists in the oil and gas industry	Oil / Gas Company Leadership
6	General public consumer	General public	General public
7	Agriculture Sensing	Agriculture Firms	Agriculture Firm Leadership
8	Wind energy utility	Utility Firms	Utility Firm Leadership
	Charitable Stakeholders		
1	Airline Passengers	NA	NA
2	General public safety	NA	NA
3	General public consumer (people interested in weather)	NA	NA

Table 2: Customer Needs

Ref #	Customer / Market	Key Needs	Un-met Needs
1	Aviation Industry	1. Ensuring weather safety for takeoff and landing 2. Tracking planes	1. Reliable weather reporting 2. Timely Reporting
2	Weather Broadcasting Industry	1. Reliable local weather 2. Timely reporting 3. Affordable 4. Manageable for new platforms	1.Improvements on the reliability of local weather 2.Timely reporting 3.Manageable for new platforms
3	National Weather Safety Industry	1. Improve weather decision services for events that threaten lives and livelihoods (Reliable and timely Data) 2. Improved water forecasting 3. Enhance climate services to help communities and businesses 4. Improve sector-related information in support of economic productivity	Improvements on all four goals
4	General public consumer / Storm Chasers	1. Affordable 2. Assessable - Easy to use 3. Open Platform Options	Current availability is limited to information provided by the NWS and broadcasters.
5	Urban Weather Management and Safety (Hydrology)	1. Timely reporting to take immediate action on local trends 2. Reliable data - Information would be used to reduce flooding by managing reservoirs and dams	New Industry, so all needs are un-met
6	Agriculture Sensing	1. Timely reporting for warning off-shore teams to save lives and equipment 2. Reliable data 3. Affordable	Market is currently dominated by international software companies using WSR-88D data
7	Off-shore drilling industry	1. Timely reporting for warning off-shore teams to save lives and equipment 2. Reliable data - Current large radar systems can miss storms especially ones in non-populated areas	Current large radar systems can miss storms especially ones in non-populated areas
8	Wind energy utility	1. Detailed local weather to better predict energy generation 2. Ability to use wind energy generation at airports 3. Affordable	Future customer

Customer Prioritization

The customer list was prioritized based on the "attractiveness" of the customer to the product. This activity was computed by weighing certain attributes that are important for a successful CASA product launch. It should be noted that this was done with limited resources and is shown here as an example of the process, not the complete solution. The result of this analysis is displayed in Table 3.

The customers are ranked based on three key attributes. Each customer's attribute is ranked on a scale of 1 to 3, with 3 representing the highest value. Each attribute is prioritized by weight or 1, 2 or 3 based on its importance to the system. The first attribute is the size of the market. Since it is often easier to distribute a product through services, the size of the market is important. For this reason, the size of the market is ranked highest among the three attributes. The second attribute is the difficulty to enter the market. A product's ability to penetrate an existing market is crucial for success. Based on the projected service offering, each customer was ranked based on the product's ability to enter that respective market. The third attribute is the budget of the customer. While the budget of the customer is important, it is ranked third among the priorities due to the fact that there are many possible simultaneous customers of the system. This elevates the need to focus on customers with large budgetary resources. These values have been derived from the qualitative information detailed in the customer descriptions.

Table 3: Customers Prioritized

	Rank	Customer / Market	Size of Market	Difficulty to Enter Market	Budget of Customer	Total with Weighting
Primary	1	Aviation Industry	3	2	3	16
	2	Weather Broadcasting Industry	3	2	2	15
	3	National Weather Safety Industry	3	2	2	15
	4	Urban Weather Management and Safety	2	3	2	14
	5	General public consumer	3	2	1	14
Secondary	6	Agriculture Sensing	2	1	2	10
	7	Off-shore drilling industry	1	1	3	8
	8	Wind energy utility	1	1	2	7
		Weighting of priority	3	2	1	

The customers are then segmented into groups based on the customer's purpose and the magnitude of their budgets. The customer's purpose is the goal of that organization. For example, flight tracking for the aviation industry and early weather warning for the National Weather Service. The first group contains the big business of aviation. The second group includes the three safety industries. The third group is the general public and the storm chasers who have the largest market, but the weakest individual budgets. This group also includes private businesses that use the public data to make business decisions. The secondary customers were not included in the three groups because it is deemed that these customers currently do not have enough impact on the business to sway the system's value stream. These secondary customers may prove to be useful once the system is active and prices have been reduced, but cannot be accounted on to provide revenue.

Table 4: Primary customers segmented into groups

Rank	Customer / Market	User	Purchasing Agent	Size of Market	Difficulty to Enter Market	Budget of Customer	Total with Weighting
1	Aviation Industry	Airport Weather Analyst, Air Traffic	FAA / Airports / Government Funding	3	2	3	16
2	Weather Broadcasting	Commercial Meteorologists and	Broadcasting Leadership	3	2	2	15
	National Weather Safety Industry	Research Meteorologists	NOA and NWS	3	2	2	15
	Urban Weather Management and	City / DPW	City or State Leadership	2	3	2	14
3	General public consumer	General public	General public	3	2	1	14

Secondary customers not included (Agriculture, Offshore Drilling, Wind energy utility)

5.5 Product

The product is the CASA Radar system. The high-level intent of the system is to provide surveillance for a specified area with a single radar or multiple radars connected through a network. This surveillance can be characterized as weather detection and airplane tracking.

The agile beam phased-array radar is the central technology that drives the function delivered by the radar. The second-level goals and functions are listed in the table below. Each product goal is connected to a solution specific function in Table 5: CASA Radar System's Goals and Functions.

CASA Product Functions

The product goals are listed and described below [21] [25] [41].

Table 5: CASA Radar System's Goals and Functions

Ref #	Product Goal	Product Function
1	Timely Data	Phased array rapid scanning
2	Multi-Mission	Multiple Phased Array Radar technology
3	Safety	Low-Powered Radar
4	Affordable	Low-Cost Individual Radar. Can act as shared resource and cost among users
5	Assessable - Easy to use	Adaptable and trainable
6	Focused sensing for concentrating on locations and removing blockage objects	Phased Array Radar permits the ability to use adaptive scanning to vary focus and beam angles.
7	Better Data	Low atmosphere sensing with the absence of beam smearig
8	Weather Sensory	Vertical profiling of horizontal winds and improved measurements of rainfall and retrieval of refractivity
9	Low Maintenance	1. Simple radar without pivoting aspects therefore no downtime for failures to gears and motors 2. Gradual radar degradation instead of the total loss seen in most radars
10	Multiple End Users	Scanning strategy optimizes user preferences and needs with a users computing limitations in mind.
11	Accompanying software package	Real-time detection algorithms, automated to detect hazardous weather conditions from data from the CASA radar.

* Since the CASA Radar is still in testing, the product functions here are as-published developmental functions.

The utility provided by the CASA Radar Systems is the radar's ability to provide better radar image from the lower atmosphere. The phased radar has the ability to focus and concentrate on locations and remove blocking objects, such as land masses, buildings, and other obstacles [25].

