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Fast Glass: Modernity, Technology, and the Cinematic Lens

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FAST GLASS:

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by

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ABSTRACT

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This dissertation tells a cultural history of how lenses became cinema lenses. While lenses are essential for film production, we know very little about the early history of cinema lenses. Rather than just focusing on which lenses were used on certain movies, I historicize how lens production became an industry. Between the 1880s and the 1920s, lens production shifted from an artisanal craft to a commercial industry. By looking at how companies created lenses for film production and projection, I expand early film history to account for the creative work of opticians, engineers, advertisers, and distributors. In more specifically focusing on how lenses became "cinema lenses," I historicize how ideas central to film studies – perspective, objectivity, subjectivity, and realism – were considered in relationship to lenses. I examine four influential optical companies in Germany (Zeiss), France (E. Krauss), the United States (Bausch & Lomb), and England (Taylor-Hobson). By examining international optics alongside film history, we can see that lenses were not just the product of remarkable inventors or ever-improving designs. Ultimately, I argue that lenses were shaped by a wide range of social, cultural, and industrial debates about the role that technologies of vision played in 19th and 20th century life.

For my Mom

For my Dad

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Introduction | Lens Culture

> For the successful photographing of motion pictures in studios and in all kinds of weather, a lens of considerable speed is needed.
>
> *Motion Picture News (1916)*

“Fast glass” describes lenses ideally suited to photographing subjects that are either quickly moving or in low conditions of natural light. The phrase, poetically collapsing the space of the lens’ view with the speed of the camera shutter, is an informal term used by photographers and cinematographers to describe lenses with wide apertures. Fast glass is also emblematic of a belief that photography and cinema encouraged at the turn of the 20^{th} century: that technology could arrest and illuminate a world beyond direct human perception.

Lenses supplemented and enhanced human perception during a period of intense and rapid technological change in Europe and the Americas. Cities were undergoing rapid industrial expansion; manufacturing technologies were reshaping visions of labor and leisure time; railroads accelerated the circulation of people and products alike.[1] Science, art, literature, and philosophy sought to represent dramatic changes in perceptions of time and space that occurred as a consequence of an increasingly rapid technological world. This constellation of changes constituted cultural modernity: a term Anson Rabinbach uses to describe the intimate connection that developed between rapid industrialization and representations of time and space. In contrast

[1] For broader discussions of the relationship between technology and modern culture, see Rabinbach, *The Human Motor*; Jonathan Crary, *Techniques of the Observer: On Vision and Modernity in the 19th Century* (Cambridge: MIT Press, 1990); Leo Charney and Vanessa Schwartz, eds., *Cinema and the Invention of Modern Life* (Berkeley: University of California Press, 1995); Brian Jacobson, *Studios Before the System: Architecture, Technology, and the Emergence of Cinematic Space* (New York: Columbia University Press, 2015); and Mary Ann Doane, *The Emergence of Cinematic Time: Modernity, Contingency, the Archive* (Cambridge, MA: Harvard University Press, 2002). For a more detailed discussion of modernity and transit, see Wolfgang Schivelbusch, *The Railway Journey: Trains and Travel in the Nineteenth Century* (New York: Urizen Books, 1979); Kristen Whissel, *Picturing American Modernity: Traffic, Technology, and the Silent Cinema* (Durham, NC: Duke University Press, 2008); and Ott, “Iron Horses: Leland Stanford, Eadweard Muybridge, and the Industrialised Eye.”

to technological modernity, which foregrounds technology as the central criteria of modernization, cultural modernity emphasizes that any technological development should be recognized in the context of its self-construction by society. Amidst these changes in social experience were scientists, artists, and entrepreneurs who sought to capture moving images of a changing world through a camera lens.

Perhaps more than any other representational form, cinema held a privileged relationship to modernity. As Leo Charney and Vanessa Schwartz contend in *Cinema and the Invention of Modern Life*, cinema became the "fullest expression and combination of modernity's attributes" due to the fact that "modern culture was 'cinematic' before the fact."[2] A changing relationship between vision and experience characterized modern culture's cinematic nature. Workers saw their time materialize as commodities.[3] Passengers took pleasure from the railroad's collapse of time and space.[4] Citizens increasingly looked at the world as consumers in urban shopping centers and brought these practices to the world more broadly.[5] Cinema did not just represent the modern world: the modern world was increasingly experienced as cinematic.

Although less closely examined by early film historians in comparison to manufacturing, transit, or urbanization, the industrialization of precision lenses emerged in and through the same changes that gave rise to the emergence of cinema and modern life. As theorist Mary Ann Doane argues, photographic images, especially motion pictures, best expressed and visualized the abstract knowledge authorizing the interlocking social projects of science, government, and

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[2] Leo Charney and Vanessa Schwartz, "Introduction" in *Cinema and the Invention of Modern Life*, eds. Leo Charney and Vanessa Schwartz (Berkeley: University of California Press, 2007), 1.
[3] Mary Ann Doane, *The Emergence of Cinematic Time: Modernity, Contingency, The Archive* (Cambridge: Harvard University Press, 2002), 7
[4] Wolfgang Schivelbusch, *The Railway Journey: The Industrialization of Time and Space in the Nineteenth Century* (Berkeley: University of California Press, 1986).
[5] Anne Friedberg, *Window Shopping: Cinema and the Postmodern* (Berkeley: University of California Press, 2000).

industry. The public fascination with daguerrotypes, stereoscopes, photography, and cinema was a fascination with the "encoding of lens imagery in a permanent, retrievable form."[6] If modernity was cinematic, this was due in no small part to the industrialization of lens production and the adoption of optical technologies by a wide array of modern institutions. Between the 1880s and the 1920s, lens production widely shifted from an artisanal practice to an industrial system. Lens production was predominantly located in newly industrial cities like Jena, Rochester, and Leicester. International systems of modern traffic brought together resources like clay, fuel, refined silica, and professional knowledge.[7] The mass production of lens-based instruments – ranging from to microscopes to binoculars to photographic cameras to cinema cameras – manufactured perception as an object for mass-consumption.

In optics, lens history is frequently written as the product of remarkable inventors or as an ever-improving series of physical designs. Rudolf Kingslake's foundational work, *A History of the Photographic Lens* (1989) is an exemplary work of optical history that provides a wonderfully complex, but primarily technical, history of lens design. As he writes early on in his book:

> Any attempt to develop a strictly chronological approach to the history of the photographic objective is invariably confused by a hopeless mass of crosscurrents. It would be easier if each type of lens had been invented, developed, perfected, and then abandoned in a limited period of time…Unfortunately for the historian, but fortunately for the working photographer, the lenses available at any one time cover a wide range of constructional types."[8]

Kingslake's history traces the history of photographic lenses through different types of lens designs. In contrast to most optical histories, Kingslake's work is nuanced and accounts for the multiple and overlapping trajectories of lens production. But, the latter third of Kingslake's book

[6] A.D. Coleman, "Lentil Soup," *Et Cetera* (Spring 1985): 20.
[7] For more on modern traffic, see Kristen Whissel, *Picturing American Modernity.*
[8] Rudolph Kingslake, *A History of the Photographic Lens* (Boston: Academic Press, 1989), 7.

exemplifies a pervasive tendency that infects histories of science and technology more broadly: the history of optics written as a pantheon of fifty-nine white men, with nearly all hailing from Europe or from European descent.[9] Kingslake himself acknowledges that even this list was the result of a difficult search, with hundreds missing. To challenge this history is not to invalidate the work or contributions of these opticians, but to ask: what else affected the development of lenses over time? The multiple forms of visual culture that emerged from the use of lenses were not solely the product of new technologies, remarkable inventors, or commercial promotors.

This project argues that the industrialization of precision lenses in the late 19th and early 20th century – explored here as both a material and a cultural practice – was as much a cultural event as it was a series of technological developments. For most of the 19th century, individual opticians created lenses on the basis of refined craftwork and intuition. Beginning in the 1880s, when Zeiss began to manufacture new kinds of distortionless lenses on the basis of scientifically designed glass, optics began to closely align with practices that sought to apply "new scientific modes of perception to social questions" that could bring a utopian spirit of scientific neutrality to 19th century culture.[10] The idea that lenses could improve society was not a techno-determinist misunderstanding so much as it was a product of the way that technology was becoming interwoven in the social fabric of industrial modernity.[11] As Brian Winston suggests, technologies are "embedded in the social sphere and are themselves and ideological expression of the culture."[12] As David Noble similarly suggests, technology is deeply within culture, and

[9] This biographical section of the book makes up over a third of the volume's length. Rudolf Kingslake, 192-314.
[10] Anson Rabinbach, *The Human Motor: Energy, Fatigue, and the Origins of Modernity* (Berkeley: University of California Press, 1990 (1992)), 86.
[11] Readers of David Noble's *America By Design,* Olivier Zunz' *Why the American Century?*, and David Hounshell's *From the American System to Mass Production, 1800-1932* will find striking parallels between the industries of chemicals, electricity, higher education, and optics.
[12] Brian Winston, *Technologies of Seeing: Photography, Cinematography, and Television* (London: BFI, 2009), 39.

constitutes "fundamental social development in itself: the preparation, mobilization, and habituation of people for new types of productive activity, the reorientation of the pattern of social investment, the restructuring of social institutions, and, potentially, the redefinition of social relationships."[13] Lenses did not descend upon modern life fully formed for the use of photographers and cinematographers. As technologies, lenses were shaped by a series of social, cultural, and industrial activities that shaped the conditions under which a lens came to function as a reliable and practical technology of vision.

This project examines the cultural history of the motion picture lens from the 1880s to the late 1920s. To do so, I trace the history of early cinema through four influential optical companies in Germany (Zeiss), France (E. Krauss), the United States (Bausch & Lomb), and England (Taylor-Hobson). In Chapter 1, I use Zeiss to examine how industrial lens production was part of a broader 19th century cultural movement that believed in the social and economic benefits of scientifically measuring vision. By implementing scientific practices in the predominantly artisanal practice of lens construction, Zeiss influenced a global shift towards the industrial production of precision lenses. In Chapter 2, I use E. Krauss to examine the emergence of cinema alongside fin-de-siècle Parisian instrument culture. In analyzing how instrument makers branded and sold lenses in relationship to cinematic practice, I illustrate that lenses came to circulate in ways that departed from and often exceeded the initial ideals of lens designers and distributors. In Chapter 3, I use Bausch & Lomb to trace the effects of World War I on the national and international production of lenses between 1914 and 1918. By examining the wartime development of Bausch and Lomb, I argue that national anxieties about the provenance of optical glass played a key role in expanding international optical industries in ways that were

[13] David Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (Oxford: Oxford University Press, 1979), xxii.

unintentionally beneficial to the industrialization of film production. Finally, in Chapter 4, I examine how and why Taylor-Hobson lenses became so closely linked to cinematic practice in the 1920s. By examining the horizontal and vertical integrations of the studio system, I demonstrate how lenses became most clearly defined as "cinema lenses" on the basis of studio-specific practices of film production.

Ultimately, I argue that lenses became cinema lenses on the basis of a broad range of criteria that often had nothing to do with film form, but everything to do with cinema. As a note on my methodology: this project does not trace which lenses were used on which films, and neither does it trace a history of lenses solely through the lens designs that were used for cinematography. In this effort, I run the risk of alienating both the cinephile and the technophile. But, in looking for evidence of cinema culture at the intersection of new things and old habits, I hope to deconstruct the inscription of optics as an industry defined by objectivity and rationalism and illustrate the power that lenses had in shaping the relationship between modernity, technology, and cinema.

The Myth of a Total Cinema

One might be tempted to see lenses as important to the history of cinema because lenses satisfy the necessary technical prerequisites for the capture of clear motion pictures. However, as André Bazin writes in "The Myth of Total Cinema," the idea of cinema long predated its supposed technical invention. The photographic cinema "could just as well have grafted itself onto a phenakistoscope foreseen as long ago as the sixteenth century."[14] What cinema does

[14] André Bazin, "The Myth of Total Cinema," *What is Cinema, Vol. I.*, trans. Hugh Gray (Berkeley: University of California Press, 1967), 19.

emerge from is a particular convergence of "various obsessions, that is to say, out of a myth, the myth of total cinema."[15] The guiding myth of cinema, according to Bazin, was an "integral realism, a recreation of the world in its own image, an image unburdened by the freedom of interpretation of the artist or the irreversibility of time" that found manifestation in the late 19th century.[16] Cinema expressed the desire to adequately represent and express the experienced reality of a rapidly changing modernity.

Film studies has historically used the myth of total cinema to combat a reduction of cinema down to its technical components. As evidenced by the foundational works of Tom Gunning, Edward Dimendberg, Mary Ann Doane, and Anne Friedberg, linking cinema's emergence to changes in subjective experience is a useful strategy for countering the technological determinism that characterize techno-centric histories of the cinema. Indeed, as Charles Musser writes, early film studies' disciplinary turn to archival evidence following the highly influential 1978 Brighton FIAF conference was a methodology that avoided the nationalist-inspired searches for the 'origin' of cinema and technological 'firsts' that dominated early film history.[17] A disciplinary emphasis on social configurations rejects the ideology of institutional imaginations and prioritizes the role of culture in social change. As Jean-Louis Comolli suggests in "Machines of the Visible," the cinema does not follow directly from technological or scientific progress, but rather, the "offsettings, adjustments, arrangements carried out by a social configuration in order to represent itself, that is, at once to grasp itself, identify itself and itself produce itself in its representation."[18] In representing its history as a

[15] Ibid. 22.
[16] Ibid. 21.
[17] Charles Musser, "Nationalism and the Beginnings of Cinema: The Lumière Cinématographe in the US, 1896-1897," *Historical Journal of Film, Radio and Television* 19, no.2 (1999): 149.
[18] Jean-Louis Comolli, "Machines of the Visible," in *The Cinematic Apparatus*, eds. Teresa De Lauretis and Stephen Heath (New York: St. Martins Press, 1980), 120.

social configuration, the study of early film has richly produced the cinema as more than the sum of its technological parts.

This suspicion of technology can be traced to the historical divorce between film studies and the sciences, a division rooted in the development of film studies as an academic discipline in the 1940s and 1950s. As Dudley Andrew suggests in "The Core and the Flow of Film Studies," cinephilia has historically been the driving force of film studies. Many of cinema's earliest theorists, such as Ricciotto Canudo, Rudolph Arnheim and Hugo Munsterberg, sought to legitimize film as art, often in relationship to literature. However, in the 1940s and 1950s, the discipline of film studies was taken over by French structuralism. Filmologie, which described an impartial and scientifically objective study of the relationship between cinema and the social sphere, took on increased academic prominence.[19] Coined by Gilbert Cohen-Séat, who published *Essai sur les principes d'une philosophie du cinema* in 1946, filmologie became a justification for the integration of cinema into other academic disciplines whose enrollments were, in turn, vitalized by their offerings in film studies. Bazin's 1946 claim that the cinema owes "virtually nothing to the scientific spirit" was likely in dialogue with these efforts to institutionalize a more structured and systematic approach to the study of film.[20] Filmologie and its related efforts to legitimize film studies as a technical science were often antithetical to the cultural interests in

[19] Sarah Cooper, "Film Theory in France," *French Studies* 66.3 (1 July 2012): 376-382. https://doi.org/10.1093/fs/kns078

[20] Bazin, "The Myth of Total Cinema," 164. It is worth noting that the hermeneutics of suspicion revolving around the role of science in film studies is alive and well. At the 2018 Society for Cinema and Media Studies conference, a paper on Bazin rallied against the idea of film studies without film. The speaker claimed that this direction of study would be like going to a restaurant and finding that "the only thing left to eat were the menus." While I appreciate the speaker's zeal, they demonstrate a willful ignorance and refusal to recognize cinema's participation in larger conditions of production. To follow the speaker's analogy, there are significant moral and ethical stakes in food production, and I would argue that it does make a significant difference whether we know if our food is locally sourced, sustainably produced, culturally appropriative, or part of an indirect effort to gentrify a neighborhood.

representation and narrative that characterized cinephilia and, in turn, the invention of cinema by the spectator.[21]

Optical science and the science of cinematography are primarily (and often necessarily) preoccupied with questions of physics and mathematics that allow little space for cultural considerations. Science, nonetheless, has a cultural history that intersects and parallels many of the established genealogies of early cinematic culture. As Anson Rabinbach suggests, scientific ideas often elude cultural historians in accounts of social change because they rarely emerge directly, or rather, visibly, from class conflict.[22] Recent early film scholarship has begun to interrogate this historical gap, most notably Virgilio Tosi's *Cinema Before Cinema: The Origins of Scientific Cinematography* (2005), Inga Pollman's dissertation *Cinematic Vitalism: Theories of Life and the Moving Image* (2011) Oliver Gaycken's *Devices of Curiosity: Early Cinema and Popular Science* (2015) and Scott Curtis' *The Shape of Spectatorship: Art, Science, and Early Cinema in Germany* (2015). However, these intersections are a relatively recent development in early film scholarship. As the relationship between film and cinema becomes increasingly unsettled at the turn of the 21st century, our current historical moment begs expanded considerations of the ways that film and media technologies might be thought of as part of "a larger experimental arrangement" that does not cleanly match our existing disciplinary boundaries.[23]

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[21] Exemplified by Christian Metz's semiological approach to film language, Jean-Louis Baudry's apparatus theory, and Raymond Bellour's narrative formalism, the high film theory of the 1960s and 1970s dovetailed filmologie's approach to cinema and carried forward its myopic attention to cinema's structure. Following the rise and fall of structuralism in the 1970s, film studies retained a skeptical relationship to structural approaches to cinema but pursued these critical aims through the disciplinary approaches of feminism and cultural studies. We can also see similar skepticism of structural approaches to film in the critical responses to the work of David Bordwell.

[22] Rabinbach, *The Human Motor*, 15.

[23] Scott Curtis, *The Shape of Spectatorship: Art, Science, and Early Cinema in Germany*, (New York: Columbia University Press, 2015), 3.

The various obsessions with realism that make up Bazin's myth of total cinema were at the heart of parallel 19th century debates about vision, representation, and objectivity in optical science. The convention of some of the most influential ideas of realism and perception did, in fact, emerge from classist distinctions that formed around the use of lens-based instruments to demonstrate knowledge in the sciences. The division between the hard sciences and the humanities has created both ontological and epistemological divisions between nature and culture that, in turn, delegitimize the hybrid forms of knowledge. Lenses are a difficult object in this respect – existing scholarship tends to analyze lenses along these disciplinary divisions.

While historical knowledge about motion picture lenses ironically remains a blind spot for film studies, when engaged with directly, the existing scholarship in film studies has often used lenses to think through broader ideological questions of the cinema. Bordwell, Staiger, and Thompson's *The Classical Hollywood Cinema* offers a significant historical overview of lenses in cinema, although their accounts of lenses are primarily restricted to the role of lenses in relationship to cinematography. Comolli's "Machines of the Visible," in critiquing Jean Mitry's determinist claims of lenses, argues that lenses are part of a broader negotiation of what constitutes realism in mass culture. In addition to using philosophers as "Lens" interludes between her chapters, Anne Friedberg's *The Virtual Window: From Alberti to Microsoft* builds one of its central points around lens practice, arguing that the cinema emerged as a combination of "optical trickery with the projective illusions of the camera obscura – the projection of light in a darkened room."[24] The tendency to immediately link lenses with form, realism, and spectatorship speaks to a common cultural foundation that lenses tap into: a convergence of

[24] Anne Friedberg, *The Virtual Window: From Alberti to Microsoft* (Cambridge: The MIT Press, 2006), 86.

obsessions and anxieties about representation, the representable, and our capacity to apprehend these images with and through technology.

The lens, as Comolli suggests, often stands in for the whole of the cinema. They are simultaneously highly visible (often standing in for the whole of the cinematic dispositif) and highly invisible (immediately subordinated to the camera, the celluloid film, or the screen). As technological modernity decentered the role of the human eye in perception, the lens functioned as "a *guarantor* of the identity of the visible with the normality of vision."[25] This is to say: lenses helped affirm the centrality of human perspective in the midst of the many visual technologies offering potentially more objective claims to reality than the human eye. The metonymy of lens and eye does reduce the cinema to one of its technological parts, but perhaps more interestingly, the substitution suggests that lenses have borne a significant amount of imagination about cinema's relationship to modernity, technology, and perception.

Intuitively it might seem that this history ought to be traced through still photography and extend to the work of early photographer-opticians like Niépce and Daguerre. As Jonathan Crary argues in *Techniques of the Observer: On Vision and Modernity in the 19th Century*, though, the invention of photography and the cinema are often mistakenly imagined as part of a continuous unfolding of "a Renaissance-based mode of vision in which photography, and eventually cinema, are simply later instances of an ongoing deployment of perspectival space and perception."[26] To correct the notion that cinema did not emerge as the technological evolution of the photographic camera, we must also recognize that its emergence was not limited to a history of aesthetic photographic or screen practices. For example, foundational developments in the design,

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[25] Comolli, "Machines of the Visible," 124.

[26] Jonathan Crary, *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century* (Cambridge: MIT Press, 1992), 3-4.

production, and conception of photographic lenses were most strongly influenced by debates not in photography, but in the industrial structures that emerged around microscopy. These overlaps also occurred on the side of material supply. For example, W.K.L. Dickson experimented extensively with microscope lenses when designing the Kinetograph for Edison in 1892.[27] Seemingly stable divisions between motion pictures and other fields of practice were less clear at the turn of the 19th century. This project intends to track how, and more importantly why, these distinctions formed the way they did.

Following these historical overlaps between cinema and the sciences, we ought not to think about cinema as fundamentally divided from sciences – nor, for that matter, should we think about science as being fundamentally divided from cinema. As Curtis suggests, “There is an intimate and complex relationship between any technology and the agenda that makes use of it. The technology is not merely applied to the problem; the problem presents itself in part because of the technology.”[28] In order to understand a history of cinematic lenses, it is necessary to understand the culture of optics in which lenses became imagined as useful and valuable in the first place.