Another goal of the product is to provide a high speed of data scanning and transmission. This is accomplished by the rapid scanning ability of the phased array technology [41]. Another goal is the phased array's ability to track multiple types of objects simultaneously [25].

The next goal is to provide a safe environment for the people who live or work in close proximity to the radar. The radar is designed to minimize the power emitted by utilizing a multiple of small low-energy radars instead of one, high-powered radar.

The cost is an important factor since the CASA Radar System requires numerous radars. One WSR-88D radar costs $10M per radar and takes one to three years to construct due to site selection, land preparation, site access, tower, communications, and electric power installation. There are 156 radars in the WSR-88D radar system, amounting to $1.56Billion in radar costs [42]. In comparison, the CASA Radar is relatively inexpensive. There are many predictions on the cost of the CASA Radar once it hits a mass size production and estimates range from $20k to $200k per radar with an annual maintenance cost of $20k. Since the CASA Radar can be placed on cell-phone towers and roofs, the costs and time to install is minimal [41].

Another important feature of the radar is that it requires low maintenance. The low maintenance is due to the fact that the phased array radar is mechanically simple, as it does not require any rotation or pivoting. The system also gradually degrades instead of the total loss seen in most other current radars. The gradual degradation allows for the system to still operate if the maintenance schedule slips [25].

Another important aspect of the CASA Radar System is the ability for users to easily generate data and images. For this reason, the CASA team has provided a Quantitative

Precipitation Estimator (QPR) along with the accompanying software package [41]. The system can also operate for a multiple of end users.

Table 6: Product Mapping with Delivery Methods

Product Goal	Product Function	Service Delivery Method(s) for Function
Timely Data	Phased array rapid scanning	Speed discrimination
Multi-Mission	Multiple Phased Array Radar technology	Different costs plans based on mission need
Affordable	Low-Cost Individual Radar. Can act as shared resource and cost among users	Price discrimination based on system performance
Focused sensing for concentrating on locations and removing blockage objects	Phased Array Radar permits the ability to use adaptive scanning to vary focus and beam angles.	Quality and location discrimination
Better Data	Low atmosphere sensing with the absence of beam smearig	Quality discrimination
Weather Sensory	Vertical profiling of horizontal winds and improved measurements of rainfall and retrieval of refractivity	Quality discrimination

Table 7: Product mapping for system attributes that are not part of service model

Product Goal	Product Function	Service Delivery Method(s) for Function
Safety	Low-Powered Radar	Attribute of System
Assessable - Easy to use	Adaptable for multi users without training	Attribute of System
Low Maintenance	Simple radar without pivoting aspects therefore no downtime for failures to gears and motors	Attribute of System
Multiple End Users	Scanning strategy optimizes user preferences and needs with a users computing limitations in mind.	Attribute of System
Accompanying software package	Real-time detection algorithms, automated to detect hazardous weather conditions from data from the CASA radar.	Attribute of System

It should be noted that the product functions in Tables 6 and 7 are specific to the product. Once the delivery method of the service is defined, complimentary assets based on these functions will be developed to add value to the system.

CASA Phased Array Radar and the Dynamics of Product Innovation

James Utterback defines the maturity of a design by the product's phase of the innovation. The MIT professor determines the phases by the number of entries into the market [16]. Since there are not many entries into the weather sensing industry, it is difficult to quantify the phase. It could be argued that the S-Band WSR-88D Doppler radar is the current dominant design but the existence of the X-Band Phased Array may very well be a disruptive innovation in this market. Clay Christensen examines the concept of disruptive innovation in *The innovator's dilemma: when new technologies cause great firms to fail.* Christensen defines a disruptive innovation as a product or service that disrupts the existing market and eventually displaces the existing technology [20].

5.6 Organization Objectives

The theoretical organization used for this case study is a radar and software engineering manufacturer. The organization is large enough to support the manufacturing of the radars as well as producing and updating the software. The organization is also financially capable of producing numerous CASA Radars to begin the initial phase of deployment.

The following are the goals of the theoretical organization.

1. Be recognized as the top radar and software firm in the US
2. Be recognized in the community
3. Produce a profit for the owners or shareholders
4. Provide excellent service, including accessibility, reliability, timeliness, reasonable prices

The organization values the risk versus reward trade-off and the firm is established enough to be able to leverage calculated risks for future profit.

5.7 Connection: Goals to Value

The stakeholders are mapped to the corresponding goal and value-added function by means of the value added delivery method. Using the method from the Product-Service Transformation Process, displayed in Figure 14, the goals-value connection is detailed. The results are noted in Tables 8 and 9. Table 9 follows the process for each customer and Table 10 uses the customer groups described in the Customer activity and presented in Table 5. In addition, Table 9 also displays the different service models available for each customer group and their respective needs. The following activity analyzes these models and the expected return on investment for each. The assessments on the best delivery mechanism are derived from the information in Tables 6 and 7.

Table 8: Goals to Value Connection for the CASA Radar

Need Rank	Customers	Product Goal	Product Function	Service Delivery Method(s) for Function
1	Weather Broadcasting Industry, NWS, Urban Weather Management, Off-shore drilling industry, Agriculture Sensing	Timely Data	Phased array rapid scanning	Speed discrimination
2	Weather Broadcasting Industry, NWS, Urban Weather Management, Off-shore drilling industry, Agriculture Sensing	Better Data	Low atmosphere sensing with the absence of beam smearig	Quality discrimination
3	Weather Broadcasting Industry, NWS, Urban Weather Management, Off-shore drilling industry, Agriculture Sensing	Weather Sensory	Vertical profiling of horizontal winds and improved measurements of rainfall and retrieval of refractivity	Quality discrimination
4	Weather Broadcasting Industry, NWS, Urban Weather Management, Off-shore drilling industry, Agriculture Sensing	Focused sensing for concentrating on locations and removing blockage objects	Phased Array Radar permits the ability to use adaptive scanning to vary focus and beam angles.	Quality and location discrimination
5	General Public	Affordable	Low-Cost Individual Radar. Can act as shared resource and cost among users	Price discrimination based on system performance
6	Aviation Industry	Multi-Mission	Multiple Phased Array Radar technology	Different costs plans based on mission need

Table 9: Connection for Stakeholder Groups

Customers	Product Goal	Product Function	Service Delivery Method(s) for Function	Specifics of Delivery
Aviation Industry	High Quality Data	- Low atmosphere sensing with the absence of beam smearig - Vertical profiling of horizontal winds and improved measurements of rainfall and retrieval of refractivity	Quality discrimination	1. Sell radar with maintenance contract 2. Lease radar 3. Sell radar data per customer usage (following the discrimination methods detailed in the Weather Safety group)
	Timely Data	Phased array rapid scanning	Speed discrimination	
	Multi-Mission	Multiple Phased Array Radar technology	Different costs plans based on mission need	
Weather Safety	High Quality Data	- Low atmosphere sensing with the absence of beam smearig - Vertical profiling of horizontal winds and improved measurements of rainfall and retrieval of refractivity	Quality discrimination	Users pay for the precision of data (high cost for high precision data, low costs for less precise data)
	Timely Data	Phased array rapid scanning	Speed discrimination	Users pay for the speed of data (high cost for real-time data, low costs for lagged data)
	Focused sensing for concentrating on locations and removing blockage objects	Phased Array Radar permits the ability to use adaptive scanning to vary focus and beam angles.	Quality and location discrimination	Users pay for the local or national data
General Public	Affordable	Low-Cost Individual Radar. Can act as shared resource and cost among users	Price discrimination based on system performance	Price discrimination based on system performance (speed, price, precision, and location) - low levels for most population
	High Quality Data	- Low atmosphere sensing with the absence of beam smearig - Vertical profiling of horizontal winds and improved measurements of rainfall and retrieval of refractivity	Quality discrimination	Users pay for the precision of data (high cost for high precision data, low costs for less precise data)

5.8 Service Model Concept Consideration

Utilizing the information from the Connection, Goals to Value process activity, the CASA Radar System can be considered for the three product-service models, product oriented, use oriented, and results oriented. Below is a description of the three models with a following pricing model based on each service concept.

Product Oriented: The product oriented service model is the typical business model for a radar product system. The organization would sell the radar system to a large budget corporation and continue to sell whole life services for the product. This is a similar approach to many large, expensive systems today, in particular, defense-oriented products. The product oriented service model provides the most risk adverse approach for the organization but limits the potential customers to only firms or organizations with an extremely high budget. In the CASA Radar System example, this amounts to only one customer; the agencies of United States Government, in practically the FAA. While individual CASA Radars are only projected to cost $200k, a sizeable network of CASA Radars needed to provide adequate coverage would be expensive. Since the FAA has funded the other active radar systems, this would be a great opportunity but may be difficult as the WSR-88D system is still operational. The proposal effort would need to be supported by the scientists and meteorologists at NOAA and the NWS. While this is a profitable approach, the likelihood of the government funding the entire system is not certain due to the current climate of government spending and the fluctuation of political administrations,

Use Oriented: A leasing model would be a use-oriented service model that would fit the CASA system. This model would consist of an organization leasing the CASA Radars to customers. This model would allow the organization to reach more customers than the product oriented model, but would still alienate customers with lower budgets such as the general public and the safety customer group. The organization in this case would accept the risk of maintaining the radars while the customers would be responsible for running the radars themselves or through an additional service contract with the organization.

Results Oriented: A pay for usage service model would be the optimal results-oriented method for the CASA Radar. This model would enable the largest number of customers to utilize the radar's data and would add to the population's weather awareness. A similar model is that of the Bloomberg Terminal. The Bloomberg Terminal is leased to customers an annual fee per user. The service is for the terminal and the financial data on the system. This fee, $20,000 per user, is paid to access the Bloomberg Professional service, to monitor and analyze real-time financial market data. With more participants using the service and contributing data, the Bloomberg service can offer a richer experience as its customer base grows.

To accomplish this model for the CASA Radar System, the organization would offer several levels of service. The levels would be differentiated based on the radar's attributes such as speed, quality, security, and mission. Each level of service would be priced on a log-based scale similar to the notional scheme in Figure 20. The highest level of service would be designed with the FAA and the air travel industry in mind. This service would include the fastest radar transfer speeds, the best quality of data, the ability to provide multi-mission support, and the data security for tracking planes. This package would cost significantly more when compared to the lower level packages.

The service performance and cost for data would decline from the top-level package. The next group would be the national piece of the Safety group, the NWS. This would focus on providing meteorologists with speed and quality to provide safety for the nation. An addition to this package, there would be a plan that would focus on the commercial broadcasters and urban weather management. Their needs are similar to that of national weather broadcasters, but would focus on local weather forecasting.

The lower level service would focus on meeting the needs of the general public. This level would have two sub-levels, a paid subscription and a free plan. The paid version would provide a level of quality based on a certain precision. The free version would be limited similar to the free content provided by the Weather Channel and AccuWeather. The free version would benefit from additional revenue from advertisements and add-on services.

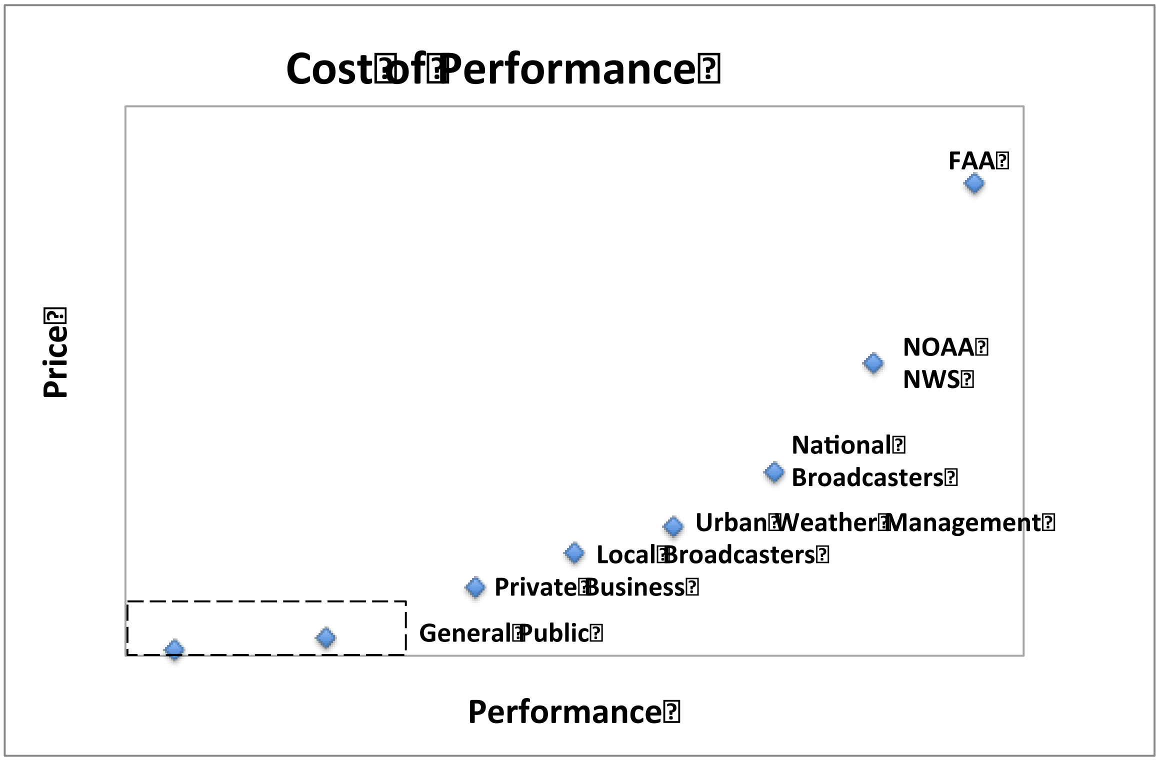

Figure 20: Cost of Performance

The price and time it takes to build a customer base may leave the radar producing organization in a vulnerable position. An alternative approach in this results-oriented service model would be to sell data to the Weather Channel and AccuWeather and allow those firms to disseminate the data based on their current subscribers. In 2005, AccuWeather reported that their firm had 150,000 subscribers including 180 Fortune 500 companies (many in transportation, agriculture, and energy), state and local governments, and media outlets [43]. The company estimated that the overall audience is 100 million people in 45 markets, 200 radio stations, 850 newspapers, and 600 websites [43]**.** The Weather Channel and AccuWeather currently based a majority of their forecasts on data from the WSR-88D [36].