Lens Culture

Lenses are technologies, but lenses are also objects. As objects, lenses offer lessons in understanding how culture has organized itself around the material of glass. Humans invest beliefs in lenses, but lenses are also cultural because “that culture could only have emerged in the first place through the interactions between embodied humans and a creative material world.”[29]

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[27] Paul C. Spehr, *The Man Who Made Movies: W.K.L. Dickson* (Bloomington: Indiana University Press, 2008), 237.
[28] Curtis, *The Shape of Spectatorship,* 2.
[29] Timothy LeCain. *The Matter of History* (Cambridge: Cambridge University Press, 2017), 236.

Lenses exist at the surface of a complex set of material processes – they are crushed down into silica from the quarries of Fontainebleu, melted by constant and intense heat in specially designed clay pots, examined by testers for defects, ignored in the shop windows of Parisian instrument retailers, worn down from excessive handling and use, laid away in attics, bought online and shipped across the world to be remounted on digital cameras. As Lewis Mumford claims, "Without the use of glass for spectacles, mirrors, microscopes, telescopes, windows and containers, the modern world as realized by physics and chemistry could scarcely have been conceived."[30] Glass, as both a material and a way of organizing space, arranged people, places, and their relation to each other.

Modern culture was a lens culture. Broadly conceived, lens culture is the idea that optical principles both characterize and constitute a lived relation with the world as a *visual* relation to the world. In "Lentil Soup," photographer AD Coleman defines lens culture as "an interlocking set of instruments and paradigms which permits the endless reframing of man as perceiver, the world as perceived, and the lens image as both vehicle and repository for that transaction."[31] In a society that based a significant amount of its informational exchanges on visual knowledge, lenses became important because they enabled viewers to perceive the act of perception. Lenses permit us "to see the imaging process itself – to contemplate that process, abstract ideas from it, and metacommunicate about it."[32] Lens-based practices like photography and cinema enabled people to apprehend images of the technological world and, in turn, imagine it. Or, as Jean-Louis Comolli writes, culture manufactures itself from representations which are at once the "means, matter and condition of sociality."[33]

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[30] Lewis Mumford, *Technics and Civilization* (New York: Harcourt, Brace and Company, 1934), 180-181.
[31] Coleman, "Lentil Soup," 24.
[32] Ibid. 23.
[33] Comolli, "Machines of the Visible," 121.

The lens culture of the mid to late 19th century was not invented by a certain lens, but rather, came about through the complex integration of mass-produced lenses with a wide variety of social, cultural, and political representational practices. Through their widespread use, lenses sustained a broader belief in the capacity of technology to bridge a perceived gap between human bodies and the field of the visible. Although not immediately accepted as the best object for viewing reality, when combined with film, lenses became an essential tool for representing reality when they became *invisible*. For photography and cinema to emerge as a "new" technology in the 19th century, modern culture had to replace the existing world of signs, activities, and social fabrics and replace them with "a 'new world' of objects, classification, laws, technologies, and meanings."[34] Simultaneously a capitalist and ecological enterprise, lenses reinforced the belief that vision could link together humans, things, nature, and culture together through technology.[35]

Over time, the practice of using lenses to see the world has become ordinary to the point of invisibility. Microscopy, photography, and cinema introduced "optical principles and concepts into the *givens* of our culture."[36] Lenses shape, filter, and inform the information that we see in and through them – yet, as Coleman writes, "even the most blatant distortions tend to be taken for granted as a result of the enduring cultural confidence in the essential trustworthiness and impartiality of what is in fact a technology resonant with cultural bias and highly susceptible to manipulation."[37] As Winston suggests, technologies of seeing often have little to do with helping

[34] Ariella Azoulay, "Unlearning the Origins of Photography," *Still Searching…,* June 9, 2018. https://www.fotomuseum.ch/en/explore/still-searching/series/155238_unlearning_decisive_moments_of_photography
[35] John Garrison, *Glass* (New York: Bloomsbury Academic, 2015), 23-24.
[36] Coleman, "Lentil Soup," 20.
[37] Coleman, "Lentil Soup," 30.

us understand their own historical and social realities: "On the contrary, their basic illusionism disguises their artifice, their cultural formation and their ideological import."[38]

We frequently recognize cinema's materiality only in states of decay or inconvenience: scratched celluloid film, sticky theater floors, a multiplex with limited parking, the cracked screen of an iPad. But, more often than not, the material culture of cinema goes unnoticed: a smooth transition between multiple reels of film, correctly focused projectors, the energy required to power a home television screen. Simply because cinematic materials go unnoticed does not mean that they do not shape film culture. On the contrary: as celluloid film is displaced by digital formats for both recording and projecting motion pictures, the lens reveals itself as one of cinema's most persistently material objects. To be sure, film without celluloid, theatrical exhibition, and changing reception practices all signal a shift in what we understand cinema to be. While celluloid has been central to the definition of film studies, the unmooring of cinema from film stock at the close of the 20th century calls for new questions, and new histories, of cinema without film.

This project uses optical history to more squarely plant film history in a tradition of sight and seeing that is less dependent on the centrality of celluloid film. In addition to film history, I use a wide range of archival resources – ranging from early optical treatises to scientific publications to Hollywood trade press to lens catalogues 8– to read the history of the lens from within its production contexts. This is not to say that these archival sources tell a more fundamental truth about the history of lenses. If anything, these corporate and scientific publications demand just as much of a cautious and critical eye to narrative structure and aesthetic representation as film and literature. Nonetheless, these sources do offer useful insights

[38] Winston, *Technologies of Seeing*, 118.

about lenses in ways that classical film history has neglected. In attending to the history of the motion picture lens, I hope to provide some tactical avenues to rethink the stakes of the "end" of cinema. Part of this involves deconstructing the logics of techno-fetishism and rational thought that are endemic to optical history, which obscure the ways in which lenses are connected as much to imagination as they are imaging.

Chapter 1 | Modern Glass: Zeiss and the Industrialization of Vision

> Nothing in the history of science, not even the airplane, or the radio, is a greater monument to human invention than the anastigmat.
> *Karl Brown (1922)*

In 1922, *American Cinematographer* published a five-part series of articles titled "Modern Lenses." *American Cinematographer,* which began publication in 1920, was a newsletter published by The American Society of Cinematographers about the practice and craft of cinematography. By the 1920s, the role of the camera operator was becoming the role of the cinematographer. The change in job title reflected an ongoing struggle to elevate the labor and value of operating motion picture cameras. Written by Karl Brown, a cinematographer who collaborated with D.W. Griffith, "Modern Lenses" surveyed both the historical development of lenses and notable kinds of contemporary lenses such as soft-focus and super speed lenses. Part historical overview, part technical reflection, and part advertising, "Modern Lenses" was emblematic of *American Cinematographer*'s ongoing efforts to give cinematographers a history and more professional legitimacy. In linking lenses to broader histories of scientific innovation, industrial production, and contemporary aesthetics, Brown's series defines lenses as more than tools. Rather, lenses are imagined as emblems of modern vision.

The lens most closely associated with modernization at the turn of the 20th century was the anastigmat, a standard type of lens used in both photography and cinematography. Brown, dedicating the third installment in his series to anastigmats, dramatically emphasizes the historical significance of this lens, claiming that "Nothing in the history of science, not even the airplane, or the radio, is a greater monument to human invention than the anastigmat."[39]

[39] Karl Brown, "Modern Lenses: Section Three," *The American Cinematographer*, July 1, 1922, 4.

Anastigmat was originally the brand name for a lens released by the German optical company Zeiss in 1890. These kinds of lenses were exceptionally valuable to photographers and cinematographers because they simultaneously corrected two significant kinds of lens distortion: chromatic aberration (where different colors of light reached a recording medium, like celluloid film or a collodion plate, at different points) and spherical aberration (where image focus was clear in the image center but increasingly softer at the edges of the film). Prior to anastigmats, most lenses could correct for chromatic aberration or spherical aberration – but not both. Anastigmat became such a generic term for corrected lenses that, in 1900, the Zeiss anastigmats became advertised by the "Protar" brand name to distinguish them from the multitude of lenses that were being advertised as anastigmatic.[40] By the turn of the 20th century, a lack of distortion in photographic lenses had shifted from a special feature to a basic expectation.

The historical significance of the anastigmat is more than a question of brand loyalty or product placement. As optical historian Rudolf Kingslake provocatively declares in his 1934 article "The Development of the Photographic Objective," lens history "divides itself naturally into two parts, the 'old' period from 1812 to 1886, and then the "anastigmat" period from 1886 to the present day."[41] The Zeiss Anastigmat was released in 1890; 1886 marked the year that the Zeiss *Glastechnisches Laboratorium Schott und Genossen* (Schott and Associates Glass Technology Laboratory) began distributing barium crown glass. The industrial production of barium crown glass enabled lens designers to create distortionless lenses, like the Anastigmat,

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[40] H.H. Nasse, "From the Series of Articles on Lens Names: Tessar," *Carl Zeiss AG: Camera Lens Division*, March 2011, 4. https://lenspire.zeiss.com/photo/app/uploads/2018/04/Article-Tessar-2011-EN.pdf

[41] Rudolf Kingslake, "The Development of the Photographic Objective," *Journal of the Optical Society of America* 24 (March 1934): 73. This arrangement is also seen in C.B. Neblette and Allen E. Murray's *Photographic Lenses*, which begins its section on the development of the photographic lens with the subheader "Photographic Lenses Before the Anastigmat."

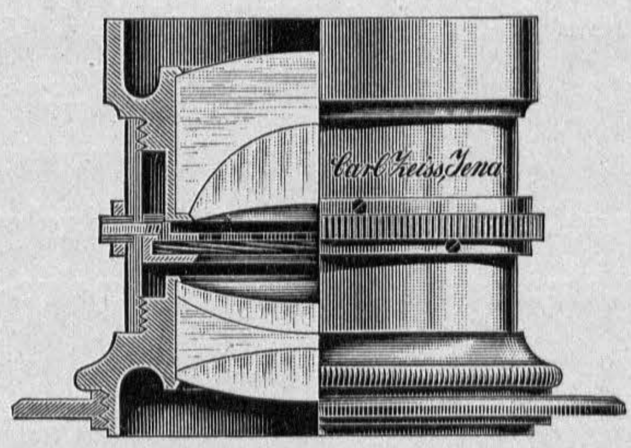

Fig. 3.
Anast. 1/4.5, $f = 150$ mm $= 5^{15}/_{16}$"
ab. $^{2}/_{3}$ full size.

Figure 1 Zeiss Anastigmat. Carl Zeiss Optical Works Jena: Photographic Objectives and Photo-Optical Auxiliary Appliances. 1894. 15.

that many designers had previously thought to physically impossible. In creating these new kinds of optical glass, Zeiss chemist Otto Schott was hailed by the *Deutsche Glastechnische Gesellschaft* (The German Glass Society) as "the creator of modern scientific glass technology."[42] In turning optical glass into a technical material that could be systemically designed and reliably used to produce precision optical systems, Schott "allowed optics to become a technology."[43] Technically measured glass was imagined as a key material not only for optics, but for "virtually all technology, i.e., in the end, for modern life in general."[44] The modernization of glass was a practice of subjecting glass to increased measurement, elevating it from a material to a technology, but it was also a practice of making it possible to think of vision

[42] "Technical Note: Centenary Recognition of Dr Otto Schott," *Journal of the Optical Society of America* 42, no. 3 (1952): 218.
[43] Peter Hartmann et al, "Optical glass and glass ceramic historical aspects and recent developments: a Schott view," *Applied Optics* 49, no. 16 (June 2010): D159.
[44] Ibid. D157.

and technology as interchangeable. Anastigmats were emblematic of growing associations between modernization, technology, and perception in the science of optical glass production. But what was modern about this vision? And how exactly did optics' imagination of modern vision come to coincide with the cinema?

This chapter argues that the modernization of precision optics, exemplified by the anastigmat, was as much as a cultural development as it was a technological development. The scientific production of lenses was part of a broader cultural movement in Germany that saw social and economic benefits resulting from the scientific measurement of vision. In order to understand why scientifically designed lenses became so valuable, this chapter will lay out a longer tradition of anxieties about the reliability of vision and visual technologies that were addressed – albeit unevenly – by the scientific design of optical glass and precision lenses. Using Zeiss as a case study, I argue that that modern glass emerged at the confluence of three significant cultural developments: the professional acceptance of theoretical science by optical designers, the standardization of previously artisanal practices of lens production, and the convergence of these scientific practices with photographic lens production. By implementing scientific practices in the predominantly artisanal practice of lens construction, Zeiss influenced a global shift towards an industrial production model of precision lenses. While the modernization of glass has been historically equated with practices of remarkable industrial innovation, as Miriam Bratu Hansen writes, "We should not underrate the extent to which modernism was also a popular, or more precisely, a mass movement."[45] Together, these cultural

[45] Miriam Bratu Hansen, "America, Paris, The Alps: Kracauer (and Benjamin) on Cinema and Modernity," in *Cinema and the Invention of Modern Life*, eds. Leo Charney and Vanessa Schwartz (Berkeley: University of California Press, 1995), 365.

influences aligned modern vision with a historically specific practice of mass manufacturing lenses according to scientific measurements.

Modern Vision

Modern culture was frequently cinematic before the fact of cinema.[46] As Leo Charney and Vanessa Schwartz contend in *Cinema and the Invention of Modern Life*, the cinema as it came to be understood at the turn of the century emerged from "a historically specific culture of the cinematic which emerged from − yet also ran parallel to − other transformations associated with modernity in the late nineteenth and early twentieth centuries."[47] Modernity – the insistence upon the present and its future as a resistance to the past – characterized a broad range of social, economic, cultural, and subjective transformations to Western life in the late 19th and early 20th centuries.[48] The majority of scholarship on early cinema's relationship to modernity places cinema in relationship to a series of ongoing transformations in 19th century modern society such as the rise of consumer culture, the annihilation of space and time by the railroad, and the urbanization of cities. As theorist Mary Ann Doane argues, photographic images, especially motion pictures, best expressed and visualized the abstract knowledge authorizing the interlocking social projects of science, government, and industry. Motion pictures were not invented so much as they participated in an ongoing cultural imperative to represent and apprehend a profoundly disembodied sense of reality.

The increased experience of abstraction in daily life was one of the defining characteristics of modernity. As Crary argues, photography and cinema are best understood as "a

[46] Charney and Schwartz, "Introduction," 1.
[47] Ibid. 2.
[48] Susan Stanford Friedman, "Definitional Excursions: The Meanings of Modern/Modernity/Modernism, *Modernism/modernity* 8, no.3 (2001): 503.

crucial component of a new cultural economy of value and exchange" rather than as increasingly advanced form of visual representation.[49] Paper money, iron and glass architecture, clocks, railroad travel, urbanization, and photography all participated in the broad disintegration of "a stable and local presence" in the 19th century.[50] Industrial capitalism's search for expanding markets, and its creation of institutions that could support those markets, enacted abstraction as a daily experience – an experience, in Karl Marx' words, characterized by the sense that "All that is solid melts into air."[51]

As labor time became central to the functioning of industrial capitalism, conceptions of time and its representability became crucially supported by processes of abstraction and rationalization.[52] For Crary, photography and cinema were adjuncts to a larger social project to refigure how "an observer was figured in a wide range of social practices and domains of knowledge."[53] Many of the dominant forms of producing realistic effects in 19th century mass visual culture, such as the stereoscope, were based on "a radical abstraction and reconstruction of optical experience."[54] A handheld set of slightly distorted lenses that enabled spectators to see far off scenarios in three dimensions, the stereoscope was immensely popular and made it possible for spectators to make pleasure out of an experience of abstract viewing. These seemingly disparate modern practices were, as Mary Ann Doane contends, "effects of a historical pressure to rethink time in relation to its representability."[55] In the context of an

[49] Crary, *Techniques of the Observer,* 13.
[50] Ulf Strohmayer, "Technology, Modernity, and The Restructuring of the Present in Historical Geographies," *Geografiska Annaler. Series B, Human Geography* 79, no. 3 (1997): 156.
[51] Marshall Berman, *All That Is Solid Melts into Air: The Experience of Modernity* (New York: Simon and Schuster, 1971), 288.
[52] Doane, *The Emergence of Cinematic Time*, 21.
[53] Crary, *Techniques of the Observer,* 7.
[54] Ibid. 9.
[55] Doane, *The Emergence of Cinematic Time,* 21.

industrial economy that relied deeply on abstraction, the value of perception expanded from the capacity to *see* to the capacity to *stabilize* multiple abstract representations as real presence. In turn, human perception – the unaided eye – was increasingly experienced as inadequate to the apprehension of a rapidly moving and abstract experience of modern time.

Developments in 19th century sciences increasingly demonstrated that visual perception provided an incomplete vision of lived reality. In particular, statistics and thermodynamics unsettled previously firm beliefs in the relationship between human perception and reality. Statistics, as a way of accounting for and managing random variation, challenged the belief that individual perception alone was adequate to apprehending the natural world.[56] Similarly, Hermann von Helmholtz' theories of thermodynamics gave rise to a deep crisis of faith in future of human progress. Thermodynamics established a scientific justification for the equality of humanity and nature by stating that energy could not be created or destroyed, only changed. Helmholtz was not the first to discover the theory of the conservation of force, but he conceived of its mathematical principles in a structure that "encompassed and surpassed the individual findings and ideas of his codiscoverers."[57] The law of energy stated that energy, unmanaged, flowed naturally into disorder – simultaneously suggesting that human beings were equally subject to the inevitable flow of energy into chaos.

In the wake of Helmholtz's theories, the application of the scientific method to society took on a moral imperative. Helmholtz himself was an influential agent in linking science to society. Following his 1847 address on the universal law of the conservation of energy, Helmholtz's writings and popular lectures on thermodynamics linked together planets, forces of

[56] Robin Kelsey, *Photography and the Art of Chance* (Cambridge: Belknap Press, 2015), 12–16, 163-165.
[57] David Cahan, *An Institute for an Empire: The Physikalisch-Technische Reichsanstalt, 1871-1918* (Cambridge: Cambridge University Press, 2004), 62.

nature, machines, and human labor power as examples of the principle of, and the social need for, the conservation of energy.[58] Helmholtz was an influential agent of what Anson Rabinbach terms "social modernity:" the practice of applying "new scientific modes of perception to social questions and bringing to bear a spirit of utopian and scientific "neutrality" that was opposed to the forces that rent 19th century society along lines of class and ideology."[59] A series of social projects studying industrial accidents, fatigue, and human motion through photographic images demonstrated the far-reaching impact of scientific understanding on social philosophy. Using the human body as the site of measurement, theories of energy conservation proposed by thermodynamics were translated into the politics and social policies that grow up around labor power and fatigue, as exemplified by the politics of Karl Marx and the efficiency studies of F.W. Taylor. Thermodynamics suggested that, much like the natural world, social energy might be measured, conserved, and perhaps even optimized.[60]

The increased study of energy challenged broader beliefs in the relationship between perception and reality. As Crary contends, "a massive reorganization of knowledge and social practices," particularly in the sciences, unsettled the stability of the relationship between sight and knowledge. The direct correlation between sight and experience exemplified by the Renaissance perspective was "severed from the scientific base that had once authorized it" by developments in 19th century optical science.[61] Investigations of color, motion, sight, and light contributed to the idea that models of perspectival representation "no longer had the legitimation of a science of optics."[62] Scientists such as d'Arcy, Roget, Brewster, Faraday, Plateau, Stampfer

58 Rabinbach. *The Human Motor*, 3.
59 Ibid. 86.
60 Ibid. 69.
61 Crary, *Techniques of the Observer*, 86.
62 Ibid. 86.

and Babbage carefully observed how "the eye could be tricked into creating visual superimpositions, or even illusions of motion, by viewing rapidly changing images."[63] Vision increasingly came under scrutiny and lost its stability as a privileged form of knowledge and knowing. As Martin Jay writes in *Downcast Eyes: The Denigration of Vision in Twentieth-Century Thought*, the initial euphoria of visual experimentation gave way to a profound suspicion of vision.[64] The "frenzy of the visible" characterizing mid-nineteenth century experiments shifted to a "violent decentering" of vision that manifested in various arts movements like Impressionism, Cubism, Futurism, Vorticism, and Naturalism.[65]

As vision became increasingly suspect, the sciences made a concerted effort to reassert the possibility of a dependable observer through the establishment of professional conventions and agreed upon measurements. An idea that became (but was not always) central to practices of observation in the sciences was objectivity. As Lorraine Daston and Peter Galison historicize in *Objectivity*, objectivity was a historically specific idea that emerged in the late 19th century as a belief in habits, techniques, and practices which were accepted as credible due to training and daily repetition. Contrary to how the term is often used, objectivity didn't emerge as a belief in universal, essential forms of knowledge. Objectivity was not an effort to reinstitute an essential truth of vision. Rather, instead of considering how objective knowledge was different from subjective knowledge, scientists and philosophers "confronted the problem of observations that varied among and within individuals. The problem was not solely of humans and nature. It was also of *humans against humans*. It was not only about *what* was true, but about *who* was right

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[63] Tom Gunning, "Introduction," In *The Great Art of Light and Shadow: Archaeology of the Cinema,* Laurent Mannoni (Exeter: University of Exeter Press, 2000), xxvi.
[64] Martin Jay, *Downcast Eyes: The Denigration of Vision in Twentieth Century French Thought* (Berkeley: University of California Press, 2009), 14.
[65] Ibid. 150-154.

[orig. emphasis].”[66] Culminating in the 1860s and 1870s, scientific culture began to privilege practices of objective investigation and representation that safeguarded scientists against “a new kind of obstacle to knowledge: themselves.”[67] Scientific practice increasingly took on a moral dimension of self-discipline that cultivated a “scientific self grounded in a will to willnessless.”[68] What characterized the acceptance of objective visual evidence was “*self*-surveillance, a form of self control at once moral and natural-philosophical.”[69] The possibility of objective representation was “a moral, as much as a technical, quest” for a scientific culture seeking to legitimate the now-suspect observer with a set of more dependable and objective practices.[70]

What characterized the modern vision of industrial modernity was the institutional desire to visualize, measure, and stabilize the abstractions necessary to the functioning of a capitalist economy. The desire for “optical neutrality” enacted in the arts and the sciences alike created the conditions under which subjects could consume vast new amounts of visual imagery and information.[71] Visual studies like astronomy, microscopy, and photography, implemented across a variety of social projects, institutionalized of a way of seeing, feeling, and experiencing that held the promise of progressive social change. If modernity was the insistence of the now, then optical neutrality emphasized that lenses could be used to stabilize experiences of modernization that increasingly took place beyond unaided biological sight.