5.9 Operations

The operations management plan oversees the design, implementation, and control of the production and repair of the product and service infrastructure. Understanding the nuances of the operations' plan for the selected concept, the results-oriented pay per service, the operations, is key to a successful service.

The life cycle cost of the service is a main factor of the operations plan. This is largely based on the level of service required by the customers. With three diverse customer groups, the organization needs to satisfy the highest level required by the groups. This requirement would be the FAA who will be using the system to constantly monitor planes. This requirement is consistent across the three service models discussed in the concept selection. Since the radars are networked together to produce a composite depiction, the FAA would drive the service requirement. An incentive for the results-oriented service model is that it would demand a higher fee from the FAA due to this need. The general public that does not require the same attribute and would be able to receive a lower level of service for a lesser fee.

This requirement impacts the amount of hardware maintenance that is essential for the service. While the CASA is more reliable and significantly easier to maintain than the WSR-88D system, it will still require periodic hardware servicing. Another aspect of the hardware maintenance is the consequence of users mishandling the radar hardware. This is not an issue for the results-oriented model, but it is an issue for the other two service models. From a software point of view, the task will be more straightforward. While upgrades for most large-scale systems are costly, this service model creates a simpler, more direct approach to product modernizations. Since customers will not own or possess, in terms of leasing the radars, the organization will be able to fix software bugs and make upgrades whenever they are necessary.

Another important operations aspect of the CASA Radar for any of the product-service models is the radars integration with current the radar systems. Until the CASA radar becomes the standard for weather detection, the CASA radar system will need to connect with all the current early alert weather systems.

Managing new employees and the additional infrastructure is another task for the organization. The organization used for this examination can manage the new employees needed through a technical services business unit, but the additional software needed for a weather analyzing platform will be an added component. This software component will provide a customer-facing distribution platform and user-facing applications development to enhance the usefulness of the radar data to a widening set of customers.

Adhering to a cradle to grave policy, the organization will need to consider how it will salvage the radars at the end of their lives. This will be applicable to all the product-service models in consideration. The most likely salvage answer is the opportunity of moving the system to another market, most likely a foreign market, or selling the hardware to another company with an alternative mission or market. This would be contingent on export protocol for selling products that have had previous military use. For the both the results-based approaches and the use-oriented approaches, the system can still be sold by the organization. For the product oriented service model, the organization would act as the middleman for salvaging the radars.

5.10 Finance

There are financial impacts of the results-oriented model in regards to the CASA Radar system. The top priority for any organization is a product's return on investment (ROI) and the time period to reach the return given both the opportunity costs and calculated risk of the investment. This risk is understood as the transferred capital risk to the organization. In the traditional product model, the customer bears this financial risk when the product is purchased. The results-oriented model transfers all the financial risk to the producing organization.

The financial risk can be partially mitigated by two strategies, phasing the deployment of radars and concentrating the radars in areas where data purchasing subscriptions are the highest. The phased deployment of the radars is a consistent strategy for many products on the market, but the idea of concentrating radars in high subscriptions areas is noteworthy in this case since the radars are being used for safety purposes. The radars would be positioned in areas of high subscription, likely major cities, NWS hotspots like tornado alleys, and airports. While this could theoretically leave some areas without radar coverage, the thinking would be that NOAA would step in to supplement these areas.

5.11 Marketing

The organization will need to use a different approach for each customer. Connecting to the FAA and the NWS will require a government relationship, and marketing to broadcasters will require a different tactic.

Using a platform software approach, the organization will be able to grow the profitability of the radar by offering a software platform to users with basic tools and more complex tools for an additional cost. This approach will also help the organization build an online store to shop high level tools and analytics tools. In an optimal solution, this would work similar to Apple iStore or Google Play. This would command a non-trivial addition to the cost and maintenance of the radar's accompanying software system.

5.12 Brand

The organization's brand will improve based on the fact that the service provided is a community safety program that improves on the current system. The general public will appreciate the low-level free service while the higher level services will be utilized by meteorologists and broadcasters working to alert the population in times of dangerous weather patterns.

Another thought-provoking aspect that should be considered in terms of commercial weather is the political and societal impacts associated with the product. The fact that weather information is currently free to the public is an important facet to consider. Highlighting this issue, in 2005, Pennsylvania Senator Rick Santorum sponsored a bill in the Senate to essentially give private companies exclusive access to the data provided by the NWS, in particular the data from the WSR-88D [44]. This was a blatant attempt to bring more business to AccuWeather, a Pennsylvania firm. While the bill was not approved in Congress, the backlash he received highlighted the particular concerns of corporate involvement in public safety [36]. Although the CASA Radar Network is designed to complement the existing weather sensing systems and the results-oriented model does provide a level of free reporting, the public-corporation interface is an important one.

5.13 Business Model Composition

Comparing the methods with a value model

To further evaluate the CASA Radar's service opportunities, a value model was designed to assess the three service methods. Using a quantitative approach to understand the number of users and their projected budgets for atmosphere sensing, the return on investment (ROI) was evaluated for each product-service model using net present value (NPV) with a 6% discount rate. The attributes for this analysis are built from assumptions made from publications cited in this paper. The variables are meant to act as an example of what a corporation should do to understand which service-model is a best fit given the risk-reward comparison. Each model was built to generate a 10% margin on all products including maintenance. Note, uncertainty was not realized in this model. With sufficient information, one could add uncertainty to variables such as demand, cost, and competition interference.

Product Oriented

The product-oriented model defines this method as one large purchase by a customer, the FAA, and an on-going maintenance contract. The number of radars needed to satisfy the continental United States is set to 3,120 units. This is based on an assumption that 20 CASA radars can mind the ground currently covered by one of the 156 deployed WRS-88D radars [45]. The cost of the radars is set to $200,000 per radar with an annual maintenance of $20,000 [45]. Since the product is sold to the customer, there is not a salvage value at the end of the radar's life. The pricing was determined as a 10% margin on all products including maintenance. The profit per year is displayed graphically below. This illustrates the initial jump in profit when the radar network is sold, followed by a stream of profit due to the maintenance contract. The NPV results, displayed in Table 10, exhibit the expected value for this approach. This is a great model when a high-budget market is available. The NPV slowly rises over each time period due to the on-going maintenance contract. Note that this model does not see the NPV fall below zero.