Optical instruments of measuring and perception took on new significance and value in a period when belief in both the popular and the scientific observer was increasingly subject to question. Rather than offering a clear way to see the world, lens-based instruments initially

[66] Jimena Canales, *A Tenth of a Second: A History* (Chicago: University of Chicago Press, 2011), 9.
[67] Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2007), 34.
[68] Ibid. 34–38.
[69] Lorraine Daston and Peter Galison. “The Image of Objectivity,” *Representations*, no. 40 (Fall 1992): 103.
[70] Ibid. 116.
[71] Crary, *Techniques of the Observer*, 97.

introduced further questions about the possibility of objective knowledge. The French use of the term *objectif* for lens in French is not coincidental to these broader concerns with perception and knowledge. However, its usage requires some historical unpacking. Due to the curved shape of the glass, the words for lens in English, French, and German derived from the Latin name of the lentil plant, *lens culinaris.* However, in mid-17th century France, the word *objectif* also began to be used to describe the optical glass of telescopes and microscopes. According to the *Französisches Etymologisches Wörterbuch* (The French Etymological Dictionary), one of the earliest uses of objectif to describe a lens or set of lenses in instruments turned towards an object to be examined occurred in the 1666 issue of *Le journal des sçavans,* the first academic journal to appear in Europe along with *Philosophical Transactions* in 1665.[72] It's important to recognize that, in the 17th century, objectivity meant the opposite of how the term came to be used in the 19th century. Objectivity referred to things "as they are presented to consciousness" whereas subjectivity referred to "things in themselves."[73] Using *objectif* rather than *lentille* to describe the lenses of telescopes and microscopes emphasized that the instruments mediated, rather than revealed, observations about the natural world.

Objectif began to be used to describe lenses at the same time that philosophical instruments like telescopes, microscopes, and magic lanterns began to be used in scientific practice. When philosophical toys initially made their way into acceptable scientific practice in the 17th century, they began to "do more than provide premises for, or confirm the conclusion of,

[72] David Banks, "The Beginnings of Vernacular Scientific Discourse: Genres and Linguistic Features in Some Early Issues of the *Journal Des Sçavans and the Philosophical Transactions*," *E-rea* 8, no. 1 (2010). doi:10.4000/erea.1334. Accessed April 12, 2018. URL : http://journals.openedition.org/erea/1334 While the FEW is pretty clear on the location of the usage in the Journal des scavans, I have yet to actually find the usage of *objectif* in the 1666 journal despite multiple articles on microscopes and telescopes. The FEW suggests that *verre objectif* was in use since 1680, rather than 1666, but gives no source for this.
[73] Daston and Galison, *Objectivity*, 29.

a "demonstration" – they became the demonstration itself."[74] The use of instruments to show phenomena fundamentally altered what, precisely, was being demonstrated. It was not clear that the demonstration of an instrument was definitively the same as the demonstration of knowledge. A divide opened up between instruments that were used for research and instruments that were used for demonstration.[75] Lenses were recognized as presenting a view of the world – which was not necessarily the same as subjectivity of the world in and of itself. Much like how the term objectivity shifted to connote unbiased reality, as scientific practices changed how they thought of the relationship between knowledge and mediated perception, *objectifs* also shifted in this discourse.

The use of the term 'scientific' to describe investigative technologies, rather than exhibition technologies, was suggestive of a broader division that was emerging between theoretical and technical knowledge. The expression "scientific instrument" only became common in the late nineteenth century.[76] During the second half of the nineteenth century, advertisements for instruments increasingly appeared on the first and last pages of scientific journals, scientific books, and treatises.[77] While the origin of the term "scientific instrument" is unclear, as Warner writes in "What is A Scientific Instrument, When Did It Become One, and Why?," the term first became important at the 1851 Great Exhibition of the Works of Industry of All Nations at Hyde Park, London. Held in The Crystal Palace, a magnificent cast-iron and plate-

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[74] Thomas L. Hankins and Robert J. Silverman, *Instruments and the Imagination* (Princeton: Princeton University Press, 1995), 41. Furthermore, as Olive Cook writes, the use of the magic lantern by Dutch scientist Christiaan Huygens popularized associations of the magic lantern with entertainment rather than religion, as it had previously been associated with by Jesuit scholar Athansius Kircher. Olive Cook, *Movement in Two Dimensions: A Study of the Animated and Projected Pictures Which Preceded the Invention of Cinematography* (London: Hutchinson, 1963), 19.

[75] Hankins and Silverman, *Instruments and the Imagination,* 58.

[76] Paolo Brenni, "From Workshop to Factory: The Evolution of the Instrument-Making Industry, 1850-1930," *The Oxford Handbook of the History of Physics*, ed. Jed Z. Buchwald and Robert Fox (Oxford: Oxford University Press, 2013), 585.

[77] Ibid. 609.

glass building built specifically to house the event, The Great Exhibition was the first of a series of exhibitions of culture and industry that became popular in the 19th century. Great Britain, the dominant producer of optical glass and instruments at the time, learned that "other industrialized countries were fast approaching, and in places surpassed, her own achievements" at the event.[78] The challenge to Britain's technological supremacy led to the establishment of Great Britain's Department of Science and Art, and through the institution, the term scientific instrument came to be associated with practices "specially for the performance of experiments."[79] Through class, vision became associated with a trained eye and not with the exhibition of knowledge to a wide audience.

These epistemological divisions between embodied knowledge and optical neutrality were not based solely on the impartial pursuit of truth and knowledge. As scientific instruments increasingly contributed to national wealth and prestige in the mid-1800s, scientists "tightened their allegiance to an aristocracy of intellect and reiterated the moral virtue of their disinterested search for truth."[80] It is important to remember that this moral virtue was an ideal, rather than universal, confidence. The search for reliable truth depended on resolving significant doubts about both seeing observers and instruments of sight. One way that objective knowledge was affirmed was through a belief in reliable, professional practices of observation – and, by association, the instruments regularly used in those scientific practices. The distinction between different kinds of instruments relied on, and affirmed, the idea that "the observations, measurements and experiments of natural philosophers were made in a search for truth, and thus differed from the observations, measurements and experiments which mathematicians and

[78] Deborah Jean Warner, "What Is a Scientific Instrument, When Did It Become One, and Why?," *The British Journal for the History of Science* 23, no. 1 (March 1990): 86.
[79] Ibid. 88.
[80] Ibid. 89.

mechanics made for merely practical purposes."[81] While this served to cultivate the regime of practice necessary to justifying objective knowledge, the division of instruments also served to delegitimize forms of subjective knowledge gained from practical, day-to-day experience.[82] The lack of authoritative perspective presented by changing ideas of natural knowledge was giving way to a reestablishment of truth through conventions that privileged aristocratic practices of sight and perception.

What made optical science modern was the institutional stability of conventions that made visual abstraction viable on a day-to-day basis. However, the professional embrace of objectivity – optical neutrality – did not directly follow from the invention of technologies that helped instrumentalize these ideas. Objectivity was an ideal, and as such, it was subject to failure and error over time. The increased abstraction of a stable and local presence in day to day life was motivated less by an institutional control motivated by scientific evidence and more by the "anxiety linked with the revelation of a body that cannot even trust its own senses, when vision is uprooted from the world and destabilized."[83] Studies of vision and perception provided the promise of efficiently managing social change, but they also unsettled prevailing beliefs about the reliability of sight and perception. It was through debates about the extent to which observers could trust technology that lenses found a place in professional practices of observation. While this process of stabilization occurred across a number of different fields of knowledge, the discourse around optical instruments – particularly the discourse engineered by Zeiss – would serve as one of most formative grounds for the commercialization of lens-based vision.

[81] Warner, "What is a Scientific Instrument," 84.
[82] Ibid. 83. The division of instruments by "curators, historians, dealers, authors of tariff regulations, and officials of exhibitions and patent offices" sustained the artificial divisions between scientists and practitioners. These categorical histories also served to further obscure the connections between men of science and aspiring tradesmen.
[83] Doane, *The Emergence of Cinematic Time,* 80.

Visions of Science: Zeiss and Scientifically Designed Lenses

It is in the context of this anxious nineteenth century that Carl Zeiss, the son of a toy-shop proprietor, opened a small workshop at Jena, Germany, for the manufacture of optical and philosophical instruments in 1846. The bulk of Zeiss' business was in selling eyeglasses and doing small repairs, and only occasionally did the workshop sell telescopes and microscopes in its early years.[84] However, following the advice of his former teacher, the botanist Mattias Jacob Schleiden, Zeiss began producing simple microscopes, and later produced compound microscopes throughout the 1850s.[85] Zeiss produced microscopes to supply scientists, and Carl Zeiss justified his application to open a workshop in Jena based on the contacts he had made with university scientists as an intern at the university's institute of physiology.[86]

In particular, microscopes figured strongly into the discourse about how to define and understand distortion. The increasingly abstract conditions of visual knowledge, and the suspicious relationship between sight and knowledge, unsettled the ontological grounds on which scientists could confidently demonstrate truth – and, by association, distortion. During the 18th century, professional science had established its metaphysics and methodology on nature's "uniformity and order:" distortions, anomalies, and the extraordinary were seen as variations on the "regular and monolithic" workmanship of Nature.[87] As Daston and Park argue in *Wonders and the Order of Nature*, over the course of the sixteenth and seventeenth century, natural

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[84] Stuart Feffer, "Ernst Abbe, Carl Zeiss, and the Transformation of Microscopial Optics," in *Scientific Credibility and Technical Standards in 19th and Early 20th Century Germany and Britain*, ed. Jed Z. Buchwald (Dordrecht: Kluwer Academic, 1996), 26.

[85] "Company History: At a Glance." *Zeiss*. https://www.zeiss.com/corporate/int/history/company-history/at-a-glance.html#inpagetabs-0

[86] Guido Buenstorf and Johann Peter Murmann, "Ernst Abbe's Scientific Management: Theoretical Insights from a Nineteenth-Century Dynamic Capabilities Approach," *industrial and Corporate Change* 14, no. 4 (2005): 550.

[87] Lorraine Daston and Katharine Park, "Unnatural Conceptions: The Study of Monsters in Sixteenth- and Seventeeth-Century France and England," *Past & Present* 92 (August 1981): 25.

wonders shifted from religious consideration and became objects of scientific inquiry.[88] Distortion was largely defined as a fault or divergence in the natural order. However, due to challenges to beliefs in visible evidence in the 19th century, the definition of distortion shifted inwards "to the multiple subjective viewpoints that shattered a single object into a kaleidoscope of images."[89] Scientific studies of vision created a crisis of belief in the viability of human senses to account for the world. Rather than a failure of natural design, scientists increasingly framed distortion as a failure of human perspective.

At a basic level, scientists struggled to define what, precisely, counted as distortion in microscopic images. It was difficult to say whether distortion was "a meaningful category, or merely a term applied to representational styles that were *unfamiliar* and *unconventional*."[90] This is to say: while microscopes presented images, there was a period of time in which scientists had to articulate conventions for explaining and interpreting new visual phenomena. Philosophical instruments were considered to "distort" vision because they "did not provide the kind of common, repeatable, direct sense experience from which philosophers usually drew their premise."[91] Indeed, microscopes were seen to have no place in serious scientific work well into the 1830s. As *Popular Science* noted in its 1872 review of *The Lens: A Quarterly Journal of Microscopy and the Allied Natural Sciences*, prominent physiologists denied that microscopes had any use in scientific work as late as 1839.[92] Professional distrust of the microscope lessened during the 1830s as German and central European biologists began to use newly available

[88] Lorraine Daston and Katharine Park, *Wonders and the Order of Nature: 1150-1750* (New York: Zone Books, 2001), 176.
[89] Daston and Galison, *Objectivity*, 113.
[90] Hankins and Silverman, *Instruments and the Imagination*, 177.
[91] Ibid. 38.
[92] "Review: *The Lens: A Quarterly Journal of Microscopy and The Allied Natural Sciences*," *Popular Science* (September 1872): 629.

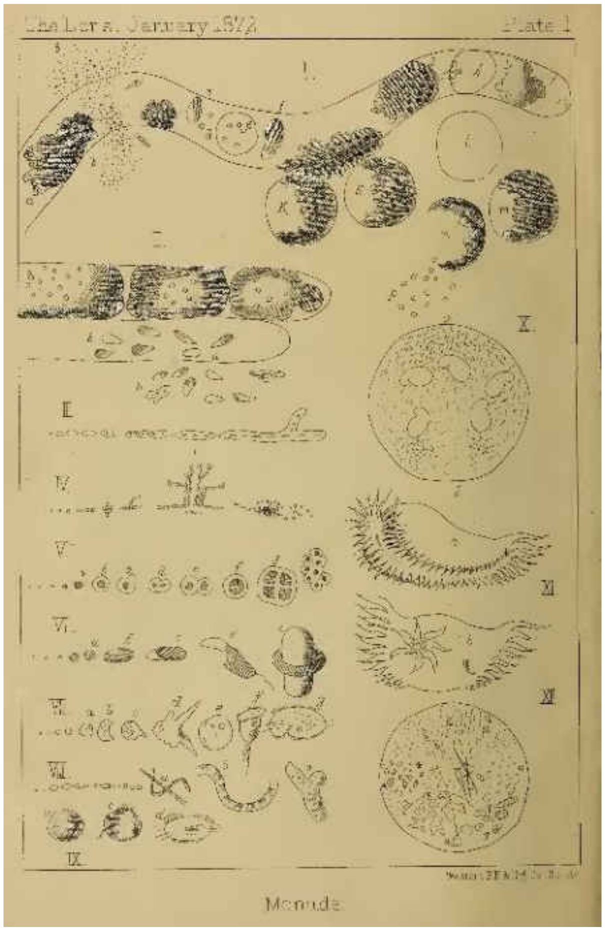

Figure 2 Diagram of Bits and Blobs. The Lens: A Quarterly Journal of Microscopy and the Allied Natural Sciences, No 1 Vol I: 1872. Chicago: The State Microscopial Society of Illinois. Editor: S.A. Briggs.

achromatic microscopes. However, early treatises on microscope practice consistently emphasized the importance of "proper observational technique."[93] There were no reliable and repeatable explanations about lenses that could prove how "the balls, blobs, rings, halos and general fuzziness could exist and still not threaten the basic premise of microscopy: that, properly interpreted, the microscopist could believe what he saw."[94] For most of the nineteenth century, the microscope was "a piece of technology that artisans could build, microscopists could use, but physicists could not understand."[95]

Microscopists' skepticism about lens-based vision in the mid-1800s had less to do with physicists not understanding microscopes and more to do with their construction by artisans. Until the 1880s, precision lens production was an artisanal practice. Nearly all workers engaged in the production of optical instruments in the early and middle 19th century were "tradesmen with training in metalwork and the construction of small machines who had picked up their optical skills after gaining employment in a shop engaged in building and selling optical

[93] Feffer, "Ernst Abbe, Carl Zeiss," 31.
[94] Ibid. 31.
[95] Ibid. 23.

instruments."[96] Even the best microscopes of the period were "not scientific achievements but the results of hundred-fold trials."[97] As Karl Brown writes in "Modern Lenses," in the old days, "the optician, guided by experience and a more or less trustworthy intuition, would grind lenses by way of a trial, combine them, and then proceed to vary the curvature of the lenses and their combinations until the desired result was attained in a more or less complete manner."[98] Instrument making was seen as "a form of highly-skilled handicraft" and instrument makers in Germany, France, and England found that "the use of machines tools was more appropriate for industrial manufacturing than for small precision industry."[99] Machine-tools operated by small steam engines were used routinely in lens production after the 1850s, but the lenses produced by these machines were largely considered to be of inferior quality to the hand-made variety and were generally used for mass-produced instruments like spectacles, theater binoculars, or cheap telescopes.[100] Belief in high quality optics was usually attached to a single craftsman who could intuitively manage the distortions of a lens. Of the few precision instruments sold at Zeiss in the 1840s and 1850s, the belief in their quality was largely a belief in Zeiss' journeyman, August Lober, who made the difference between optical quality and "blurry junk."[101]

As late as the 1870s and 1880s, the prevailing belief remained that lens objectives were "too difficult to be constructed in accordance with [purely] theoretical requirements."[102] Photographic lenses like the Petzval Portrait Lens and the Steinheil Aplanat were constructed

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[96] Feffer, "Ernst Abbe, Carl Zeiss," 25.
[97] Felix Auerbach and R. Kanthack, *The Zeiss Works and the Carl Zeiss Foundation in Jena; Their Scientific, Technical and Sociological Development and Importance Popularly Described* (London: W. & G. Foyle, 1927), 8.
[98] Karl Brown, "Modern Lenses: First Section," *The American Cinematographer*, May 1, 1922, 5.
[99] Paolo Brenni, "From Workshop to Factory: The Evolution of the Instrument-Making Industry, 1850-1930," in *The Oxford Handbook of the History of Physics*, ed. Jed Z. Buchwald and Robert Fox (Oxford: Oxford University Press, 2013), 600.
[100] Ibid. 604.
[101] Feffer, "Ernst Abbe, Carl Zeiss," 27.
[102] In fact, optical instrument producers used to recommend their microscopes by stating that "they were not like those made at Jena" (Auerbach 1904, 14).

according to theoretical designs as early as the 1860s, but by and large these successes "did not convince the optical world of the need for a good theoretical background."[103] Opticians, as Rudolph Kingslake historicizes, were "far too willing to make empirical trials and put together a series of lens elements, hoping that a miracle would happen and that their system would turn out to be better than those currently available."[104] As Helmholtz concluded in his 1874 article "The Theoretical Limits of Optical Capacity of the Microscope," craftsmen could make scientific instruments that approached, but could never exceed, fundamental limits in the physics of magnification.[105]

Ernst Abbe, a physicist who began to collaborate with Zeiss in 1866, was dissatisfied by the idea that lenses had a fundamental limit.[106] Abbe was a lecturer at University of Jena who was hired on the basis of his technical thesis on the calculation of errors in scientific observations.[107] Abbe was drawn to a collaboration with Zeiss as his experience as both a student and lecturer at the University at Jena made clear a need for reliable instruments.[108] Initially, Abbe worked at Zeiss to develop an array of measuring instruments to precisely determine the optical characteristics of lenses.[109] Abbe's main goal was to furnish the university's physical

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[103] Kingslake, *A History of the Photographic Lens,* 3.
[104] Ibid. 3.
[105] Hermann von Helmholtz, "The theoretical limits of resolving power in the microscope," *Poggendorff Annalen* (1874): 557.
[106] Part of Zeiss' decision to hire Ernst Abbe can be traced to his atypical training. Prior to opening his workshop, Zeiss undertook his apprenticeship with the mechanic Friedrich Korner. Korner, who had no official educational credentials, was encouraged and supported by Goethe to teach at the University at Jena, and he received honorary doctorate on the basis of his technical practice (Feffer 26). Though his apprenticeship, Zeiss was permitted to attend university lectures during his technical apprenticeship (Feffer 26). This foundation of technical work and theoretical knowledge was likely influential in his decision to encourage work that hybridized science and culture.
[107] T.G. Spates, "Industrial Relations in the Zeiss Works," *International Labor Review* 177, no. 198 (1930): 179.
[108] David Cahan, "The Zeiss Werke and the Ultramicroscope: The Creation of a Scientific Instrument in Context," in *Scientific Credibility and Technical Standards in 19th and Early 20th Century Germany and Britain*, ed. Jed Z. Buchwald (Dordrecht: Kluwer Academic, 1996): 72.
[109] "Ernst Abbe Joins Forces With Zeiss: 1866 to 1878." *Zeiss*. https://www.zeiss.com/corporate/int/history/founders/carl-zeiss/ernst-abbe-joins-forces-with-zeiss.html

facilities with a proper set of physical instruments for teaching and research. To do this, Abbe turned the physics of lens operation. Whereas the prevailing belief was that objectives could not be constructed according to theoretical physics, Abbe maintained that "the old and time-honoured theory of the formation of microscopic images was wrong."[110] At Zeiss, Abbe pursued a theory of microscope lenses that scientists could rely upon.

The idea to manufacture lenses according to universal designs rather than through intuitive crafting was not exclusive to Ernst Abbe. Ongoing studies of light, color, and perception all suggested that there might be a way to construct lenses according to theoretical principles. Between the 1840s and the 1860s, collaborations between academically trained mathematicians and craft-trained instrument makers also become more common, especially in the areas of telescope and camera making.[111] Their successes were suggestive of the possibilities of a dependable, scientifically-explained production of lenses.

But, what was considered improvement by physicists was not always the same as what was considered improvement by practitioners. While Abbe's theories assisted in the production of homogenous immersion lenses that increased resolution through a greater aperture, the problem of chromatic aberration remained. "Abbe's early ideas did not always advance the state of the art, and one of his first calculated microscope designs proved to be inferior to that already being produced by Zeiss."[112] However, Abbe's microscopes demonstrated that lenses *could* be designed on optical theory. As Friedberg reminds us, while the technologies of glass and transparency played "a determinate role in the scientific transformation of the modern world," it

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[110] Felix Auerbach, *The Zeiss Works and the Carl Zeiss Stiftung in Jena; Their Scientific, Technical and Sociological Development and Importance Popularly Described*, Trans. Siegfried F. Paul and Frederic J Cheshire (London: W. & G. Foyle, 1904), 19.
[111] Stuart Feffer, "Ernst Abbe, Carl Zeiss," 28.
[112] Martin Cohen, "Carl Zeiss – A History of the Most Respected Name in Optics," *Company Seven*, 1994. http://www.company7.com/zeiss/history.html

is also necessary to emphasize "the nonscientific role of the glass-enabled instrument."[113] In and of itself, the establishment of a theory of lens construction was not enough to spur interest and adoption of Zeiss' optical instruments. The theory needed to be both reliable and relied upon.

Where Abbe succeeded was not only making the microscope an instrument that physicists could build, but making the microscope an instrument that microscopists could understand. Abbe successfully advertised the credibility of his lens theories to practitioners. Abbe had to convince and "reeducate" users of the microscope "so they could appreciate the features that made his objectives, produced by Zeiss, superior."[114] Zeiss' 1872 catalog featured a brief introduction that suggested that Zeiss' microscope systems were "entirely constructed on the basis of the theoretical calculations of Professor Ernst Abbe," but it was Abbe's 1873 article in *Archiv für Mikroskopische Anatomie* (Archive for Microscopic Anatomy) that did the most work to communicate these theories to practicing microscopists, botanists, biologists, and physicians.[115] *Archiv für Mikroskopische Anatomie*, published between 1865 and 1922, was a specialty journal aimed at subject-matter experts who were not necessarily university researchers.[116] Abbe's article made the case that his particular brand of scientific knowledge, as opposed to the "purely craft knowledge of the optician," created a superior microscope objective.[117] Abbe suggested that distortion was less connected to the craft of the lens than a refined understanding of the physics of image formation. A belief in lenses' capacity to objectively depict the world – a capacity that was formerly understood to be purely theoretical – became viable not only in the construction of lenses, but more importantly, in the mind of the

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113 Friedberg, *The Virtual Window,* 63.
114 Feffer. "Ernst Abbe, Carl Zeiss," 58.
115 Ibid. 44.
116 Alan G. Gross, Joseph E. Harmon and Michael S. Reidy, *Communicating Science: The Scientific Article from the 17th Century to the Present* (New York: Oxford University Press, 2002), 117.
117 Feffer, "Ernst Abbe, Carl Zeiss," 44-45.

practitioners by assuring them that the fault was not in technology, but in the untrained human observer.

For all that the production of lenses with specific and reproducible physical properties made lenses more reliable, science and rationality were not inherent linear improvements on human perspective. The design of microscopic lenses that could provide close-ups of the material and biological world did not only provide a basis upon which scientists could generate knowledge: they also renewed the revelatory possibilities of vision. When Benjamin writes about the optical unconscious in his 1931 "Little History of Photography," he writes about how the lenses of photography and microscopy alike blurred, rather than separated, science and magic:

> It is through photography that we first discover the existence of this optical unconscious, just as we discover the instinctual unconscious through psychoanalysis. Details of structure, cellular tissue, with which technology and medicine are normally concerned – all this is, in its origins, more native to the camera than the atmospheric landscape or the soulful portrait. Yet at the same time, photography reveals in this material physiognomic aspects, image worlds, which dwell in the smallest things, but which, enlarged and capable of formulation, make the difference between technology and magic visible as a thoroughly historical variable.[118]

If we consider that the difference between magic and technology is a "thoroughly historical variable" rather than a natural progression of invention, we can see that the process by which lenses became a technology made vision mystical by a different name. The close-up, which Jean Epstein would later take up as the "emblem of cinema's affective power," evoked a cinematic promise of new knowledge partially because its interest in the revelatory possibilities of vision "recalls the possibilities inherent in observing things closely."[119] The linkage between sight and

[118] Walter Benjamin, "Little History of Photography," in *Selected Writings*, Walter Benjamin (Cambridge: The Belknap Press of Harvard University Press, 1999), 512.
[119] Jocelyn Szczepaniak-Gillece, *The Optical Vacuum: Spectatorship and Modernized American Theater Architecture* (Oxford: Oxford University Press, 2018), 68-73.

revelation was significantly grounded in debates about lenses prior to film, even if the power of vision is often associated with the indexicality of photography and cinema's recording mediums.

The growing association between lenses and objectivity was by no means a steady or evenly distributed process. In the early days of Zeiss' production of lenses according to scientific principles, makers of optical instruments used to recommend their microscopes by stating that they were *not* like those being developed at Jena.[120] These professional doubts were also expressed in the popular sphere of literature. For example, "The Diamond Lens," an 1858 short story by Fitz-James O'Brien, tells a tale of a microscopist who uses a diamond lens to discover a woman living in a droplet of water. When he accidentally lets the droplet evaporate, though, the microscopist goes insane with grief. One of the earliest uses of the term *objectif* to describing photographic lenses was in Jules Verne's 1874 novel *L'Île mystérieuse* (The Mysterious Island). After taking a photograph of the horizon, one of the castaways, Herbert, discovers a speck on the photographic plate. While he first assumes the speck to be a defect in the lens, he realizes that the photograph revealed a ship on the horizon of their deserted island. Unfortunately, Herbert and the other castaways soon discover that what the camera lens actually revealed was a ship filled with dangerous pirates.

Figure 3 Herbert and Smith examine the "defect" on a photographic plate. L'Île mystérieuse. 1874

[120] Auerbach, *The Zeiss Works* (1904), 14.

Exemplified by Verne's irony of the term *objectif*, the popular response to lenses was, very much, a suspicion of the visible in the mid-1800s. Yet, despite the different stages and places of adoption, the increasingly regular practice of lens-based instruments in scientific research helped to associate lenses with objectivity over time. Over the course of 1873 to 1880, Zeiss increasingly became associated with prestige and quality, and so did their lenses. This was due to the advertising of optical theory as well as Zeiss' collaboration with universities and research institutions, which legitimated these instrumental tools through their use in objective scientific practice. In shifting the idea that distortion was caused by fundamental misunderstandings of perception rather than poor techniques of lens crafting alone, Zeiss cultivated a belief in the progressive benefits of theoretical science for the construction of lens-based instruments. By the end of the 1870s, the entire process of microscope and other optical instrument production at Zeiss was "cut to meet Abbe's theory."[121]

The Work of Glass: Anastigmats and The Industrialization of Vision

While Abbe had succeeded in emphasizing the professional benefits of a scientifically oriented process of lens production to microscopists, another element of design became increasingly insurmountable to the working quality of scientifically designed lenses: the raw glass. Physicists were limited by the physical properties of the glass available for lens construction. In 1876, on the occasion of the exhibition "The Special Loan Collection of Scientific Instruments" in South Kensington, London, Abbe wrote an impassioned report on the state of the optical field. Abbe lamented the fact that the optician had at his disposal "a fully-

[121] Cahan, "The Zeiss Werke," 75.

developed theory and thoroughly-tested practice – everything, in fact, except suitable glasses for the construction of the necessary lenses."[122]

The market for scientific instruments in the mid-19th century was quite small; the demand for glass industries was predominantly for window glass and glassware. Consequently, glass manufacturers had "little or no economic incentive to improve the quality of glass used in optical instruments."[123] Abbe suggested that improvements in the glass-making industry would benefit not only microscopy, but "all sciences and arts that need optical appliances."[124] Abbe sought to link lenses to a broader ideal of using science in the service of a social modernity, but found no promise of this change in the commercial industry alone. Abbe's report attracted the attention of Otto Schott, a young chemist who had completed a doctorate on "Contributions to the Theory and Practice of Glassmaking" in sheet glass and was pursuing melting experiments in his father's sheet glass factory.[125] In response to Abbe's report, Schott wrote Abbe a letter in May of 1879 inquiring whether some experimental lithium glass that Schott had made might have optical applications. Schott sent samples of his experimental glass to Abbe, and the two struck up a collaboration.[126] In 1882 Schott settled in Jena, and shifted from small-scale experimental glass meltings that he had been performing in Witten to large scale experiments.

Optical historians have often anchored the modernization of glass as the product of Ernst Abbe and Otto Schott's collaboration. This inventor-centric narrative sustains the idea that optical development occurred "a result of the collective creative mind of technologists; that technologies in communications (and, indeed, everywhere else) are primarily the products of

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[122] Auerbach, *The Zeiss Works*, 26.
[123] Cahan, "The Zeiss Werke," 76.
[124] H. Hovestadt, *Jena Glass and Its Applications to Science and Art* (Jena: Fischer, 1900), 4.
[125] Werner Vogel, *Glass Chemistry* (Berlin: Springer-Verlag, 1985 (1994)), 4.
[126] "Otto Schott Joins the Company: 1879 to 1884," *Zeiss.*
https://www.zeiss.com/corporate/int/history/founders/carl-zeiss/otto-schott-joins-the-company.html

unfettered human creativity."[127] The modernization of glass was not solely a product of Abbe and Schott inventing new kinds of optical glass on the basis of their ingenuity. While Zeiss actively linked the success of optical glass to its scientific production conditions, as noted in "A Modern Scientific Industry" (1900), the experimental work carried out as Zeiss "was only rendered possible by repeated and large subventions from the State."[128] Ernst Abbe and Carl Zeiss had previously personally financed the melting experiments, but eventually sought out governmental support for investment in glass. In order to secure this support, in May of 1883, Ernst Abbe traveled to Berlin to visit Hermann von Helmholtz. At the time, Helmholtz was a professor of Physics at the University of Berlin. Both German and international scientific communities viewed Helmholtz as "the most charismatic scientist of the late nineteenth century."[129] Following his groundbreaking work in thermodynamics, Helmholtz had become one of the strongest proponents of German instrument culture. He was one of the initial members of 1882 *Physikalisch-Technische Reichenstalt* (The Imperial Institute of Physics and Technology) planning committee, a German institute for scientific progress which sought to develop a national institute for scientific mechanics. While the institute was not be formally created until 1887, Helmholtz advocated early on for the institute to exist as "an administrative authority that granted funds for precision instruments."[130] In connecting instruments to institutional support, Helmholtz also connected lens-based vision to broader ideals of social modernity like measurement and standardization.

Instruments, in Helmholtz's view, made it possible for scientists to measure humanity and nature in a common field. While Helmholtz is primarily regarded for his contributions to

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[127] Winston, *Technologies of Seeing*, 1.
[128] G, R.T, "A Modern Scientific Industry," *Nature* 1625, no. 63 (December 20, 1900): 173.
[129] Cahan, *An Institute for an Empire,* 59.
[130] Ibid. 30.

physics, most of Helmholtz' early career was dedicated to physiological optics and acoustics. For Helmholtz, "the eye and the ear were instruments," an idea perhaps most directly expressed by his invention of the opthalmascope in 1850.[131] In his tenure as the president of the *Physikalisch-Technische Reichenstalt*, Helmholtz advocated strongly for the creation of international standards of measurement that could support "not only the natural sciences and technology, but also the social sciences and humanities."[132] The philosophy behind Helmholtz' work in both thermodynamics and his research on human perception was the desire to explain life in terms of mechanical forces instead of vital principles – where the scientist "accumulated 'intellectual capital' (*Kapital des Wissens*) that society eventually used to control nature's 'hostile forces.'"[133] Helmholtz saw instruments as an important site of agreement necessary for the application of science to social problems.

Abbe's decision to seek Helmholtz' assistance in securing funding for Zeiss' experimental glass meltings was part of Germany's broader national shift towards scientific and industrial development in the late 19th century. The Second Reich, formed in 1871, saw professional and technical instruments as important to the development of universities, the new

[131] Ibid. 62.
[132] Ibid. 66.
[133] Ibid. 61, 67.

Figure 4 Glastechnisches Laboratorium, 1884. Schott AG.

science-based electrical and chemical industries, and laboratories and observatories.[134] As instruments became financially valuable to the development of the German national economy, standards and understandings of these instruments became important to their regular use. Physics contributed to the Reich's material welfare and ideal values, but researchers lacked physical workspaces and infrastructural support to carry out this work. The necessity for a strong, active, and supported community of instrument makers led to the foundation of nationally supported institutes, like the *Deutsche Geselleschaft fur Mechanik und Optik* in 1879, and the publication of journals devoted to scientific instruments and their use.[135] The need for a belief in lens-based instruments was extending from a singular professional capacity to a broader cultural demand –

[134] Brenni, "From Workshop to Factory," 617.
[135] Ibid 617.

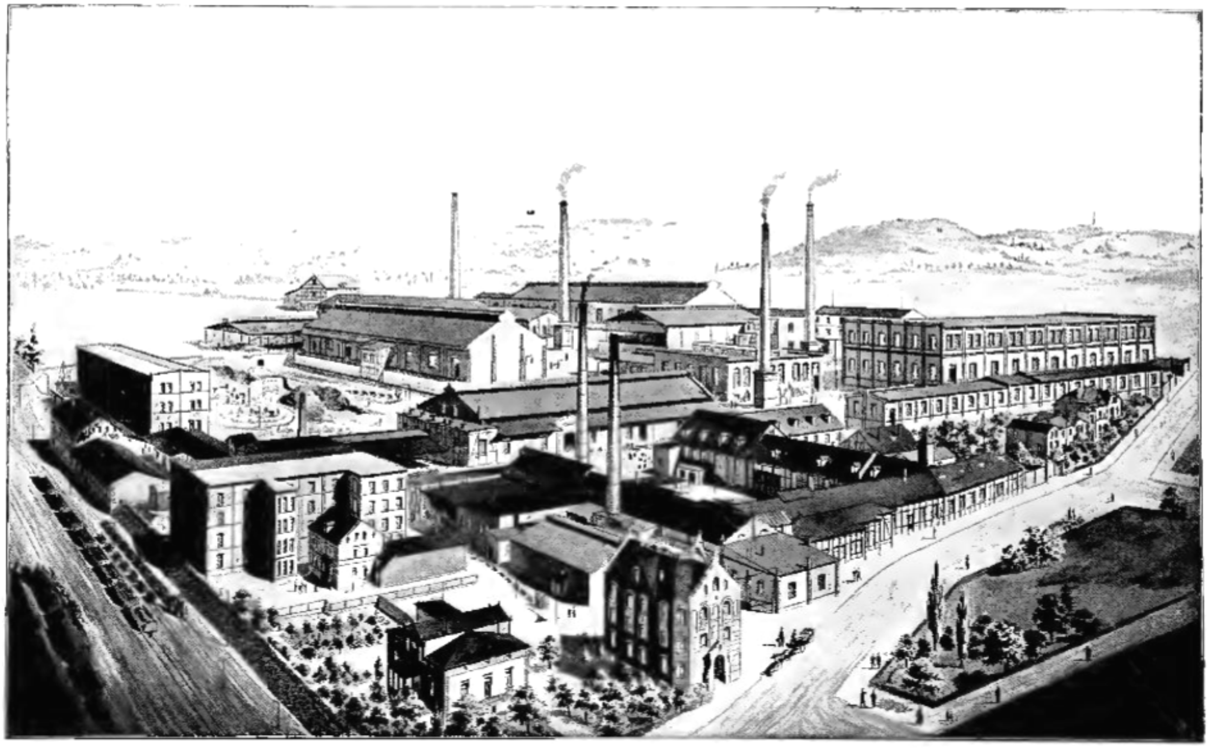

Figure 5 The Glass Works of Schott & Genossen. Felix Auerbach, The Zeiss Works. 1904. 22.

an extension that was ideally served by the potential of a nationally-supported precision lens industry. Abbe convinced Helmholtz of the necessity of supporting the lab, and in 1882 Zeiss was given 60,000 marks by the Prussian Ministry of Education to help support two years of research on new kinds of optical glass.[136]

Zeiss' 1884 establishment of the *Glastechnisches Laboratorium Schott und Genossen*, otherwise known as The Glass Works, marked a profound shift in the production of precision lenses at Zeiss. In the same way that Abbe established professional beliefs in the scientific construction of instruments, Schott established optical glass as a technical material: one that was "precisely specified and reproducible in its properties."[137] In 1886, the year that Kingslake marks

[136] Cahan, "The Zeiss Werke," 80.
[137] Hartmann et al, "Optical Glass," D159.

as the beginning of the anastigmat era, The Glass Works began issuing catalogs for their new optical glass. The catalogs contained 44 types of optical glass, of which 19 were "new composition."[138] The first catalogue for these new optical glasses clearly foregrounded Zeiss' scientifically-grounded production conditions, emphasizing that "The industrial undertaking which is here announced for the first time arose out of a scientific investigation into the connection between the optical properties of amorphous fluxes and their chemical constitution."[139] In 1888 The Glass Works issued a supplementary catalog contained 24 additional glasses, of which 13 were "new."[140] Among these, as Hovestadt highlights in *Jena Glass and Its Scientific and Industrial Applications* (1900), were glasses intended for thermometers and photographic objectives.[141] Hovestadt's simultaneous foregrounding of thermometers and photographic lenses invokes the long socio-economic legacy of Helmholtz: linking body and society together through a common practice of measuring energy and perception.

One of the most significant glass formulas at Jena was for barium crown glass. Barium crown glass enabled the construction of new types of photographic lenses as barium crown glass enabled a wider functional aperture than existing combinations of crown and flint glass allowed.[142] The main contention at the time was that "high aperture and a wide angular field [of

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[138] Hovestadt, *Jena Glass*, 18.
[139] Ibid. 5.
[140] Ibid. 18.
[141] Ibid. 19.
[142] The design of any photographic lens, as Kingslake explains, is subject to a mathematical expression known as the Petzval sum. Simply put, the Petzval sum is the relationship between the curvature of a lens and the power of the lens to let light onto the photographic plate. While they appear flat, all photographic images are registrations of a curve of light. Lens design curved incoming light to make the outgoing light rays register as flatly as possible on the photographic surface. Light travelling in the exact center of a lens will register more or less directly at the center of the photographic image, but the light coming from the outside of the lens curve is in focus at a different place than the light at the center. This is why many early photographs had clear focus in the center of the image but blurriness around the edges: the light coming in further away from the center was not in focus at the same focal plane as the light of the center images.

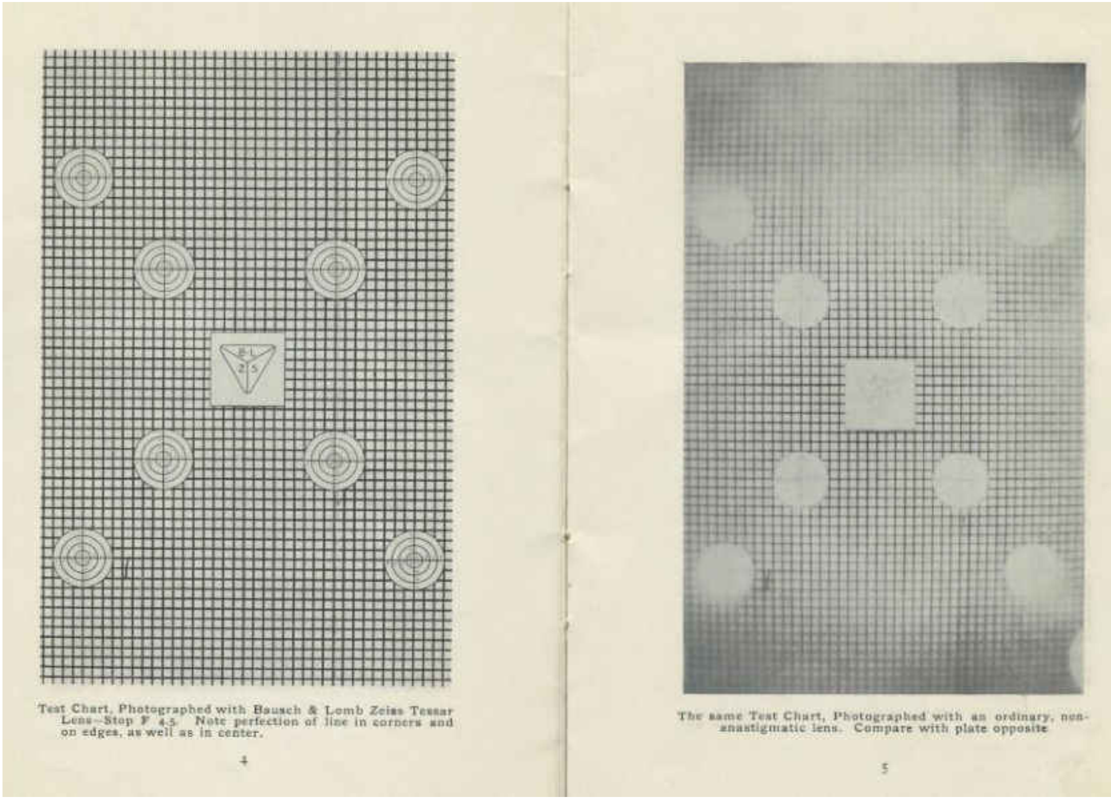

Figure 6 Demonstrating the benefits of scientifically-designed lenses was an important part of communicating technical progress to a popular and professional community. Lens Test Chart, The Prism 2, no 1 (1908). 4-5.

view] were incompatible."[143] As a result, many existing lens designs chose between allowing chromatic aberration (a function of too strongly curved glass) or spherical aberration (a function of too weakly curved glass). Barium crown glass quickly became an optical standard for photographic lens construction because of its "absolutely clear transmission power" and freedom from chromatic and spherical aberrations."[144] Barium crown glass, in combination with flint glass, enabled the simultaneous correction of both chromatic aberration and spherical aberration without significant compromise to the amount of light that came in through the lens.

Barium crown glass was a necessary part of the design for the Zeiss Anastigmat lens.

[143] Kingslake, *The History of the Photographic Lens,* 5.
[144] EA Schiebe, "America's Optical Emancipation," *Purchasing Agent*, July 19, 1919, 14.

The physical properties afforded by barium crown glass enabled lens designers to overcome what was largely assumed to be a stable and immutable relationship between light and refraction. Professional practice to date had suggested that the larger the relative aperture on prior lenses, the greater the necessary aberrations. Paul Rudolph, a physicist who worked on microscope and telescope calculations, began to work as Abbe's assistant in 1886 and came to design the Anastigmat, which was released in 1890. The anastigmatic design enabled sharpness at both center and edges while the lens was wide open. On a material level, Zeiss provided a model for the production and circulation of distortionless lenses at a mass scale. On a conceptual level, the prominent advertising of their production processes, testing practices, and production materials in Zeiss' catalogs promoted a particular faith in the capacity of lenses to accurately represent the world. Furthermore, as Zeiss' instruments came to be used regularly within scientific research communities, the practice of using scientifically-designed lenses aligned lenses with their capacity to objectively depict the material world.