Table 10: Product-Oriented Model NPV

Option	NPV - 5 years	NPV - 10 years	NPV - 20 years	Payback Period (yrs)
Product-Based	$ 85	$ 105	$ 130	1
Amounts are listed in Millions				

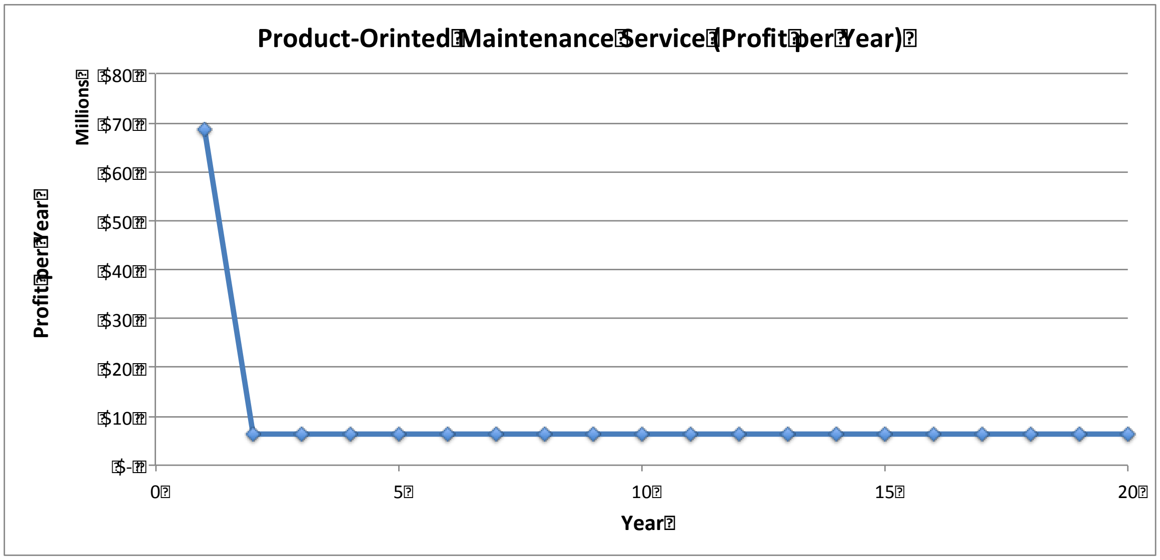

Figure 21: Annual Profit: Product-Oriented Service Model

Use-Oriented

The leasing strategy allows the customer to benefit from the radar network without the large up-front costs. This model requires the organization to build the network and requires the customers to pay an annual fee to possess the radars. The pricing for the service was computed off the annual break-even fee once a discount rate of 6% was factored into the equation. The annual leasing fee is then set to $160M/yr for a 20-year lease. Due to this large fee, only the government agencies, FAA and NOAA, are included as customers. At the end of 20 years, there is an estimated salvage return amounting to 20% of the initial costs of the radar. This is an assumed value used to represent this use-oriented service advantage. The annual profit is graphical depicted below. The graph shows the initial drop due to the deployment of the leased radars. The organization eventually realizes a profit but it takes several years.

Table 11: Use-Oriented NPV

Option	NPV 5 years	NPV 10 years	NPV 20 years	Payback Period (yrs)
Use-Oriented	$ (178)	$ 130	$ 570	7
Amounts are listed in Millions				

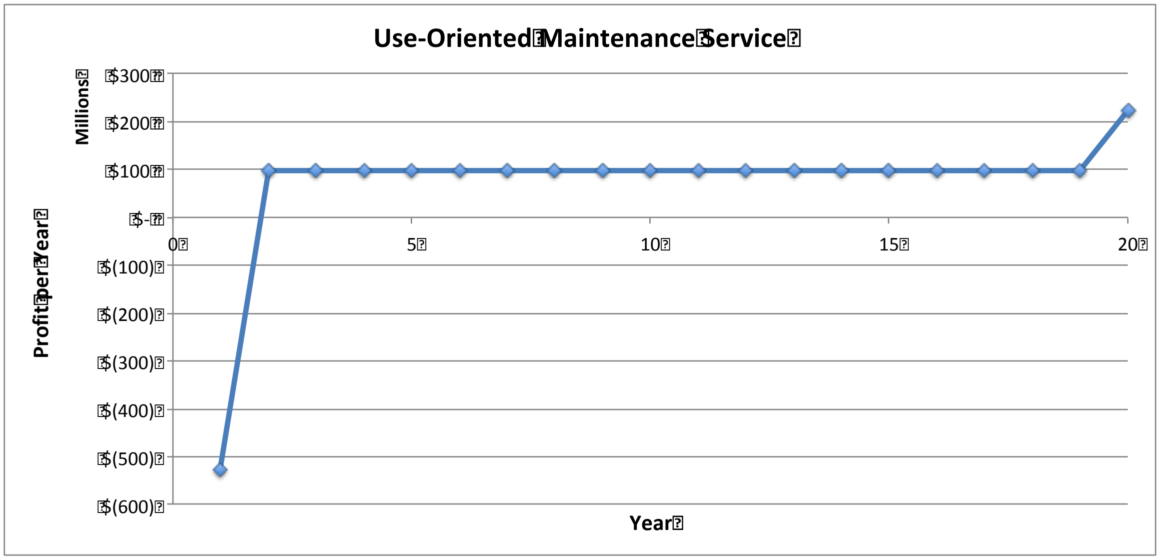

Figure 22: Annual Profit: Use-Oriented Service Model

Results-Oriented

The results oriented model is a more complicated. The previous models assumed the entire radar network would be purchased or leased to the government. For this model, the total demand for each customer is calculated based on several sources including the current customer portfolio of AccuWeather [43]. These details are listed in the table 12.

While the demand sets a cap for the firm's sales, the actual sales are limited to the firm's ability to penetrate the market. The market penetration is derived from an S-Curve, which is a method often used to represent the diffusion of a new technology or product. The parameters of the S-Curve are a = 99, b = 0.40, and M = 0.70. These parameters represent a standard S-Curve and are estimates made for this analysis. The variable 'M' represents a maximum market penetration of 70%. This is an assumed value with consideration for competition in the market at the conclusion of 20 years. A graphical display of the curve is noted in Figure 23. To account for the slow progression due to the market penetration, the radar network is deployed in phases. The initial phase is 500 radars, followed by a 20% increase each year until 3120 units have deployed. Similar to the use-oriented model, salvage value after 20 years is 20% of the initial costs of the radars system. Additional costs were also added to this model to account for the software development and maintenance expenses. This amount was assumed to be $5 million in the first year, followed by $1 million each year with an increase of %10 each year.

A very important aspect of the results based service model is the pricing structure. The pricing structure defined for this model and listed in Table 12 [43] [34] [38] was formulated based off AccuWeather's current pricing configuration. The pricing model was built to be competitive with AccuWeather and simplified into prices for each customer instead of tiers for a less complex computation.

AccuWeather currently charges a variety of prices for a collection of various services. Individual consumers are charged $100/year for their premium service. This increases to $240/yr for a high level of personal use. AccuWeather also offers a free web and mobile version that is cluttered with advertisements. For commercial customers such as private businesses, AccuWeather offers their services for $840/yr. These pay plans are discounted slightly if the consumer agrees to pay for a yearly subscription. Additional add-on services include tiered levels of RadarPlus, a local service for $500/yr, and Lightning Plus, a real time data option for $2400/yr [46].