As Schott suggested in his early report, the development of new optical glass quickly expanded beyond its formative interests in measuring the precise operation of microscope objectives. With the new kinds of quantifiable optical glass materials produced at The Glass Works, optical glass production shifted from an artisanal production model to a large-scale systematic production of lenses. In turning "optical glass into a technical material," a material "precisely specified and reproducible in its properties," Scott enabled the reliable production of multiple kinds of precision optical instruments.[145] New glass materials, as well as Zeiss' concerted effort to define quality through scientific rhetoric, resulted in Zeiss significantly

[145] Hartmann et al, "Optical Glass," 158-159.

expanding its facilities and product lines in the 1880s.[146] Equally significant, as I will examine later in Chapter 3, Zeiss also became the global distributor of precision optical glass. In 1877, when the firm was still a workshop, Zeiss employed 36 persons. By 1891, that number had risen to 500, and by 1900 it was employing over 1,000 employees. In 1917, at the height of World War I, Zeiss employed over 10,000.[147] The workshop became a factory that encompassed not only microscopes, but "the whole field of practical optics."[148] By 1900, the German precision instrument industry more broadly included nearly 800 firms that collectively employed more than 13,500 workers. Among these firms, 125 were involved in glass manufacture.[149]

As exemplified by Karl Brown's 1922 "Modern Lenses" series in *American Cinematographer*, the body of theoretical, technical, and trade literature that emerged around lenses in the 20th century locates the anastigmat as a turning point that marked a modern era of lenses. Not surprisingly, Zeiss predominantly locates its anastigmat as the quintessential example of the modern lens.[150] Zeiss played a large role in connecting lenses with modernization, but the association of modern and anastigmat extended beyond the advertising efforts of Zeiss and its

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[146] Zeiss' industrialization of optical glass production encouraged these industrial logics of precision lens production in other nations like France, England, and the United States. One of the reasons that Zeiss was so successful was that it met a domestic need for optical glass. In the early 19th century, high quality optical glass predominantly came from the English firm The Chance Brothers, Taylor Taylor and Hobson, and the French company Parra-Mantois et Cie. (Wills). German opticians were dependent on imported optical glass for their instruments – as late as 1888, Germany imported nearly all of its optical glass from Britain. [The Aims of the National Physical Laboratory of Great Britain (Glazebrook 135). French instrument makers in particular were considered the most reliable, which was significantly tied to the encouragement of research in physics, optics, electricity, and chemistry by the French Revolution and the Napoleonic regime (Brenni 614). The American demand for microscopes was met by European imports from Paris (Nachet), Potsdam (Harnack), and London (R & J Beck and Henry Crouch) (Padgitt 90-155). However, the "economies of manufacture brought about by mass production techniques introduced by Bausch + Lomb [one of Zeiss' distributors] and others doomed the large, complicated and expensive microscopes that had been the standard in America" (Padgitt 48). The industrialization of vision was both a belief in scientific progress and a belief in a particularly German model of socially-oriented industry.

[147] T.G. Spates, "Industrial Relations in the Zeiss Works," *International Labor Review* 177, no. 198 (1930): 181.

[148] Auerbach, *The Zeiss Works* (1904), 31.

[149] Mari E.W. Williams, *The Precision Makers: A History of the Instruments Industry in Britain and France* (London: Routledge, 1994), 41.

[150] Nasse, "From the Series of Articles on Lens Names." https://lenspire.zeiss.com/photo/app/uploads/2018/04/Article-Tessar-2011-EN.pdf

affiliated partners. One of Zeiss' American distributors, Bausch and Lomb, would also mobilize the term modern in their product catalogues throughout the 1900s and 1910s.[151] American lens designer W.B. Rayton suggested that historians ought to consider Zeiss' innovations as part of a broader culture of industrialization instead of as a fundamental breaking point. However, he nonetheless links anastigmats to this modernizing impulse.[152] Kingslake also argues that we read modern lens history as a breaking point from 1886, suggesting the broader meaning of the anastigmat: that it was significant not just as a tool, but as an expression of the wider shift in the applications made possible by the reliable and reproducible design of optical glass.[153] The anastigmat vitalized a technological future through professional beliefs in the utopian potential of lenses: that lenses were a form of technological perception that existed outside the embodied social contexts of human, and therefore potentially distorted, vision.

While Abbe's theories and Schott's glass were important to establishing a practical belief in lenses, the success "can only be understood within the industrial structure first established by Zeiss."[154] Contemporary to parallel practices of scientific management performed by Frederick Taylor, Ernst Abbe's management of the Zeiss Works was predicated on the division of labor and centralized decision making.[155] In comparison to Taylorism, which was rigid in its mechanistic approach to social organization, Abbe used scientific principles to "rationalize product development and product design."[156] Zeiss' success largely came from the "creation of

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[151] See especially "Introducing Ourselves and Modern Lenses" (Bausch and Lomb Optical Co Catalogue, 1912)
[152] W.B. Rayton, "The Status of Lens Making in America," *Journal of the Society of Motion Picture Engineers* (October 1939): 427.
[153] Kingslake, "The Development of the Photographic Objective," 73.
[154] Cahan, "The Zeiss Werke," 70.
[155] For further comparisons between Abbe and Taylor's scientific management systems, see Guido Buenstorf and Johann Peter Murmann's "Ernst Abbe's Scientific Management: Theoretical Insights From a Nineteenth-Century Dynamic Capabilities Approach."
[156] Buenstorf and Murmann, "Ernst Abbe's Scientific Management," 574.

an atmosphere in which the social relations between skilled technicians and (more) theoretically oriented scientists could work to their mutual advantage."[157] As Cahan suggests, Abbe's theories of image formation had less to do with improving lenses an more to do with ensuring that craftsmen "properly executed the instructions given to them on the basis of Abbe's theory and calculations."[158] In part, Abbe's search for a reliable form of labor management was also due to Carl Zeiss' advancing age, which placed more work on Abbe alone. It became a matter of "vital importance" for Abbe to find assistants who could take over management or who could become department heads.[159] Furthermore, Zeiss' decision to create a plant for the specific production of photographic lenses in 1888 was motivated by a decline in microscope business, and Zeiss' decision to license the manufacture of Zeiss lenses to other companies also came from an uncertainty about the financial sustainability of the market for photographic lenses.[160] The industrial production of precision lenses did not emerge from a disinterested search for truth or a specific desire to improve camera lenses, but rather, from a constellation of industrial investments in labor management and commercial profit.

While we ought to be skeptical and critical of industrial logics, Zeiss' industrialization expanded from Schott and Abbe's deep-seated belief in the potential contributions of industry to social progress. Schott turned down an 1882 opportunity to lead the optics department at the Prussian *Institute for the Advancement of Fine Mechanics* – a tax funded series of experiments that in all likelihood had "a stronger emphasis on national interests such as eliminating Germany's dependence on other countries for the production of military optics."[161] Instead,

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[157] Buenstorf and Murmann, "Ernst Abbe's Scientific Management," 106.
[158] Ibid. 72-73.
[159] Auerbach, *The Zeiss Works*, 31-32.
[160] Thiele, *Carl Zeiss*, 49.
[161] Stephan Paetrow and Wolfgang Wimmer, *Carl Zeiss: A Biography: 1816-1888* (Köln: Böhlau Verlag, 2016), 117.

Schott decided to work with Zeiss and Abbe to pursue these optical developments at Zeiss rather than in the government. Similarly, Abbe's role in the industrial management of Zeiss was not a betrayal of his impassioned 1876 call for a public, rather than private, investment in optical glass development. Rather, his role in managing Zeiss spoke to his belief that industry was the best way to social progress:

> To be social means to work, and to work for the society. As long as we are living in capitalist age and as long as an entrepreneur is forced by the economic system to produce capitalistically, a profit must be made…The enterprise only becomes social [by] putting its net profit, like the foundation, at the disposal of the state, that is of culture.[162]

As Carl Zeiss grew older, Abbe became the joint-owner of the Optical Works in 1876, and in 1881 Zeiss' eldest son became a third partner.[163] In 1888, though, a year after Carl Zeiss passed, Zeiss' eldest son retired and left Abbe in full control of the optical works.[164] In 1889, Abbe established the Carl Zeiss Stiftung: both a foundation for the ownership of Zeiss and a set of statutes for the administration of the optical works in the trust of the company.[165] In 1890, Abbe "ceded all his proprietary rights, both in the Optical Works and the Glass Works" to the Stiftung, and by 1891, the Stiftung was the sole shareholder of Carl Zeiss and the Glass Works.[166] The Stiftung ensured that the company was run not in the interest of profit, but rather, in the interest of social progress created by a balance between scientific progress, employee rights, and efficient management techniques.[167]

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[162] Vogel, *Glass Chemistry*, 14.
[163] Paetrow and Wimmer, *Carl Zeiss,* 107.
[164] Spates, "Industrial Relations," 179.
[165] In the preface to Auerbach's 1904 *The Zeiss Works*, translators Paul and Cheshire indicate that they chose not to translate Stiftung as they did not feel that there was a word "which accurately renders its meaning" and that "it would be better to retain the original rather than translate it by a word, such as 'Trust.'" VI.
[166] Auerbach, *The Zeiss Works*, 89.
[167] Zeiss was also the location of a thorough experimentation with the eight-hour work day. After ten years of a nine hour work day, Abbe introduced an eight-hour work day at Zeiss in 1900 and published results of the experiment the following year. Abbe's studies indicated that longer hours resulted in a waste of energy that "takes place at the cost of the corporation of intelligence and activity, and means that the valuable capital which Germany possesses in the natural intelligence of her working classes remains largely unused because the

Abbe was skeptical of industry's political potential for economic equality, but believed that progress was possible only through the support of collective labor organizations that worked with progressive interests against "backward entrepreneurs."[168] In an 1894 speech before the German liberal party, Abbe stated:

> [T]he thousands working in rusty garb for entrepreneurs are not beings of an inferior kind, but members of the same people, who but lacked rich fathers to enable them to get six to eight years more of education than they did…the call for subjection and obedience is necessarily met in two ways: The strong, resentful natures will meet it with bitterness and deep hatred; the weak, with hypocrisy or servility. I hold it to be a veritable piece of good fortune for the German nation that there is a sufficient number in the lower classes of such who meet such impositions with bitterness and scorn; for worse than this acute poison for the soul of a nation is the insidious poison of growing accustomed to hypocrisy and servility …A people whose regulations, political and social, make the free development of the personality impossible will not be able to hold its own in the industrial contest of the nations.[169]

Abbe's idea that the public interest, particularly the German national interest in scientific industry, was best served by an efficient corporate body manifested the energistic philosophy of Helmholtz. Zeiss's corporate philosophy, and its industrialization during the 1880s and 1890s, mirrored the rise of energeticism in European social reform. As Anson Rabinbach writes in *The Eclipse of the Utopias of Labor*, while the physical and biological sciences seemingly offered "an apparently neutral and objective basis for promoting the ideal of society that might ensure social harmony," it wasn't until the last decade of the 19th century that reformers found a "general synthesis" that they could draw on for policy and proposal.[170] Rabinbach primarily locates the application of science to society, especially in Germany, through the work of Solvay,

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conditions are lacking under which this intelligence can come into full play." Stephan Bauer and Alfred Maylander, "The Road to the Eight-Hour Day," *Monthly Labor Review* 9, no 2 (August 1919): 52-53.

[168] Robert Schultze, "The Shortening of the Industrial Workday," Trans. WB Schultz, *H.R. 15651 Eight Hours for Laborers on Government Work: Hearing before Subcommittee No.1, Committee on Labor of the House of Representatives* (February and March, 1908), 704.

[169] Schultze, "The Shortening of the Industrial Workday," 704.

[170] Anson Rabinbach, *The Eclipse of the Utopias of Labor* (New York: Fordham University Press, 2018), 28.

Waxweiler, and Ostwald – scientists who implemented social reform on the basis of physics and physiology. Zeiss' lenses were not simply used to visualize and capture the social modernity enacted by these ideas: lenses also brought these ideals into social practice.

What the industrialization of vision supported was lens culture: a modern logic that simultaneously dissociated and naturalized the linkage of technology and perception in popular forms. As Coleman defines it in "Lentil Soup," lens culture is "an interlocking set of instruments and paradigms which permit the endless reframing of man as perceiver, the world as perceived, and the lens image as both vehicle and repository for that transaction."[171] The industrialization of vision, exemplified by Zeiss and later practiced widely at optical companies like E. Krauss, Bausch and Lomb, and Taylor-Hobson, linked optics to an industrial logic of objectivity, standardization, and measurement. Lens-based forms of seeing like photography came to displace other popular forms of perception like the stereoscope because, according to Crary, photography made the camera "an apparatus fundamentally independent of the spectator, yet which masqueraded as a transparent and incorporeal intermediary between observer and world."[172] As Coleman writes, even the most obvious distortions and rearrangements of vision presented by the lens "tend to be taken for granted as a result of the enduring cultural confidence in the essential trustworthiness and impartiality of what is in fact a technology resonant with cultural bias and highly susceptible to manipulation."[173] Despite the long history of photography by the end of the 19th century, lens-based imaging was never necessarily or inevitably a mass practice.

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171 Coleman, "Lentil Soup," 24.
172 Crary, *Techniques of the Observer,* 134.
173 Coleman, "Lentil Soup," 30.

Lens-based forms of vision became widely practiced and popular in the late 19th century because of the increased mass production of distortionless lenses, and also because the historically specific constellation of lens-based abstraction was particularly adequate to representing the anxieties and industrial realities of social modernity. As Doane writes:

> [T]he rationalization of time characterizing industrialization and the expansion of capitalism was accompanied by a structuring of contingency and temporality through emerging technologies of representation – a structuring that attempted to ensure their residence outside structure, to make tolerable an incessant rationalization.[174]

Lenses offered a productive thinking ground for modernity's contradictory desire for both rationality (in providing a way of seeing that allowed for measurement and a common basis of reality) and contingency (in its multiple perspectives). While it is not causal, it is not coincidental that the industrialization of vision that took place at Zeiss is contemporaneous with Muybridge's 1872 & 1878 motion studies, Marey's motion studies in the 1880s, Edison's 1891 patenting of the kinetoscope, or the Lumière brothers' 1895 screening. The production of lenses both participated in and were influenced by broader cultural shifts that, in turn, changed how and why lenses became a vital material infrastructure for visual culture.

Anastigmats, as an emblem of social modernity's contradictory interest in objectivity and subjectivity, functioned as a visible threshold of an imagined past and present of modern vision. As Bruno Latour contends, the use of pre-modern as a historical framing reduces the past to its capacity to lead up to the progressive potential of a modern present. In the context of 19th century visual culture, the abstraction of vision from a sensing human body, while simultaneously reinstating the centrality of human vision through the centrality and reliability of the lens, ultimately reinforced a narrow definition of human perception as optical neutrality.[175] As Crary

[174] Doane, *The Emergence of Cinematic Time,* 11.
[175] Bruno Latour, *We Have Never Been Modern*, trans. Catherine Porter (Cambridge: Harvard University Press, 1993), 27.

writes, some of the most "realistic" visual technologies of the 19th century were, on closer examination, based on radical abstractions of vision that allowed the "increasing rationalization and control of the human subject in terms of new institutional and economic requirements."[176] The linking of modern with measurement emphasized correction as the natural modern state and normalized what were radically abstract processes of representation. In conjunction with Zeiss' construction of lenses according to scientific principles, the production of scientifically-specified glass like barium crown glass demonstrated the power of science and measurement in overcoming both material and human capacities for perception. Zeiss' anastigmats became an emblem of social modernity: where science was seen to link humanity and progress together through technologies.

Zeiss lenses were not used in many of the early experiments that characterize early cinema. Dallmeyer lenses were used in Muybridge's 1878 equine motion studies at Palo Alto, Gundlach lenses were used in the 1892 Kinetoscopes, and Bausch & Lomb lenses were used in the 1892 Kinetographs.[177] Bearing this in mind, though, it is noteworthy that some of the early Lumière Cinematographes were built with E. Krauss Zeiss Anastigmats. In looking at the serial numbers of cameras located at the British National Museum of Science and Industry, later Cinematographes have non-descript unlabeled lenses, but we can see that a Cinematographe early in the production series (serial #8) was fitted with a Krauss Zeiss Anastigmatic f/6-3 54mm lens (although, one camera with the serial #357 is also seen to have a Krauss lens).[178] E. Krauss was a Parisian lens maker who was licensed to make Zeiss designs, and Chapter 2 will examine E. Krauss and Parisian instrument culture in closer detail. The use of Zeiss lenses on the

[176] Crary, *Techniques of the Observer,* 9.
[177] Cook, *Movement in Two Dimensions,* 130. Spehr, *The Man Who Made Movies,* 256.
[178] https://collection.sciencemuseum.org.uk/objects/co8090140/Lumière-cinematographe-35mm-motion-picture-camera-printer-projector

Cinematographes is not a clear optical parentage of cinema so much as a confirmation that Zeiss' lenses were amenable to the practices of motion picture production that sought to represent modern culture. If cinema responded to a particular anxiety about the representability of time, the conditions under which time became representable in the first place were influenced by the interests and practices of measuring perception that characterized modern glass – the conditions under which all that which melted into air could become solid and visible once more.

Figure 7 An E. Krauss lens on a Lumière Cinematographe. Camera Serial number 357. http://www.theracetocinema.com/cameras/Lumière/

Conclusion

Optical instruments maintained a strong place in the modern cultural imagination that often extended beyond their industrial scale. While the precision instrument industries were less significant in size, scope, and impact than other more notable 'modern' industries like transit, mining, or chemicals, a strong and highly regarded precision industry was a symbol of national progress.[179] One of the more enduring effects of Zeiss on screen practice was their infrastructural

[179] Brenni, "From Workshop to Factory," 585.

role in 1) establishing and demonstrating the viability of an industrial model for the reliable production of precision lenses and 2) supplying their new kinds of optical glass to optical companies across the globe. While Zeiss was dependent on foreign glass for most of the 19th century, by 1914, Zeiss had become the dominant global supplier of optical glass. Zeiss' supply of optical glass not only created an infrastructure for higher-quality optics on an increasingly global scale, but also increasingly aligned the modernization of precision optics with a distinctly German tradition of lens production. The alignment of technology with nationalism had both commercial and material implications for how lenses developed at the turn of the century, ideas that will be pursued at greater length in Chapters 2 and 3. Between 1886 and 1914, though, the benchmark of optical modernization was intertwined with Zeiss' industrial reputation.

In Felix Auerbach's 1904 *The Zeiss Works and The Carl Zeiss Foundation in Jena: Their Scientific, Technical and Sociological Development and Importance Popular Described*, Zeiss' technical accomplishments were given one of their strongest populist treatments. Auerbach, a renowned physicist in his own right who studied under Helmholtz, had written a broad and publicly-facing history of Zeiss' corporate history. As one cynical *Nature* reviewer noted on the occasion of the book's fifth edition in 1927, the fact that the first half of Auerbach's book "is a kind of conversational illustrated catalogue of the Carl Zeiss products and their history, an excellent advertisement through its atmosphere of solid achievement and great potentiality, is not without significance in explaining the production of the English translation."[180] Auerbach's 1903 publication exemplifies the difficulty in separating out corporate interests, scientific interests, and cultural interests – these were, and remain, intertwined in social modernity. In the 1907

[180] "Review: *The Zeiss Works and the Carl Zeiss Foundation in Jena: their Scientific, Technical, and Sociological Development and Importance Popularly Described.* Auerbach. Translated, 1927," *Nature* 3011, no. 120 (16 July 1927): 78.

edition, though, there is an interesting self-reflection by Auerbach on the ways in which Zeiss imagined the role and import of its technology to society.

The Zeiss Works and the Carl Zeiss Foundation in Jena, after giving a historical overview of the company, surveys the departments that make up the company. Microscopy was the first listed department; photography was the third. Provocatively, though, the department in between these two is "The Optical Projection and Photo-micrographic Department." Auerbach suggests that both microscopy and photography shared a common interest in how "the images obtained are not directly, or subjectively, examined with the eye, but are first objectively produced on a surface, as a wall, a focusing or projection screen, there to be either examined with the eye or chemically fixed."[181] While microscopy and cinematography came to characterize very different professional fields of observation, in the context of their lenses, they were connected by a common interest: projection.

Over time, lens design became concerned with the wide dissemination of images and the questions and concerns that came with the projection of images. What was "modern" about the new optical glasses and anastigmatic lenses was initially a reliable and agreed upon measurement of optical perception in communities of professional observation. But, over time, what emerged as modern from the mass production of lenses was the increased intersection of precision lenses with a mass public.

In examining the conditions under which lenses became valuable and useful, we can better understand the pressures and epistemic anxieties that led to the industrialization of lenses at a time when lens-based practices were also taken up in more popular forms like cinema and amateur photography. While the design of lenses was predominantly attached to debates about

[181] Auerbach, *The Zeiss Works*, 39.

precision and objectivity in narrow professional practices of scientific investigation and professional photography, in the application of mass production techniques to photographic lenses, lenses came to be preoccupied with two new markets: those of the "laboratory of the savant and the home of the amateur." [182] The popular appeal of photography during the Victorian period also "considerably widened the market for optical glass and lenses."[183] As Doane reminds us, cinema was not just a symptom of disciplinary changes in the sciences and industry: "It is a crucial participant in an ongoing rethinking of temporality in modernity."[184] The belief that science was the best tool of social progress was experienced in the lab – but modernization was also experienced in the streets, in the newspapers, and in the visual arts. Following this chapter's claim that the cinema owes, at the very least, something to the scientific spirit, the next chapter will demonstrate how optics might also owe something to the cinematic spirit.