In addition, AccuWeather offers AccuWeather Enterprise Solutions that offers an array of product for an unlisted price. These plans are based on consolation from AccuWeather's sales team [46].

Table 12: Customer Demand and References for data

Customer	Total Demand	Initial Cost per Airport/Office/User (Increased 5% per year)	Refernce
FAA	2212	$110,000	Total number of airports in the USA
NOAA / NWS	1000	$82,500	Estimated number of users at NOAA offices
National Broadcasters	10	$55,000	Estiamted number of national broadcasters. ie. Weather Channel, AccuWeather
Urban Weather Mgmt	300	$22,000	Estiamted number of US cities over 100,000 people
Local Broadcasters	1,200	$11,000	Estimated from the 'Weather Radar Market Report'
Private Business	50,000	$1,100	Estimated based on AccuWeather's customer profile
General Public	150,000	$110	Estimated based on AccuWeather's customer profile
Free Level w Ads, Ad-ons	15,000,000	$2	Estimated based on AccuWeather's customer profile

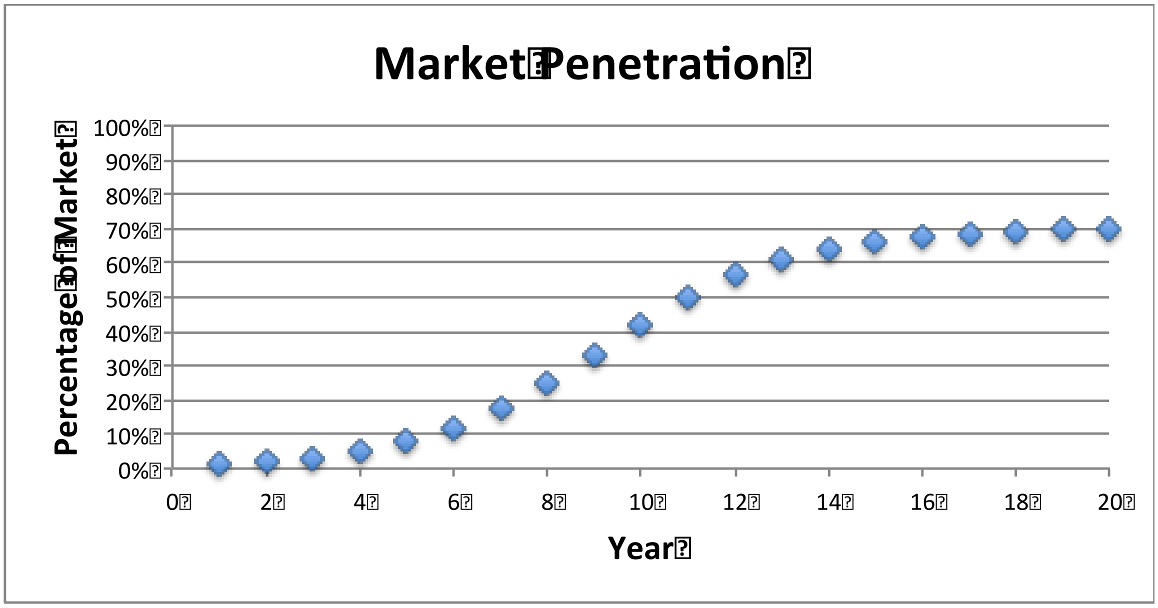

Figure 23: Market Penetration for Results-Oriented Service

The notional cost for performance (Figure 20) was updated using estimates based on the budget of the particular customer (FAA, NOAA, broadcasters) and AccuWeather's cost structure when applicable to the customer (Private Businesses, General Public). This is detailed in Table 12 and graphical represented in Figure 24.

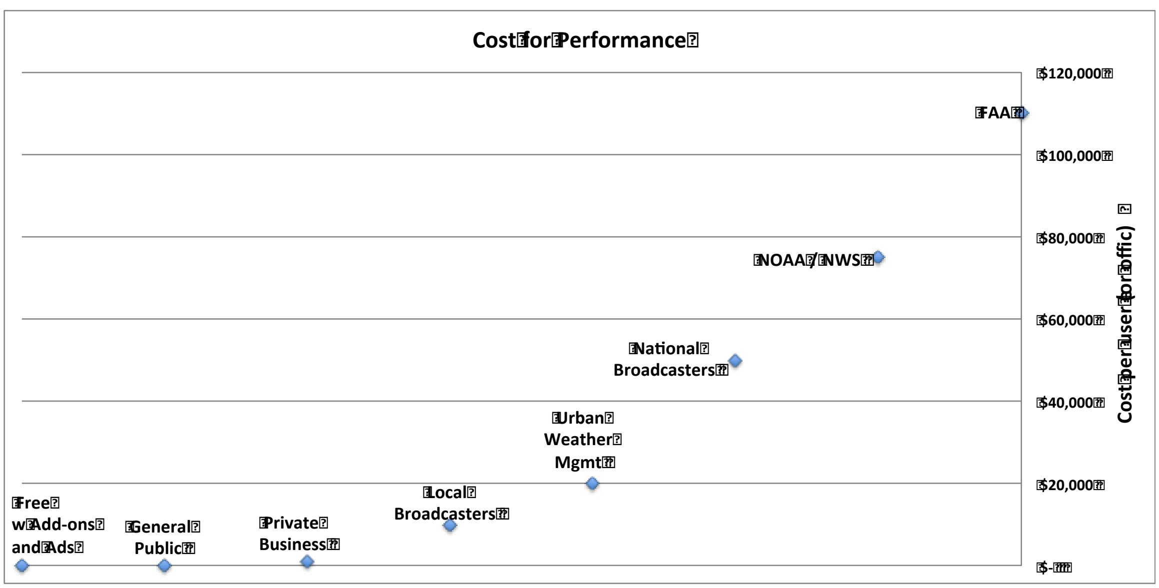

Figure 24: Cost of Performance of the Use-Result Service

The annual profit of this model is graphed in Figure 25. The slower deployment aids the initial years, but the model does not become very profitable until after the 12th year when the entire system has been deployed and radar deployment costs have subsided. There is a substantial quantity of customers at this point and pricing has slowly increased by 5% each year. This increase was computed to account for the 10% margin.