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[182] Auerbach and Kanthack, *The Zeiss Works,* 46.
[183] G. L'E. Turner, "The History of Optical Instruments A Brief Survey of Sources and Modern Studies," *History of Science* 8, no.1 (1969): 71.
[184] Doane, *The Emergence of Cinematic Time*, 20.

Chapter 2 | Vision and/as Technology: E. Krauss and Parisian Instrument Culture

> A curious fact is the transformation undergone by almost all the great houses of photographic articles: the proprietors and founders retire after fortune made and the firm passes into the hands of a Company…And please believe that the shareholders are not to be pitied, because, according to the first reports given, business is fully prosperous.
>
> *L'objectif (1897)*

What made a lens a cinema lens?

The term cinema lens has come to denote lenses specifically designed for the practice of motion picture capture, especially for studio work. These are lenses constructed with sturdy materials, precise and smooth focus control, T-stops rather than F-stops, and optical elements that ensure complete sharpness across the frame of a recording medium. The classification of a lens as a 'cinema lens' is built on a series of practices, debates, and infrastructural arrangements that make arguments about what constitutes cinematographic practice. In classifying certain properties as ideally suited to cinema production, the material infrastructures of cinema lens production make social, cultural, and economic arguments about what cinema is.

However, in the same way that spectators "clearly did not bring conventions already learned by watching cinema, to the cinema," practitioners did not immediately classify or think of their lenses as cinema lenses.[185] Lenses are defined not only by their physical qualities, but also their "location within systems of narrative and logic laid out by social discourses related to technology, culture, economy and politics."[186] Although there are some exceptions and uneven developments, the dedicated category of cinema lens was not particularly widespread until the

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[185] Vanessa R. Schwartz, *Spectacular Realities: Early Mass Culture in Fin-de-Siècle Paris* (Berkeley: Univ. of California Press, 1999), 178.
[186] Ian Woodward, *Understanding Material Culture* (London: SAGE Publications Ltd., 2007), 16.

1910s and 1920s (a development that will be more closely examined in Chapter 4). The category of cinema lens is not necessarily appropriate when examining early cinema, when cinema emerged as one of many diverse visual practices – ranging from magic lantern shows to still photography to stereoscopy – that relied on lenses to produce images of motion. A different question is in order: before lenses became cinema lenses, what were they?

To expand an understanding of how lenses became cinema lenses – or, more precisely, how lenses came to be used in early cinema – this chapter will examine the emergence of cinema alongside fin-de-siècle Parisian instrument culture. To do so, this chapter will use the case study of the optical firm E. Krauss. While their most famous cinema lens is the lens that appears in the closing shot of Dziga Vertov's *Man With a Movie Camera* (1929), E. Krauss' place in early cinema has remained unknown.[187] Established in 1882, E. Krauss illuminates a number of key relationships between the emergence of early cinema and the late 19th century optical industry. As a Parisian distributor, the firm demonstrates how photographic lenses were part of a wide variety of optical instruments that were designed and sold in the newly urban spaces of modernity. Specific to cinema, E. Krauss lenses were found on the cameras of Méliès, the Lumière Brothers, and many Pathé Freres studio cameras. Finally, E. Krauss is also a useful subject in that the firm expands this project's cultural history of lenses to include an important dimension of technological modernity: uneven development.

If the previous chapter considered the conditions under which Zeiss industrialized professional and social desires for technological vision in the mid to late 19th century, this chapter engages the decline of the French instrument industry. Whereas the industrialization of

187 Vertov used a French camera, the 1927 Debrie Parvo Model L, in his documentary. "A Glorious Piece of Mechanism – Debrie Parvo, *The First Cinemakers*. Accessed 30 August 2018. https://firstcinemakers.com/6-f-akeley-and-the-birth-of-the-newsreels-1/

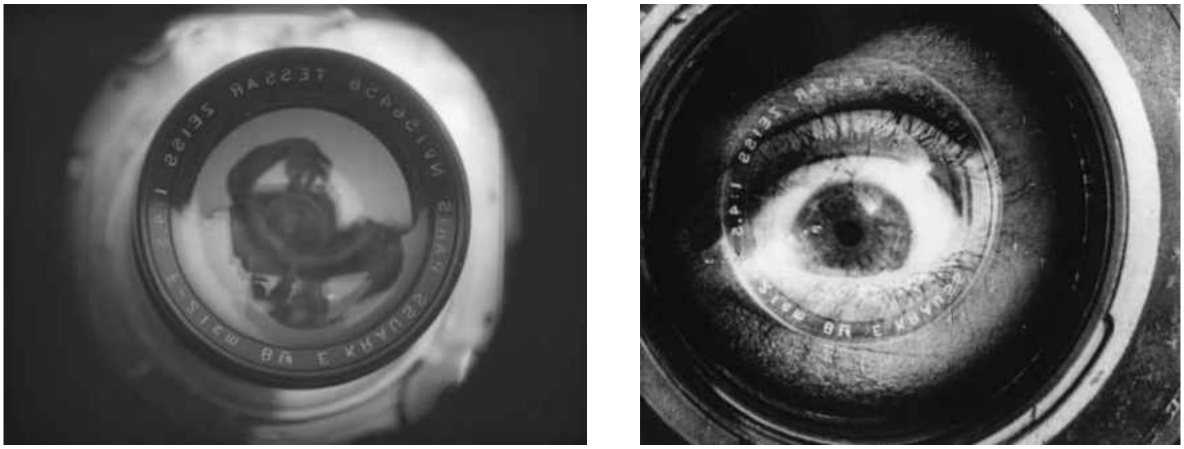

Figure 8 Mirrored images of E. Krauss Lenses in Dziga Vertov's Man With a Movie Camera (1929). 2014 BFI Restoration.

vision resulted in strong economic and culture capital for Germany, this was not the case in France. France's instrument industry maintained a craft production tendency much longer than Germany, England, and America. The limited instances of French industrial lens production led to both a lethargy of innovation in and, in some cases, a significant exploitation of workers in the instrument shops.[188] E. Krauss, who had been licensed to manufacture Zeiss lenses as early as 1892, provides a complicated example of how the modernization of glass, and its connected ideas of vision as both a technological and national commodity, came to circulate in cities in ways that often exceeded and departed from the initial ideals of lens designers and distributors. Additionally, in framing E. Krauss as a lens company in its own right and not simply considering the company as secondary to Zeiss, I use E. Krauss to attend to complexities of international exchange and national identity that formed in commercial optics.

A cinema lens is a practical category, but it is also a commercial category, and the intertwining of these practical and commercial conceptions shaped how cinema emerged as a set of technological practices distinct from other optical practices like microscopy or photography.

[188] Williams, *The Precision Makers,* 39.

As Bowker and Star argue in *Sorting Things Out: Classification and Its Consequences*, "something actually *becomes* an object only in the context of action and use; it then becomes as well something that has force to mediate consequent action."[189] A cinema lens is a boundary object: a term Bowker and Star use to define objects that "both inhabit several communities of practice *and* satisfy the informational requirements of each of them."[190] While an emergent community of cinematic practitioners came to define cinema lenses through practice, cinema lenses were also defined by an emergent community of international optical suppliers. It is not solely a question of whose definition was more correct: a cinema lens is an ideal, a standard, and a classification, which means that it is "never perfectly realized."[191] Bowker and Star theorize boundary objects as way of understanding how communities of practice with divergent viewpoints and perspectives come to identify themselves and the boundaries of their imagined communities.[192] As such, what early lenses offer are a way to understand how two communities of practice – cinema and commercial optics – managed competing definitions of what constituted an effective lens for cinematic practice.

In contrast to invention-centric histories of early cinema, I frame the emergence of cinematic lenses in Paris as a cultural event rather than a technological teleology. Commercial instrument culture was an integral infrastructure for the social behaviors that constituted early visual culture, and I use E. Krauss' lenses to consider how the commercial institutions surrounding early cinema should also be understood as a material culture. As Ian Woodward defines it, material culture is "the point where mass-produced consumer objects are encountered

[189] Geoffrey C. Bowker and Susan Leigh Star, *Sorting Things Out: Classification and Its Consequences* (Cambridge: MIT Press, 2000), 298.
[190] Ibid. 16.
[191] Ibid. 15.
[192] Ibid. 292-296.

and used by individuals, who must establish and negotiate their own meanings and incorporate such objects into their personal cultural and behavioural repertoires, sometimes challenging and sometimes reproducing social structure."[193] Lenses, which were increasingly mass produced for commercial markets in the late 19th century, provide both a material and cultural site of analysis for understanding the early visual culture of modernity. If modernity was cinematic before the fact of cinema, as Charney and Schwartz argue, then lenses were not simply used to capture images of modernity: lenses co-constituted modern visual culture.[194] In better understanding the commercial optical cultures that constituted the early field of cinema technology, we can better understand how the circulation of lenses in and across urban spaces shaped lens companies as microcosms of global, rather than national, corporate capitalism.

Visions of Paris: Photographic Lenses and Urban Instrument Culture

In order to understand why E. Krauss lenses came to be so widely used in cinematic practice, it is necessary to understand both the industrial and the national context of French precision optics in the 19th century. As I've suggested in my analysis of Zeiss, lens technologies were never adopted solely on the basis of technological progress or superior design alone. Rather, the adoption of lenses was always embedded in a series of social, cultural, and economic relationships. The dominant power of visuality in modern culture, as Anne Friedberg argues in *Window Shopping: Cinema and the Postmodern*, emerged not from new technologies, but from "the social behaviors involved in the examination of goods on display (shopping) and the experience of "foreign" spaces (tourism)."[195] Because of the ways in which practices and

[193] Woodward, *Understanding Material Culture*, 3.
[194] Charney and Schwartz, "Introduction," 1.
[195] Friedberg. *Window Shopping,* 3.

materials of optical manufacturing developed unevenly at the close of the century, the national origin of a lens strongly influenced how photographers and practitioners perceived and assessed lens quality in the commercial market. One of the most significant influences on the development of lens markets was the development of national optical industries, particularly that of Germany. The development of national optics was entangled with the rise of cities and urban spaces, and, in the context of France, the French optical industry was virtually synonymous with the optical industry of Paris.[196]

If the unfolding of modernity "cannot be conceived outside the context of the city," the capital of 19th century modernity was Paris.[197] As Walter Benjamin writes, 19th century commodity culture finds its definitive image in the urban spaces of Paris. A confluence of shopping arcades, panoramic exhibitions, world fairs, and expanded boulevards abstracted and transformed the natural world into a visual phantasmagoria that could be consumed as a visual commodity.[198] As Friedberg similarly writes, "The city itself redefined the gaze. New means of transportation provided an unprecedented urban mobility, the broadened boulevards produced unimpeded forms of urban circulation, shop windows invited passersby to engage in imaginative new sites of looking."[199] Cinematic spectatorship, particularly in the context of Paris' architectural and social history, emerged from the "social and psychic transformations that the arcades – and the consequent mobility of flanerie – produced."[200] The infrastructural developments of Haussmannization, the Metro system (first opened in 1900), and the city's first electrical grid (implemented unevenly from 1888) helped encourage "modern forms of

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196 Williams, *The Precision Makers,* 12.
197 Charney and Schwartz, "Introduction," 2.
198 Walter Benjamin, "Paris: Capital of the 19th Century," in *The Arcades Project*, ed. Rolf Tiedemann, trans. Howard Eiland and Kevin McLaughlin (Cambridge: Belknap Press, 1999), 3-13.
199 Friedberg, *Window Shopping*, 38.
200 Ibid. 68.

movement, light, entertainment, and consumption."[201] While other scholars have examined how these practices created a favorable context in which cinema emerged as a particularly affective experience of modern life, the cinematic modernity of Parisian urban development also gave rise to a precision instrument industry intertwined with – rather than simply looking in on – urban culture.[202]

While Haussmanization may have been the defining influence on Parisian commercial culture, the French Revolution of the late 18th century strongly affected how instruments came to be designed, sold, and viewed in these urban spaces. According to instrument historian Paolo Brenni, the French Revolution represented a "fundamental turning point for the Parisian instrument industry.[203] Prior to the 19th century, British instruments were held in the highest regard in the European market. In addition to forcing domestic production of instruments in France due to trade blockades, the war blockades of the Napoleonic Wars forced the development of France's primary optical glass supplier, Parra-Mantois.[204] The Revolution also had significant effects on the social organization of the instrument production community. The strict division of instrument production between different guilds was abolished, the social status of craftsmen and technicians was elevated, and the development of urban institutions such as the *Comité des Brevets* (Patents Committee) and the *Société d'Encouragement pour l'Industrie*

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[201] Brian Jacobson, *Studios before the System: Architecture, Technology, and the Emergence of Cinematic Space* (New York: Columbia University Press, 2015), 128.

[202] For further reading on the relationship between mass visual culture and Paris, see Vanessa Schwartz's *Spectacular Realities: Early Mass Culture in Fin-de-Siècle Paris*, Anne Friedberg's *Window Shopping: Cinema and the Postmodern*, Rosalind Williams' *Dream Worlds: Mass Consumption in Late-Nineteenth Century France,* H. Hazel Hahn's *Scenes of Parisian Modernity: Culture and Consumption in the Nineteenth Century,* Charles Baudelaire's "On Photography," and Walter Benjamin's "Paris: Capital of the Nineteenth Century" and his unfinished *Das Passagen-Werk*.

[203] As Brenni notes, if "a *fondeur* was using the tools of a *lunetier*, the equipment of his workshop as well as his products could be seized. Paolo Brenni, "Artist and Engineer: The Saga of 19th Century French Precision Industry," *Bulletin of the Scientific Instrument Society* 91 (2006): 2.

[204] Pat Choate, *Dangerous Business: The Risks of Globalization for America* (New York City: Knopf, 2008), 105.

Nationale (Society of the Encouragement of National Industry) resulted in new collaborations between makers and scientists.[205] While progress and investment was predominantly tied to the production of telescopes, astronomic telescopes, and microscopes, photographic lenses (such as those produced by Chevalier for Daguerre and the Daguerretype) received a boost from expansions in the field of medicine.[206] These new kinds of close infrastructural relationships between lens designers and scientists opened up manufacturing to a wider range of ideas of what made for a useful instrument. Makers not only provided instruments needed by scientists, but "their workshops were often used as experimental spaces in an epoch when universities and educational institutions were rarely equipped with proper laboratories and collections of instruments."[207] For several decades, the ateliers of optical instrument manufacturers "were the meeting place for intellectuals and scientists who found in these [workshops] an ideal place for expressing their intuition."[208] The Revolution's arrangement of urban labor gave rise to an instrument culture defined not by the objective pursuit of truth, but from the intersection of science, commerce, and aesthetics.

Coinciding with Haussman's 1853-1870 boulevard expansion, the "Golden Era" of the Parisian instrument industry was marked by the growing international visibility of French instrument makers. Almost all the French precision instrument makers established before 1914 were located in Paris. The main market was located in the city, as were several international exhibitions.[209] The visible opulence of Parisian instruments was the defining factor of their

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[205] Brenni, "Artist and Engineer," 2.
[206] Corrado D'Agonstini, *Photographic Lenses of the 1800's in France – Berthiot, Chevalier, Darlot, Derogy, Hermagis, Jamin, Lerebours, Solei* (Bandecchi & Vivaldi 2001), 19.
[207] Brenni, "Artist and Engineer," 2.
[208] D'Agonstini, *Photographic Lenses of the 1800's in France,* 19.
[209] Williams, *The Precision Makers,* 12.

prestigious reputation.[210] While, as Jonathan Crary cautions, there is a tendency to "conflate all optical devices in the nineteenth century as equally implicated in a vague collection drive to higher and higher standards of verisimilitude," the instruments of Paris were valued on the basis of craftsmen's sumptuous attention to instrument design that had little to do with realism as it is classically defined. As was the case with scientific instruments, the "elegance of a lens was of utmost importance. This was a viewpoint in line with the spirit of refinement and elitism which characterized Paris in those years and was also shared by those bought these objects abroad."[211] Post-1850, instrument visibility was also strongly promoted by the increased publication of catalogues with hundreds of illustrations and popular French scientific textbooks, which often featured a large number of detailed engravings of apparatuses and experiments.[212] In the same way that guidebooks, serial novels, and newspapers widely disseminated the image of Paris as a spectacular entity, these catalogues and textbooks circulated opulent images of instruments that made Parisian instruments a spectacle in and of themselves.[213] While instruments were characterized by their capacity to scientifically study vision, it was the elegant, well proportioned, and lavishly materiality of French instruments that defined them as the "the *nec plus ultra* of craftsmanship" from the 1840s to the 1880s.[214]

Paris' decadent instrument culture influenced the way that instrument makers thought of both themselves and their products. Parisian instrument makers were described and self-identified not as physicists or technicians, but as artist-engineers (*artistes-ingenieurs*).[215] For more than a century, Paris' situation as a capital for elegance and luxury goods put instrument

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[210] Brenni, "Artist and Engineer," 3.
[211] D'Agonstini, *Photographic Lenses of the 1800's in France,* 21.
[212] Brenni, "Artist and Engineer," 4.
[213] Schwartz, *Spectacular Realities,* 15-16.
[214] Brenni, "Artist and Engineer," 6.
[215] Ibid. 6.

makers into both a physical and imagined community of elegant/luxury goods producers. While instruments were not historically considered luxury goods, in the context of a city with a reputation for elegance, instrument makers nonetheless "shared the more or less unconscious feeling of belonging to a special category of workers."[216] While instruments may have been intended for scientific research, the use of telescopes and microscopes by amateurs for parlor entertainment encouraged the production of instruments that could also serve as "nice pieces of furniture," a tradition held over from the sale of instruments to nobility and the aristocracy.[217] What instrument makers sold was not only the instrument, but also a connection between optical instruments and broader cultural practices of spectacular reality. In Paris, like many other cities, reality was often constituted by experiences and sensations that exceeded classical pictorial notions of representation. In this respect, elegant Parisian instruments were not a more 'primitive' stage of lens development that necessarily developed into more accurate or scientifically correct optical instruments. Instead, instruments themselves expressed a mediated relationship between vision and modern experience suited to the cultural context of Parisian modernity.

However, in the 1880s, the basis of professional beliefs in optical quality began to shift from a belief in the craft of individual opticians to a belief in the universal science of optics. As examined in Chapter 1, the viability of lenses in professional practice was largely due to the industrial and commercial efforts of the German optical company Zeiss. Following their construction of The Glass Works in 1884, Zeiss began to manufacture new kinds of optical glass and other varieties of optical instruments.[218] The Glass Works was the first large-scale glass

[216] Brenni, "Artist and Engineer," 6.
[217] Friedberg, *The Virtual Window,* 63.
[218] For a more detailed history of Zeiss and optical glass, see Feffer "Ernst Abbe, Carl Zeiss."

factory capable of melting "chemically durable glass types with high reproducibility in those properties that high end optical systems require."[219] Among these was barium crown glass, which made it possible for Zeiss to manufacture new kinds of distortionless photographic lenses.

In particular, Zeiss' Anastigmat lenses, released in 1890, were especially influential in convincing photographers that scientifically designed lenses were superior to hand-crafted lenses. Anastigmat lenses were corrected for both chromatic and spherical aberration – a feat that had previously been imagined to be outside the physical capacity of lenses, especially at the level of light necessary for rapid-capture photography. Zeiss' anastigmatic lenses were lauded for capturing images with minimal distortion, and it was Zeiss' manufacture of glass with specific and reproducible material properties that made these designs viable both in practice and in the minds of practitioners. Zeiss' catalogues, trade demonstrations, and presence in educational institutions encouraged consumers and practitioners to believe that scientific systems, rather than individual professionals, could form the basis of reliable manufacture in optics.[220] Zeiss sold glass, but more importantly, they also sold a belief in a new kind of precision lens industry.

The scientific design of lenses and precision was seen to hold a great deal of promise for photographic practices, but the Parisian optical industry's tendency towards craft production meant that French lenses were increasingly perceived as out of step with the growing tendency to value lenses on the basis of scientific criteria. On January 5, 1891, Charles Fabre gave an extensive discussion on Zeiss' new anastigmatic lenses to *La Société française de photographie.* Fabre was a professor at Toulouse, author of the four volume *Traité Encyclopédique de Photographie*, and an active member of the Society. During his lecture, Fabre frequently and carefully reiterated the strength of the French industry to his audience, noting in particular how

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[219] Hartmann et al., "Optical Glass," 158.
[220] Feffer, "Ernst Abbe," 58.

the lenses of French designer Berthiot suggested that, "*when they fight on equal terms* [original emphasis]," French workers "do not yield in any way to those of other countries."[221] Yet, Fabre's address also marked his position as one of the society members who believed the French lens industry was entering a period of decline. Fabre reminded the audience of an earlier address he had made in 1877 where he urged the Society to consider how progress in microscope construction might be applied to the fabrication of photographic lenses – the same line of technical development that had led to Zeiss' optical prestige. Fabre's 1891 lecture further emphasized that the scientific principles adopted by Zeiss had "an infinity of applications" and that the new highly refractive and little dispersive glasses presented advantages that seemed "impossible to obtain with the old glasses."[222] At the heart of Fabre's lecture was an anxiety that the modern promise of precision lenses was aligned with an industrial model that Parisian instrument makers had not followed and, without convincing, would not follow.

Fabre delivered his lecture to *La Société française de photographie* at a time when sun was setting on the Golden Era of French Instruments. Between 1880 and 1914, the French precision industry experienced a period of slow decline.[223] Many blamed the success of Goerz lenses, the Zeiss anastigmats, and Zeiss' advertising strategies that (over)sold the technical quality of non-French lenses.[224] However, a 1916 review of the French optical industry in *La Nature* suggests that the "original supremacy" of French photographic lenses faded because

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[221] Charles Fabre, "Sur quelques nouveaux objectifs photographiques contruits par M. Zeiss," *Bulletin de la Société française de photographie* (1891): 131.
[222] Ibid. 133-139.
[223] Brenni, "Artist and Engineer," 2
[224] As Georges Brunel, director of the review journal *Les Nouvelles scientifiques et photographiques* and author of *Formulaire des nouveautés photographiques* (1896), writes, "Optics, after the progress realized by the Zeiss firm, is staying stationary. Whether this means that it has arrived today at perfection, we will say that we have almost arrived and we will mention only the following systems…" Brunel goes on to highlight a number of Parisian lens makers (Eurygraphes Anastigmatiques Extra-Rapides by Berthiot, Gorde's Synoscope, Trousse-Bijou, Fleury Hermagis, and Derogy). Georges Brunel, *Formulaire des nouveautés photographiques* (Paris: J.B. Baillière et fils, 1896).

"French makers did not use the new glasses and modern grinding methods, nor sufficiently avail themselves of skilled technical knowledge."[225] The greater inequality, to use Fabre's term, that led to the decline of French lenses in favor of German lenses was a lack of institutional support for optics in France. Whereas the Glass Works at Jena was supported by German governmental subsidies – a point Fabre emphasized early on in his address to the photographic society – the increased institutionalization and mathematization of science in France had made for less cooperation and a growing distrust between makers and scientists.[226] These changes were only further heightened by the opulence of French instruments, which became seen as starkly out of touch with contemporary desires for scientifically-assured precision lens design. As Brenni writes, "[I]f this love for elegance and formal accuracy was appreciated for several decades, at the end of the 19th century it became a disadvantage…French instruments appeared as old-fashioned scientific cabinet artefacts compared to these new German instruments."[227] The opulence of French instruments was believed to be the cause of France's "late" industrial development, and the idea that industrial development was a natural and necessary improvement on artisanal production was frequently validated by the profits and culture capital gained by German instrument makers.

The clashes between French and German lenses echo the conflicts that characterized national cinemas in its early years. As Charles Musser writes, the impact of nationalism on the cinema "was perhaps most profound when shaped by the presence and perceived threat of others – of foreign rivals."[228] Although the late 19th century French industry is classically narrated as being out of step with the marching progress of ever-sharper lens design, the opulent tradition of

[225] "Quotations: The Optical Industry in France," *La nature* 44, no. 1139 (1916): 612.
[226] Brenni, "Artist and Engineer," 9.
[227] Ibid. 6-10.
[228] Musser, "Nationalism and the Beginnings of Cinema," 151.

Parisian instrument makers was not quickly nor wholly replaced by the scientific tradition of industrial production. Rather, the clash between French opulence and German engineering was an encounter in which the lens, as a boundary object, served as a site of renegotiation for the national and international identities of lens manufacturers and distributors. In the same way that motion pictures expressed not only the shock of modernity, but also "the shock of a new nationalism," lenses were microcosmic encounters between nationally-specific conceptions of technological vision.[229] The criteria of optical representation, while increasingly falling under the domain of scientific research, was nonetheless entangled in existing beliefs that visual technologies were the product of specifically national industrial practices.

Spectacle, the sensory and the opulent – the qualities that defined French industry – were becoming incompatible with emerging scientific-rational ideals that defined a useful and quality instrument. The sense that French opulence was seen as antithetical to an objective "modern" vision changed how lens manufacturers organized their craft. As reported in an 1897 issue of *L'objectif,* a Belgian photography journal, many national lens companies began to reorganize their business structures at the turn of the century. Whereas most optical companies were named after their proprietors, the optical *maisons* began to pass into the management of optical companies.[230] The reorganization of lens manufacture on the basis of companies, rather than around individual opticians, sustained the dissociation of vision from the human body: what Crary refers to as "the denial of the body, its pulsing and phantasms, as the ground of vision."[231] As boundary objects, lenses and lens companies were sites in which this dissociation of vision and body became legible and not just infrastructural or ideological. The proprietors' names often

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[229] Musser, "Nationalism and the Beginnings of Cinema," 170.
[230] L. de Lissengrez, *L'Objectif*, no. 21, August 1, 1897, 165-166.
[231] Crary, *Techniques of the Observer*, 134.

remained, with French lens companies like Berthiot, Chevalier, Darlot, Derogy, Hermagis, Jamin, and Lerebours. But, what those names began to invoke were a series of manufacturing processes rather than a series of embodied practices.

Following Fabre's lecture, there was an increased interest in the new anastigmatic lenses for their technological promise of distortionless vision. The broader interest was not due only to Fabre's lecture – interest was also aided by the advent of Zeiss lens production in Paris. In the late 19th century, French patent laws initially prohibited the importation of patented goods from Germany.[232] Part of a broader imperial attempt to capitalize on colonial markets, the Paris Convention for the Protection of Industrial Property of 1883 was intended to secure import monopolies without any obligation to produce the patented article in the patent-granting country.[233] As a result, Zeiss Anastigmats could not be imported and were required to be manufactured in France, and this was done through the adoption of a Zeiss manufacturing license. The exclusive license to manufacture Zeiss anastigmats in France was given in 1892 to a friend of the prominent Zeiss physicist Ernst Abbe: Eugene Krauss.[234]

E. Krauss and Early Cinema

Jules Carpentier, the engineer of the Lumière Cinematographe, was unable to attend the Lumière Brothers' screening at the Grand Café in December of 1895. Georges Méliès attended, though, and following the Lumière Brothers' refusal to sell him a camera, Méliès decided to make his own. While unlikely, we can imagine a moment where Méliès and Carpentier crossed paths at E. Krauss' shop at 21 and 23 Rue Albouy. E. Krauss lenses were used on both Méliès'

[232] Moritz Von Rohr, *Theorie und Geschichte des photographischen Objektivs* (Berlin, 1899), 141.
[233] Rajeev Dhavan, Lindsay Harris, and Gopal Jain, "Conquest by Patent: The Paris Convention Revisited," *Journal of the Indian Law Institute* 32, no. 2 (1990): 131.
[234] D'Agostini, *Photographic Lenses of the 1800's in France,* 295.

first camera and a number of Lumière Cinematographes. According to Laurent Mannoni, George Méliès' camera was found with "an Anastigmat Weiss [sic] E. Krauss 1:63 F:54)."[235] A number of Lumière Cinematographes have also been archived in museums with E. Krauss lenses, including the Institut Lumière, and E. Krauss catalogues advertised the inclusion of their lenses with Lumière Cinematographes in the early 1900s. In an October 1895 correspondence, Jules Carpentier also explicitly mentions lending Louis Lumière a Zeiss lens.[236] It is difficult to tell whether E. Krauss lenses were the original lenses used or the extent to which they were, in fact, used. But, the presence of E. Krauss lenses on some of the more iconic cameras in early cinema suggests that these lenses held a place in the commercial market that made them particularly amenable to or desirable for motion picture production. E. Krauss' commercial reputation was strongly influenced by their commercial affiliation with Zeiss.

E. Krauss was founded in 1882 by Eugene Krauss at Luetzowstrasse No. 68 in Berlin, and in the 1880s and 1890s, the company created branches in Milan, London, St. Petersburg, and Tokyo. E. Krauss had established a branch in Paris as early as 1893 (first at 32 Rue de Bondy and later at 21 et 23 Rue Albouy). While the company began in Germany, E. Krauss became closely associated with their Parisian location in the late 19th and early 20th century. Foreign periodicals regularly referred to E. Krauss in the context of their Parisian location, such as when *American Amateur Photographer* and *Revue Suisse de photographie* advertised E. Krauss' 1896/1897 photography contest.[237] A newspaper notice about Eugene Krauss' marriage to Agnes Hoering also suggests that he was residing in Paris as early as 1895.[238] E. Krauss sold a wide

[235] Jacques Malthête and Laurent Mannoni, *Méliès: Magie Et Cinéma* (Paris: Paris Musées, 2002), 122.
[236] *Letters: Auguste and Louis Lumière*, eds. Jacques Rittaud-Hutinet and Yvelise Dentzer, trans. Pierre Hodgson (London: Faber and Faber, 1995), 25.
[237] "Photographic Competition," *The American Amateur Photographer* 8 (1896): 440. "Correspondence," *Revue Suisse de photographie* 9 (1897).
[238] "Avis de Mariages," *Figaro*, June 16, 1895, 3.

variety of optical instruments, but their exclusive 1892 license to manufacture Zeiss anastigmats made the company one of the few places in Paris where photographers could purchase the increasingly popular Zeiss anastigmats.

E. Krauss highlighted the Zeiss name on their catalogue covers and also prominently advertised their "anastigmat" lenses in trade publications. In 1893, for example, E. Krauss created a full-page advertisement in *Les Nouveatés Photographiques* announcing their exclusive production license of Zeiss lenses in France. The phrase "ANASTIGMATS-ZEISS" is the largest text on the page, larger even than the company's name at the top of the page.[239] In addition to two large images of the lenses – one with a cross section to show the inside of the lens, and another displaying the side of a lens with elegant engraving – the bottom of the advertisement included a testimony from Carl Zeiss. The notice, dated February 1892, reassured consumers that E. Krauss had the same processes and quality as those produced by Zeiss in Germany. E. Krauss repeatedly and emphatically linked the quality of their lenses to the reputation of Zeiss. As a Parisian company with strong ties to the German tradition of lens craft, E. Krauss complicated the popular belief that lens quality was the product of a particularly national set of practices. In doing so, E. Krauss made visible the reality that lens quality was predicated on international, rather than solely national, practices.

[239] "E. Krauss & Cie," Advertisement in Frédéric Dillaye's *Les Nouveatés Photographiques* (Paris: 1893).

Figure 10 Notice of Krauss' Exclusive License for the Production of Zeiss Anastigmats. Les Nouveatés Photographiques. Frédéric Dillaye. Paris: 1893.

Figure 9 E. Krauss advertisement for binoculars. 1897.

E. Krauss prominently advertised their anastigmats, but they also manufactured and distributed a wide range of optical instruments. In addition to their photographic lens offerings, the firm's 1899 catalog offered binoculars, loupes, microscopes, and telescopes. This was not particularly uncommon in late 19th century Parisian instrument culture. The sale of photographic lenses was a typically a secondary business within a larger practice of Parisian instrument and apparatus sales. As Paolo Brenni suggests, it is unlikely that instrument makers produced everything that they advertised.[240] There were three broad categories of Parisian instrument

[240] Brenni, "Artist and Engineer," 5.

sellers: 1) makers, who manufactured their own instruments but also sold other apparatuses, 2) maker-retailers, who only produced the most basic instruments and whose business was primarily reselling more expensive instruments and repairing apparatuses, and 3) retailers, who simply sold instruments.[241] As Mari E. W. Williams similarly suggests, optical firms at the turn of the century were genuinely fluid rather than narrowly specialized:

> They might have specialised in a particular type or range of measuring device, but if requested they would diversify into new areas. It was possible to distinguish between makers of different types of instrument in a general way, for example, producers of meteorological instruments as opposed to optical, but often this difference was mainly one of emphasis rather than of any fundamental kind.[242]

Much in the same way that early film studies has recognized cinema as one of many visual attractions at the turn of the century, distinctions between different kinds of optical instruments were more fluid than they came to be in later years. This lack of optical specialization – and a commercial emphasis on variety – created an urban instrument culture that emphasized an aesthetics of variety over technical specialization.

Even though E. Krauss was not exclusively dedicated to manufacturing photographic lenses, the benefit of E. Krauss' licensing of Zeiss strongly differentiated E. Krauss' lenses against its domestic competitors. As Bernard Vial suggests in a 1974 retrospective of Krauss, obtaining the license to construct Zeiss objectives was like a "consecration."[243] Krauss-Zeiss anastigmats offered experimenters like Méliès and Carpentier the promise of technical affordances that were, at the very least, optimal for the technical requirements of motion picture capture. To record images on flexible celluloid film stock, practitioners needed fast lenses that could capture distortionless images at quick exposure speeds – a practical feat that anastigmats

[241] Brenni, "Artist and Engineer," 4.
[242] Williams, *The Precision Makers,* 10.
[243] Bernard Vial, "Un grand constructeur francais: E Krauss," *Photo-Revue* (November 1974): 521.

were particularly suited to in comparison to other lenses. As McKay would later suggest in the 1927 *Handbook of Motion Picture Photography*:

> The lens used with the motion camera may be any photographic lens, but in practical work, the choice is limited to a great extent. The motion picture lens must be an anastigmat. The anastigmat is the only lens which will give the critical definition all over the frame which will stand the two hundred and eighty-eight times linear enlargement which is not uncommon.[244]

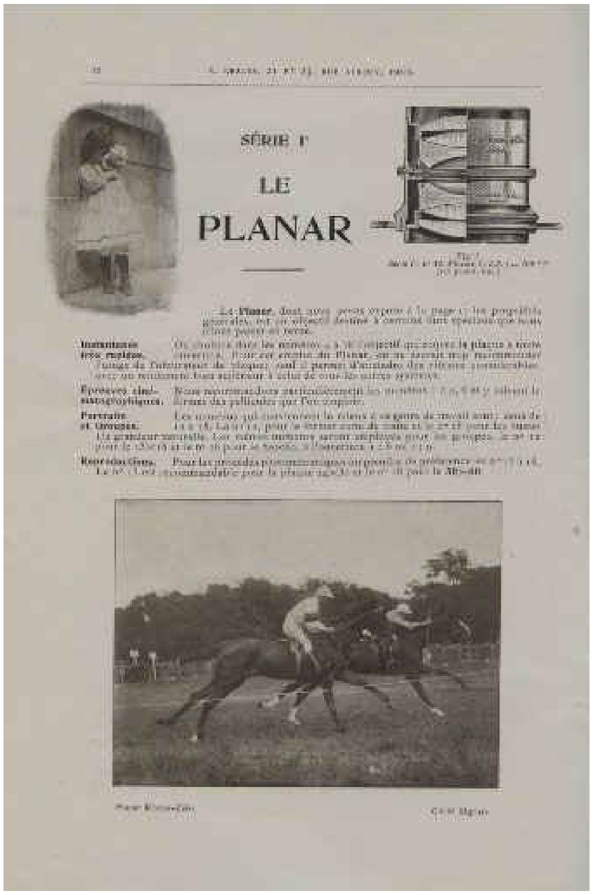
E. Krauss lenses, more than other lenses in a struggling French optics industry, were particularly suited to fulfill a practical need for fast lenses that could 1) benefit the capture of images on celluloid film and 2) capture motion pictures with enough fidelity to be effectively projected for an audience. Fast lenses were not exclusively Zeiss lenses – and, as motion pictures became an international industry at the turn of the 20th century, the use of Voigtländer, Dallmeyer, Goerz, and Cooke lenses quickly became more common. In mid-1890s France, however, the popular sentiment was that these qualities were most closely aligned with lenses of German manufacture.

E. Krauss advertised their Zeiss anastigmats in an attempt to differentiate their lenses on the basis of scientific construction rather than practical specialization. By the 1890s, manufacturers were beginning to specialize in the production of photographic lenses, such as Dallmeyer and Taylor-Hobson in England, Voigtländer and Zeiss in Germany, and Derogy and Berthiot in France. However, in Paris, lens vendors were rarely dedicated to the production of a single instrument or product – particularly when it came to the commercial culture of selling and distributing these lenses. Even Parisian vendors who specialized in the sale of photographic lenses typically sold a variety of products. According to the Syndicate of Precision and Optical Instrument Constructors' 1901-1902 survey of the French precision instrument industry (a survey initiated on account of France's poor national performance at the 1900 Exhibition), a

[244] Herbert C. McKay, *The Handbook of Motion Picture Photography,* (New York: Falk Publishing Company, 1927), 58.

number of firms did specialize in the sale of photographic lenses, such as the Maison C. Berthiot and the Maison A. Darlot.[245] More often than not, though, photographic lenses were sold as part of a broader range of optical apparatuses, devices, and instruments. Louis Feuillet, whose firm is recorded as producing over 30,000 photographic objectives a year, primarily lists its products as photographic, cinematographic, and projector lenses, but also lists a secondary tier of binoculars and viewfinders.[246] Clément & Gilmer, which initially only built a series of common photographic lenses, had expanded its work to include tele-photography, anastigmatic lenses, lenses, prisms and mirrors of scientific experiences, etc., and came to specialize in apparatuses for light projection and photographic enlargements.[247] The emphasis of a given optical firm or lens vendor often changed over time, and the Syndicate's 1901-1902 industrial survey often included notes about how a firm changed over time (for example, the Maison Eard Degen was at one point preoccupied with optics for binoculars and instruments, but later specialized in photography while also selling microscopes).[248] Makers did not only make instruments, but also organized production, managed the workshop, prepared catalogues, and conducted sales.[249] While distinctions between lenses used in still cameras and other optical instruments were clear at the level of practice and design, at the level of the instrument maker, these distinctions were more ambiguous and often shaped more by agreements with suppliers more than practitioners.[250]

[245] Syndicat général des industries techniques de la précision and Marie Alfred Cornu*, L'Industrie française des instruments de précision, 1901-1902 ... Catalogue publié par le Syndicat des constructeurs en instruments d'optique & précision* (1901), 26-27, 72-73.
[246] Ibid. 100.
[247] Ibid. 59.
[248] Ibid. 81-83.
[249] Brenni, "Artist and Engineer," 5.
[250] For example, E. Krauss' 1899 offering of microscopes was likely the result of E. Krauss' licensing relationship with Zeiss, who had a similar licensing agreement with Bausch and Lomb since the early 1890s.



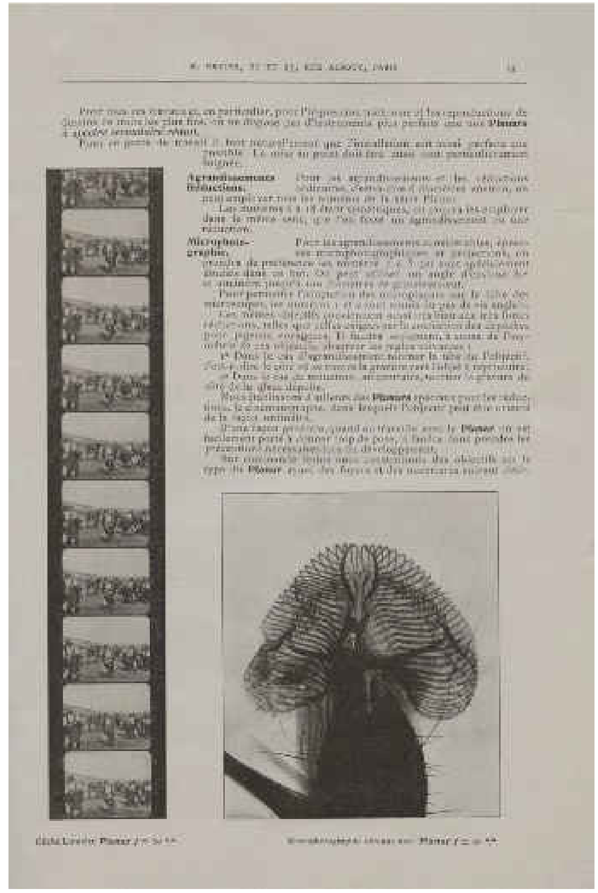


Figure 11 Horses in motion, Lumière film strips, and a micrograph of a fly are all used as part of a Planar Advertisement in a 1902-1903 E. Krauss Catalog. 12-13.

Although lenses were used for motion picture production since the mid-1890s, there was a period of delay before lenses became specifically identified as useful for the practice of cinema. Consider how E. Krauss advertised their Planar lenses in a 1902-1903 catalog. The Planar was a relatively fast lens, with an f/3.8 aperture, and E. Krauss' catalogue specifically designates a number of variations of the Planar for cinematographic work. The use of the Planar lenses for cinematographic use is listed second in the catalogue entry. While it is a brief mention, the inclusion of a large image of a horse in unsupported transit (a possible homage to Muybridge's motion studies) and an enlarged Lumière film strip printed on the catalog page indicates that E. Krauss sought to explicitly link these Planar lenses to contemporary high-speed image practices. The Planar was released in 1896 and appears in an earlier 1899 E. Krauss catalogue, but the lens was not identified as being useful for the practice of cinematography in this 1899 catalogue: instead, the Planar was primarily advertised as a photographic objective. Sometime between 1896 and 1902, the advertisement of lenses for cinematographic practice became commercially viable.

The period of delay in identifying lenses as such for the cinema was not a period of waiting in which practitioners slowly or inevitably perfected what a lens needed to be for cinema. As Miriam Bratu Hansen writes, cinema did not inevitably or necessarily develop into the hegemonic practices of classical Hollywood production. Cinema emerged as more than just a series of technological artifacts and forms: cinema was "a regime of productivity and intelligibility that is both historically and culturally specific."[251] Rather than developing simply as an outgrowth of photography or as a linear path of development rationalizing a Bazinian total cinema, the classification of a lens' utility for cinematic practice was shaped by a combination of factors. The same series of Planar lenses specified for cinematographic work in the 1902 catalogue was also advertised for use in a wide variety of applications. In addition to its use for cinematography, E. Krauss identifies the Planar as useful for rapid capture photography, for portrait and group photography, for reproductions, for enlargements and reductions, and for microphotography. The catalog's juxtaposition of a Lumière negative and a microphotograph of a fly suggest not only the power of the photographic image, but also the range of views made possible by the photographic lens. Indeed, the images do not identify the subject of the photographs; instead, the captions identify the 50mm and 20mm focal lengths used to take these

[251] Miriam Bratu Hansen, "The Mass Production of the Senses: Classical Cinema as Vernacular Modernism," in *Reinventing Film Studies*, eds. Christine Gledhill and Linda Williams (London: Arnold, 2000), 334.

views. The juxtaposition and inversion of small and large photographic subjects advertised the way that the 'same' lens could expand human perspective across both time and space.