Table 13: Results-Oriented NPV

Option	NPV 5 years	NPV 10 years	NPV 20 years	Payback Period (yrs)
Results-Based	$ 130	$ 41	$ 2,244	9
Amounts are listed in Millions				

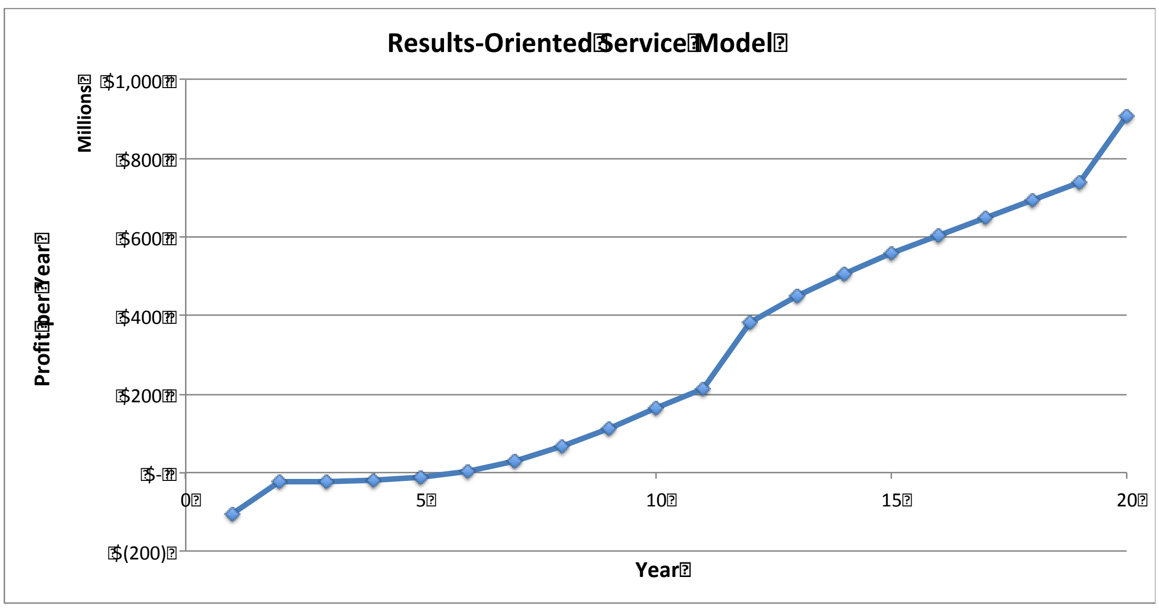

Figure 25: Profit Per Year: Results-Based Service Model Comparison

The importance of the service's ability to penetrate the market is reiterated by the model's sensitivity to the variable, maximum market penetration (M) in the S-Curve equation. The NPV of the model breaks even at 18% and has the potential to make $3.3B with 95% of the market. The plot also shows the negative affects of selling to a diverse market. If the service does not perform well and only 5% of the market is penetrated, the NPV is a loss of $600M.

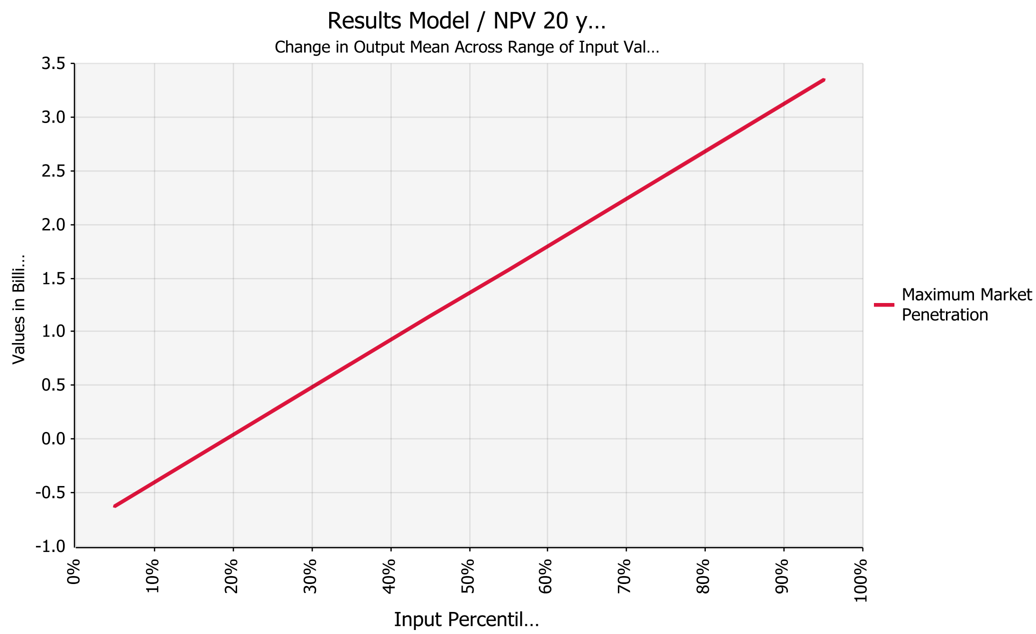

Figure 26: The variability of Market Penetration on 20 Year NPV

Table 14: Service Results in Terms of Net Present Value

Options	NPV 5 years	NPV 10 years	NPV 20 years	Payback Period (yrs)
Product-Based	$ 85.00	$ 105.00	$ 130.00	1
Use-Oriented	$ (178.00)	$ 130.00	$ 570.00	7
Results-Based	$ (173.00)	$ 41.00	$ 2,244.00	9
Amounts are listed in Millions				

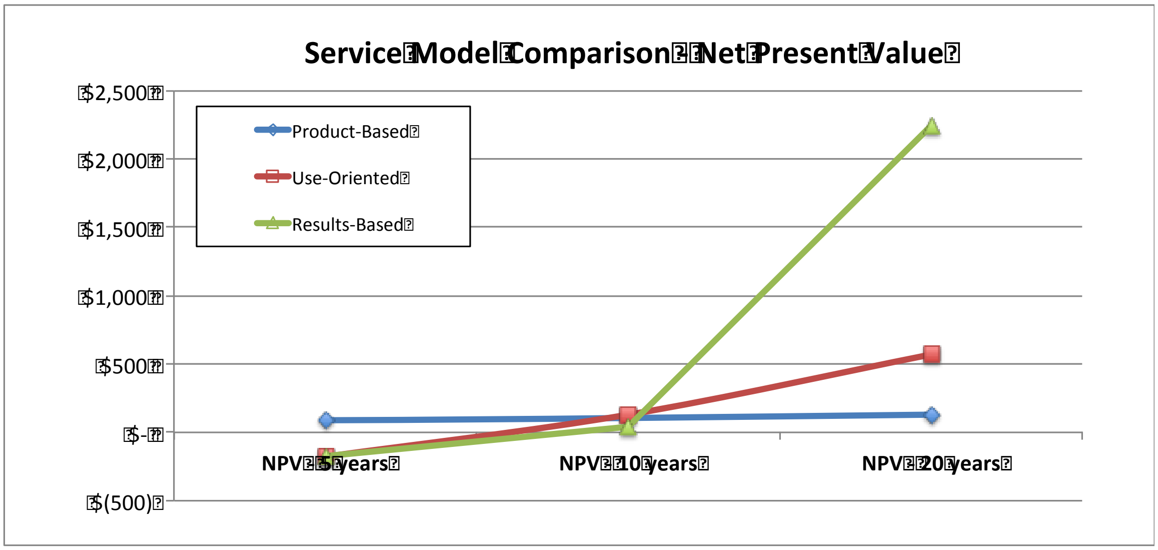

Figure 27: Net Present Value Comparison

The results in Table 14 and Figure 27 show the NPV and payback period differences in the models. The product-oriented service is a low risk, low profit approach. The use-oriented service adds more risk to the model and concludes with a higher concluding value. The results-oriented approach outlines the high risk, high reward approach. The ability of this model to reach out to a greater number of diverse customers is an advantage that cannot be overlooked. In this model, the Results-Oriented model would only need a market penetration of 22% to reach the same 20-year NPV of the Product-Based model.

The diversity of customers and potential for high profit of the results-oriented service model make it the selection for the CASA Radar Network. While the models generated in this analysis are built from several assumptions, the NPV calculations show that the underlining risk-reward theory remains constant.

5.14 Discussion of Results

Utilizing the Product-Service Transformation Process, an organization can realize the steps required to build a service from a product. In this example, the CASA radar was analyzed and the three main service models were investigated. The results-oriented model demonstrated to be the best long-term solution for the organization.

The servitizing of the CASA Radar System provides insight into the risk versus reward balancing act that organizations must consider. By accepting the capital risk of the large product deployment of the CASA Radar System through the results-oriented and use-oriented models, the organization has taken on the risk that the customer would have accepted in a standard product model. This additional risk results in a long-term profit that would not be realized in a traditional product or product-service model.

The three product-service models discussed in this analysis display the different approaches an organization can choose based on their ability to reach out to a larger, more diverse customer groups by absorbing capital costs and risk to reach out. The organization-customer relationship for standard product such as the CASA Radar ends when the product is sold. Utilizing services can extend both the organization-customer relationship and the product. The product-oriented model for the CASA radar extends the life of this relationship by forming a maintenance contract. The use-oriented model through leasing services allows the customer base to grow by removing the customer's one-time capital expense. The results-oriented model takes the CASA Radar further into the service space by not only removing the customer's capital expenses, but also using price variations to maximize the consumer market.

The pricing model used for the CASA Radar results-oriented example exhibits the means to meet the price demands of different customers by essentially providing the same service. While not performing traditional price discrimination, defined as offering the same product or service at different prices, the results-oriented approach allow for the

CASA team to operate the radars in the identical manner and produce different levels of services for each customer group.

The multi-leveled pricing model allows customer to pay for the level of service that they can afford. In doing so, the organization can reach more customers and can receive greater return on their investment.

To summarize, the Product-Service Transformation Process is a value added means to transform the CASA Radar System into a service. In today's volatile financial climate, it may not be prudent to rely on governments to supply the funds for new technologies. In this political and financial atmosphere, there is a need to reach as many customers as possible when building a market for expensive technologies that are not usually available to consumers due to high up-front capital costs. Servitizng the CASA Radar is a game changer in saving populations from weather storms that are not visible by the current weather systems.

The next step to validate the fidelity of the process will be to exercise the process on active products. While this study presented a qualitative assessment based off published literature and assumed specifics, the natural next step will be to quantify the results in a real business situation.

Chapter 6: Conclusions and Recommendations

The Product-Service Transformation Process can be an effective method to unpack and reconfigure an existing product into elements that can be employed as a service. The product-service models presented in this analysis can allow a firm to benefit from a more diverse customer base, especially when struggling with large, core customers in a recessionary environment. Through the case study method, the process is illustrated utilizing the CASA Radar as product that could be transformed into an effective service. While the study of the CASA Radar provides a valuable qualitative analysis, the limited empirical basis and lack of external validation of the model and assumptions leave an opportunity to further detail specific methods and tools used in the this study.

The product-service transformation starts by understanding the customers' un-met and latent needs. To fully evaluate the product's ability as a service, the entire array of customers is examined. While only a small set of customers may be able to afford the capital costs of the product, a potentially much larger number of customers may be able to afford the service of the product, or a new variant, often using simpler or older technology, or operating with time delay to create layers of price discrimination. An organization's understanding of its product's value to multiple types of buyers is an important principle of the product-service transformation. The value directly connects to the un-met needs of the customers. Of course, the process can only work if a firm can identify unmet needs in the market, requiring a thoughtful analysis of multiple types of competitors that compete directly or indirectly for the same business.

To be successful, a product-service program, such as the one described in this study must be understood and supported by management. Managers and shareholders, whom are concerned with short-term profit, may not have the patience to follow through with transforming a product into a service system, such as in the example of the CASA radar. Another potential challenge for an organization that enters the product-service space from a more traditional product background is the paradigm shift needed to see scope for solutions that they may not be accustomed to seeing. The process described here is designed to answer these concerns. Special attention should be paid to avoid potential pitfalls such as the ones highlighted in the Iridium and Concorde cases.

Investing in a large product-service system to profit from a services model can work if the concept matches the customer, product, and organization. Each of the core models investigated has advantages and disadvantages. The conservative product-oriented model proved to be a risk adverse approach intended for an organization with an affluent customer base. The use-oriented model is designed for the organization that will accept the majority of the capital risk in return for a higher overall margin from the customer. The results-oriented model is intended for the organization that desires to reach a larger potential customer base. This model delivers the highest amount of risk to the organization in exchange for the best ability to best profit from the larger, diverse customer population.

An incentive of the product-service system is the potential contributions to ecological sustainment by increasing resource productivity. Extending the life of products and sharing them among users can save resources. While the example discussed here focuses on a new, shared technology, there are also product-service systems that extend the lives of products. This includes extending the life of expensive military technologies once the military and security use is fulfilled. While the CASA Radar System was invented by scientists and engineering students, the basis of the technology is derived from the AN/SPY-1A naval radar. This is just one case where the life of a military technology is prolonged in the public domain.

An area of research for future studies is the process of developing products specifically for the product-service system. While transforming a product into a service can produce value, designing for this process can yield a greater profit and service. Similar to the philosophy of designing for six-sigma, designing for products-services may prove to be a profitable option for products that lose their core customer or are capable for an extended life.

The product-service system can be a potentially valuable approach for an organization to leverage domain knowledge to expand business markets to win more customers. Examined and demonstrated by the CASA Radar, this method suggested the possibility of generating recurring revenues from different market segments by creating a new business model for the existing product. The service approach was seen to be a mechanism to increase the life of products by reaching a second tier of customers who could not afford the initial capital costs of the product, but could be interested in paying for a service to meet the same needs.

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Appendix A:

Table 15: Technical specifications listed for CASA and WSR-88D radars

	CASA	WSR-88D
Operating frequency	9.41 GHz	2.7 – 3.0 GHz
Wavelength	3 cm	10.0 cm
Antenna diameter	1.20 m	8.53 m
Antenna gain	38 dB	45.5 dB
Antenna beamwidth	1.8°	1.0°
Oversampling	1.0°	Planned for future build.
Range gate spacing	100 m	250 m
Maximum rotation rate	35 deg s^{-1}	36 deg s^{-1}
Acceleration rate	50 deg s^{-2}	15 deg s^{-2}
Average transmitter power	9 W/polarization	1.56 kW
Peak transmitter power	7.5 kW/polarization	750 kW
Minimum Detectable reflectivity (10 km)	-2 dBZ	-23 dBZ
Pulse repetition frequency	1.6 kHz, 2.4 kHz	318-452 pulses/sec 318-1304 pulses/sec
Pulse width	660 nsec	1.6, 4.5-5.0 μ sec
Dual-polarization?	Yes	Scheduled for 2010-2012.
Radome, diameter	2.4 m	11.9 m

Reference: [45]