While E. Krauss' lenses were defined by their reputation for scientific engineering more than either Parisian opulence or photographic realism, we should be cautious about overstating the centrality of scientific construction in defining how early filmmakers considered ideas like realism. What constituted a standard motion picture lens was shaped by a combination of affordances that made a lens ideally suited to the light and speed needs of capturing an image on celluloid for later projection. A cinema lens negotiated a series of competing necessities: the need for wide apertures, versatility in shooting conditions, and a focal length that resulted in an image that appeared photorealistic when projected on a screen. Projection significantly influenced how camera operators captured images differently from still photography. As noted in *The Handbook of Kinematography* (1911), while motion picture operators could hypothetically adjust the lens and the aperture to obtain a crisp image without blur on the negative, "In kinematograph work one is not concerned with the freedom from movement blur or otherwise of each single picture."[252] Such clear photographic images "would not project as well seen as would a film in which the individual pictures were distinctly blurred through using a comparatively wide shutter aperture."[253] Blurring, while often discussed as a deficiency in still photography, actually helped audiences see movement better in projected images. What this tells us about the relationship between science, realism, and aesthetics is that E. Krauss lenses were adopted on the basis of their functionality for screen practice more than an inherent material affinity for representing reality objectively or without distortion.

[252] Colin N. Bennett, *The Handbook of Kinematography: The History, Theory, and Practice of Motion Picture Photography and Projection,* (London: The Kinematograph Weekly, 1911), 29.
[253] Ibid. 29.

At the turn of the 20th century, E. Krauss actively promoted the use of their lenses on cinematographic machines by connecting consumers to other Parisian manufacturers. In the rear of their 1902 catalog, E. Krauss lists an extensive number of Parisian apparatus makers, along with their addresses and instruments, that could use the Krauss-Zeiss lenses. The list is extensive, ranging from the photographic binoculars of Jules Carpentier to the Gaumont stereoscopic camera.[254] Of particular note, though, are the cinematographe machine manufacturers. Krauss-Zeiss lenses were listed as the lenses on a number of different cinematographe machine distributors. In the rear of the 1902 E. Krauss catalogue, Dr. Doyen's cinematograph was advertised with a Planar 50mm and an Unar 136mm; the Lumière Cinematographe included a Protar II 54mm with the option of a Planar 50mm; Pathé Frères Cinematographe for 35mm film was included with a Protar II 54mm.[255] Later catalogs indicate that E. Krauss expanded into projection apparatuses (1906), but then later concentrated their business on photographic lenses (1908) and eventually still photography (1914).[256] During the 1890s and 1900s, though, the firm was in the position of selling a significantly diverse body of lens based instruments, and the Zeiss brand was a way for companies to create a sense of mutual quality assurance between camera manufacturers and optical manufacturers.

The brand name of Zeiss, in the context of an emerging cinema, invoked a burgeoning international lens culture that was beginning to have standards and expectations of quality that crossed national borders instead of remaining within them. As evidenced by E. Krauss, Zeiss licensed patents and formulas to a select number of international firms in addition to manufacturing their own lenses. As Hartmut Thiele writes, licensing helped to offset Zeiss' risks

[254] E. Krauss. Catalog. Paris, 1902. 41-43.
[255] Ibid. 42-43.
[256] These assessments are based on a partial overview of what catalogues I have been able to discover. It remains to be seen if these were the only catalogues of the year, or if these samples are simply the specialized catalogues.

of investing too heavily in the material production of photographic lenses. While Zeiss promoted its expansion into photographic lenses as the continued application of science to different areas of technical development, Thiele suggests that the plant was established in 1888 due to the decline of Zeiss' microscope business.[257] Rather than significantly expanding domestic production, licensing allowed Zeiss to capitalize on the reputation of its brand with little material investment in lens production itself. The decision was made to grant licenses to lens manufacturers in every country with an optical industry. Zeiss initially licensed the construction of Carl Zeiss objectives to Bausch and Lomb in the United States, Koristka in Italy, Ross Ltd. in England, Voigtländer in Germany, and E. Krauss in France.[258] As lenses were increasingly circulated on an international level, consistency and the standardization of information became important to upholding both the reputation of the firm and the functionality of these lenses in multiple sites of practice. The national branding of optical products provided a structural logic for an emerging mass market that was drawing upon social markers to identify, brand, and sell commodities in new urban spaces.

E. Krauss sold lenses, but they also sold the connection of photographic technologies to broader beliefs in the effectiveness of scientifically-driven design. As Gerittsen and Riello argue, objects are not simply caught up in an ever shifting world of human action and culture. Rather, objects are sites of "creating, constructing, materializing, and mobilizing history, contacts and entanglements."[259] Lenses were not simply passive instruments that existed to serve the creative energies of Méliès and Lumière: the use of E. Krauss lenses tapped into an emerging belief in the power of science and technology to both capture and represent reality. The invocation of the

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[257] Thiele, *Carl Zeiss,* 49-50.
[258] Later, licenses were granted to E. Suter in Switzerland and Karl Fritsch in Austria. Thiele, *Carl Zeiss*, 49-50.
[259] Anne Gerritsen and Giorgio Riello, "Introduction: Writing Material Culture History," in *Writing Material Culture History,* eds. Anne Gerritsen and Giorgio Riello (New York: Bloomsbury Academic, 2015), 2.

Zeiss name, in the 1890s, enabled E. Krauss to structure a place in an increasingly international commercial market that, as it grew, had technical needs that exceeded both the opulent tradition of hand-crafted lenses and the initial scientific specifications of photographic lenses.

I would argue that the function of Zeiss' brand name for E. Krauss was more than just a clear indication of an objectively superior *objectif*. The imagination of what anastigmats promised often exceeded the precision design of the anastigmats themselves. According to Rudolf Kingslake, the reputation of the 1890 Zeiss anastigmat far exceeded the actual performance of the lens. Zeiss withdrew most of the Anastigmats from the market when their Planar, Unar, and Tessar lenses were circulated on the market.[260] While there are a number of contentious design disputes in the history of optics that challenge what counts as optical progress and who made what advancements, collectively, anastigmat became useful as a cultural shorthand for the wide variety of lens correction that became normalized during the 1890s. As Benjamin writes, "the most precise technology can give its products a magical value, such as a painted picture can never have for us."[261] Whether it was opulence or scientific adjectives, the increased sale and popularity of anastigmatic lenses spoke to a popular imagination of technological realism based on the mystification of technology.

Interlude: Lens Culture and Film Practice

Practitioner attention to Zeiss lenses was the exception rather than the rule when it came to professional discourse about photography, motion studies, and screen practice in the 1890s. Despite their centrality in image making processes, lenses maintain a conspicuous absence in

[260] Kingslake, *The History of the Photographic Lens*, 83.
[261] Benjamin, "Little History of Photography," 510.

discussions of early cinematic practices. Etienne-Jules Marey insisted that "all images be taken with a single lens, demanding constant intervals between them when both recording and projecting," but provided few details about which lens provided the best basis for objective representation.[262] Even in one of the few direct mentions of lenses by Louis Lumière, we can see him deflection attention away from lenses. In a letter from October 12th, 1895, Carpentier expressed some anxiety about the price of the Cinematographe, especially the lens: "The first Cinematograph has thus cost something like 950 francs not including Monsieur Cartier's time or the cost of the Zeiss lens which I lent you…As far as I can tell from your notes, you have used only the small Zeiss lens."[263] In reply, Louis Lumière refuted this claim, noting that "I obtained the picture by means of the small, ordinary lens, which is perfectly adequate – and not with the Zeiss."[264] While many Cinematographes would, in fact, later be equipped with Krauss-Zeiss lenses, in emphasizing the use of a "small, ordinary" lens, Lumière suggested that a motion picture lens did not need to be a specialized tool. Marey and Lumière's comments do not suggest that the lens was not important. Rather, what their inattention to the specifics of their lenses suggests is that lenses, as technologies of vision, became increasingly ordinary and unremarkable.

The consistent oversight of the lens is not a question of forgetfulness or insignificance. Rather, the absence of the lens in film history is symptomatic of the ideal that lenses promised: that lenses supplement or enhance other practices of seeing. As Crary writes, the rise of photographic images was part of a broader modernization of sensation that took place over the course of the 19th century. Lens-based technologies of image production became the dominant

[262] Canales, *A Tenth of a Second*, 147.
[263] *Letters: Auguste and Louis Lumière*, 25.
[264] It is likely that Lumière was discussing the capture of images for the March 1895 demonstration. *Letters: Auguste and Louis Lumière*, 27.

model of visualization because they helped dissociate perception from the body for the purposes of circulation, exchange, and measurement in commercial culture. As technological modernity decentered the role of the human eye in perception, the lens functioned as "a *guarantor* of the identity of the visible with the normality of vision."[265] This is to say: in their invisibility, lenses affirmed the centrality of human perspective in the midst of increasingly abstract visual experiences of circulation and exchange.

Photographic images may have been more amenable to capitalism's desire to abstract sensation from the body, but photographic abstraction remained connected to embodied practices. As Mary Ann Doane writes, Crary often neglects the motifs of "failure, deception, deficiency, and flaw" that accompanied discourses of visuality in the 19th century and he is "unable to consider the psychical dimension of the subjectivization of vision, its inevitable production of anxiety linked with the revelation of a body that cannot even trust its own senses, when vision is uprooted from the world and destabilized."[266] Similarly, Anne Friedberg also argues that Crary ignores the ways in which cinematic visuality was actually a *combination* of the optical systems of the camera obscura and the stereoscope. For Friedberg, neither the camera obscura nor the stereoscope adequately accounts for the mobile and virtual gaze of the spectator. Rather, the cinema was a combination of both of these models of vision that "combined optical trickery with the projective illusions of the camera obscura…cinema was a device that combined both of these models of vision."[267] In Doane and Friedberg's critiques of Crary, we can see a common framing: one that recognizes cinema as deeply interconnected with the space and place of film projection. If, as Coleman writes, "even the most blatant distortions [of a lens] tend to be

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[265] Comolli, "Machines of the Visible," 124.
[266] Doane, *The Emergence of Cinematic Time*, 80.
[267] Friedberg, *The Virtual Window*, 86.

taken for granted as a result of the enduring cultural confidence in the essential trustworthiness and impartiality of what is in fact a technology resonant with cultural bias and highly susceptible to manipulation," then we need to recognize that the invisibility of lenses – when lenses are accepted as "ordinary" lenses – came to be shaped as such through the historical entanglement of lenses with another significant technology of the late 19th century: film.[268]

There was nothing inherent about 35mm film as a format that made it the standard material for indexing time. 35mm was one of many formats, and never necessarily the recording format that so much of film production would come to be centered around. As John Belton contends in "The Origins of 35mm Film as a Standard," W.K.L. Dickson's decision to use 35mm film was, initially, a way to double the amount of footage that could be used from Eastman Kodak. At the time, Kodak was producing 70mm and 90mm celluloid strips for still cameras. Dickson cut the 70mm stock in half, and the 35mm dimensions also ensured enough space for an image large enough to ensure satisfactory reproduction and provided enough sharpness and clarity to guarantee "the illusion of reality" required for the Kinetoscope and eventually small screen projection.[269] Edison and Eastman's license agreement established these standards within the film industry, the adoption of a 35mm standard by the Lumière Brothers (who became the largest producer of raw stock in Europe), and the reliance of British producers on 35mm by the Blair Co. solidified the position of the 35mm format on the international marketplace.[270] As Deac Rossell notes, with the exception of glass-plate cinematography for amateur use, there were "no serious alternatives to celluloid in motion picture work."[271] The alignment of cinema with

[268] Coleman, "Lentil Soup," 30.
[269] John Belton, "The Origins of 35mm as a Standard," *SMPTE Journal* (August 1990): 654.
[270] Ibid. 653-656.
[271] Deac Rossell, *Living Pictures: The Origins of the Movies* (Albany: State University of New York Press, 1998) 75.

film was a relationship of standards and conventions rather than an inherent material affinity with indexicality.

Lenses are also consistently secondary to discussions of recording formats in the history of photographic development in the 1880s. In particular, the arrival of gelatin-silver bromide plates in the early 1880s overtook the contemporaneous developments occurring in optical development at Zeiss. As Jean-Claude Gautrand writes, these newly sensitive plates were not just a question of mechanical improvement, but rather, "an overturning of existing practices, a revolution which came about through cameras, new portability, ease of use, the speed with which they could take pictures, and the photographer's desire for anonymity."[272] Indeed, it was the improved processes of photographic emulsion that led to Antoine Lumière and George Eastman to systematize and rationalize the manufacture of photographic equipment, transforming the practices of emulsion production from workshop practices to commercial production. [273] In the midst of a nuanced discussion of emulsions, Gautrand remarks on Zeiss' new lenses as a "miracle of optics" that seems to simply happen alongside the changes to the emulsions. While many changes were occurring in lens development, in the 1880s and 1890s, recording formats dominated discussions of technical invention and historical 'progress' during this time.

Cinema studies has been historically preoccupied with a definition of indexicality that privileges the registration and record function of celluloid film. This is due, in no small part, to the long legacy of Andre Bazin and the centrality of Peircean semiotics in 1970s film theory and its lingering half-life in film studies. Indeed, even Benjamin's notion of the optical unconscious rests on the idea that instruments of mass communication – radio, film, and photography –

[272] Jean-Claude Gautrand, "Photography on the Spur of the Moment: Instant Impressions," In *A New History of Photography,* ed. Michel Frizot, Pierre Albert, and Colin Harding, trans. Helen Atkins et al. (Köln: Könemann, 1998), 233.
[273] Ibid. 234.

served as "virtual and actual prostheses for human perception."[274] What indexicality has come to mean, though, has been significantly restricted by the centrality of celluloid film to conceptions of cinema. There have been efforts to recoup the index in the face of film's displacement by digital formats – most notably, the collection *Opening Bazin: Postwar Film Theory & Its Afterlife* (2011). However, a preoccupation with the material of film has continued to obscure indexicality in terms of celluloid.

Indexicality has not always connoted the "reflection of a coherent, familiar, and recognizable world." [275] Rather, as Mary Ann Doane contends, indexicality "has acted historically not solely as the assurance of realism but as the guarantee that anything everything – any moment whatever – is representable, cinematic."[276] As Miriam Bratu Hansen similarly suggests, we should expand our definition of photographic indexicality beyond the recording medium of film. Rather than a clear documentation of a place and time, photographic images also actualize "a here and now that bridges the gap between inscription and reception."[277] What was perceived in the site of the film was not just a record of reality, but a virtual experience of reality that was real in and of its perception without legitimation according to hierarchies of aesthetic or cultural value.

Early cinema manifested technology as a primary, rather than secondary, site of experience: where mechanically reproduced images came to function as a primary site of experience rather than simply functioning as a reproduction of, or substitution for, nature. Cinema's social value, as Jennifer Wild contends, was not found in individual films but in the

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[274] Shawn Michelle Smith and Sharon Sliwinksi, "Introduction," in *Photography and the Optical Unconscious*, ed. Shawn Michelle Smith and Sharon Swilinski (Durham: Duke University Press, 2017), 2.
[275] Doane. *The Emergence of Cinematic Time,* 24-31.
[276] Ibid. 24-31.
[277] Miriam Bratu Hansen, *Cinema and Experience: Siegfried Kracauer, Walter Benjamin, and Theodor W. Adorno*, ed. Edward Dimendberg (Berkeley: University of California Press, 2011), 157.

way it manifested the collective display techniques found in exhibition spaces, the daily life of the street, in magazines and print culture, and in "the epistemological strata of an era that upended age-old distinctions between word and image, and reframed the classic activity of the beholder in both popular cultural and intermedial terms."[278] The invisibility of the lens was a symptom, if not a necessary precondition, for rationalizing this abstraction: its invisibility emphasizes the importance of the view and viewership. While the late 1880s and 1890s were strongly characterized by the increased use of flexible celluloid film in screen practice, these practices were also coincident with a global shift towards the production of precision lenses – a technology whose conspicuous absence in discussions of early filmic apparatuses sustained the centrality of the spectator apprehending film's indexicality of a new, abstract modern reality.

A Growing and Changing Lens Market

Krauss-Zeiss anastigmatic lenses became used in motion picture work due to the quality of their lens designs, particularly in comparison to the domestic French market in the mid-1890s. But, the language and criteria of lens quality quickly moved beyond the initial designs and intentions of Zeiss. Shortly after Zeiss, E. Krauss, and their associated distributors began selling their specifically branded "Anastigmat" lenses, many other lens producers began to use the term anastigmat to describe their own lenses. Photographers and camera operators were increasingly interested in purchasing these distortionless lenses, and the construction of lenses based on the Anastigmat patent increased. Higher end lens makers such as Emil Busch, Ernemann, Goerz, and Voigtländer all used the term 'anastigmat' to describe their lenses. CP Goerz also introduced the

[278] Jennifer Wild, *The Parisian Avant-garde in the Age of Cinema, 1900-1923* (Oakland: University of California Press, 2015), 7.

Dagor (*D*oppel-*A*nastigmat *GO*e*R*z) in 1893, and this lens was received to great acclaim.[279] The popular association of anastigmatic lenses with quality was initially influenced by the way the term anastigmat was used to describe a particular class of precision lenses.

While scientific construction provided the basis for differentiating the quality of a lens in the 1890s, this language became less meaningful as more and more companies began to 1) specialize in photographic lens production and 2) use the term anastigmat to describe their lenses. As noted in *The Camera* (1918), the term anastigmat was "appropriated or rather misappropriated by many a maker of lenses, whose instruments are anything else than anastigmat."[280] Although the term anastigmat was initially used by Zeiss to brand and denote high quality lens correction, the term anastigmat quickly came to be associated with lower quality lenses – which were, frequently, French lenses. As Collin N. Bennett, author of the British standard technical manual *The Handbook of Kinematography,* noted in a 1915 *The Moving Picture World* article on "High Grade Lenses:"

> Anastigmats have sometimes in the past been given a bad name because the word was used loosely to describe more or less cheap French goods which were not truly anastigmatically at all. Unfortunately the French, although excellent allies, have not always in the past proved themselves as careful photographic lens makers as one could wish.[281]

While Bennett over-emphasized British goods as the technical vanguard in "High Grade Lenses" – and also promoted similar kinds of national hierarchies in the equipment listed in *The Handbook of Kinematography* – a number of sources do confirm that French lenses were frequently sold under dubious labels of quality. Microscope objective makers and distributors suggested the importance of including maker names on objectives as early as 1889, noting that

[279] Von Rohr*, Theorie und Geschichte,* 141.
[280] "The Term Anastigmat," *The Camera* 16, no. 6 (1912): 248.
[281] Colin N. Bennett in F.H. Richardson, "The Projection Department," *The Moving Picture World* 25, no. 10 (September 4, 1915): 1639.

the European custom was generally to omit placing a makers name on a lens and that "French objectives quite often reach [the United States] without name."[282] Although the lack of a maker name was often a tendency of custom rather than a nationally coordinated attempt to subvert the market, the lack of maker name nonetheless came to signal dubious quality on the international optical market.

If E. Krauss lenses continued to be used in motion picture work, it was no longer on the basis of being the only anastigmats on the French market. Rather, their use was due to a constellation of industrial affiliations that revolved around the perceived reputation of their lenses. The utopian promise of scientific vision was complicated by the material realities of commercial vendors who mis-branded lenses circulating across national lines. E. Krauss and Zeiss attempted to control the discourse and teach consumers how to properly understand lens technologies. When the brand "Anastigmat" finally became a generic term for corrected lenses, Zeiss rebranded these lenses under the name of Protar in 1900.[283] In the front matter material of a 1902 catalogue, E. Krauss wrote the following explanation for the changes in brand naming:

> We have named our premiere objectives "anastigmats," for the reason of their excellent anastigmatic correction. But since the term "anastigmat" is only a scientific expression, many houses have used it to introduce their productions in the market, creating a regrettable confusion. We decided therefore to abandon the term "anastigmat" and took its place with the PROTAR which is the proper name for our series IIa, IIIa V, VII, and VIIa lenses. The construction of these lenses did not suffer, without saying, from this change.[284]

While the term anastigmat may have come from the optical lab and was intended to denote a reliable form of scientific design, the idea took on its own life in the streets and the markets. Anastigmat came to function as a shorthand for the role that lenses played in photography and

[282] "Queries: Putting the Maker's Name on Objectives," *The American Monthly Microscopial Journal* 10, no. 12 (December 1889): 279.
[283] Nasse, 2011, p.4
[284] E. Krauss. Catalog. Paris, 1902.

cinema: it was a general promise that the lens could accurately express reality without distortion. As Zeiss – and, by association, Krauss – was no longer as distinct on the basis of manufacturing their glass and lenses according to scientific principles, these construction principles were no longer enough to differentiate E. Krauss' distortionless lenses among the many other 'anastigmats' that populated the market.

For all that the modernization of lenses was characterized by the ideal of scientific design, the market saturation of anastigmats ultimately weakened the prestige and quality associated with scientific lens design. As lens production became an international market with broadening communities of practice – expanding from the scientific community to the commercial market – the market for lenses made technical terms like anastigmat unreliable. If lenses became standardized, it was not because technical standards were the best and necessary practice, nor was standardization solely motivated from within the industry on the basis of improving technology. Rather, lenses became standardized because the mass market for lenses made it increasingly difficult for consumers to reliably determine the functional quality of a lens.

In 1900, at the same time that Zeiss was rebranding its Anastigmats under the name of Protar, The Commission of the International Congress of Photography held a conference that set out a series of decisions for the numbering of lenses, diaphragms, and kits. As lenses became an important part of a growing commercial industry for photography and cinema, engraving began to shift from solely a question of aesthetic flourish and a guarantor of lens quality and began to include technical information useful for the practice of photographic capture. One of the committees – which included Academy of Sciences president Alfred Cornu, Louis Lumière, and representatives from Gaumont, Parra-Mantois, and E. Krauss, among others – provided a report on proposed standardization initiatives for lenses. Among the proposed statues, the Commission suggested that opticians engrave 1) the name of the maker and the place of fabrication, 2) the name of the objective type, 3) the working diameter of the biggest usable diaphragm, 4) the absolute focal length, 5) a serial number, and 6) if possible, the position of the nodal points.[285] The reason being for this was that lens makers did not necessarily have to include this information on their lenses – and frequently did not.

In the context of an explosion of lens manufacturers attempting to capitalize on the promise of scientific quality and giving none, and the increased standardization of basic information, the reputation of a given firm served an important role in the selection of a lens. While the scientific design of lenses was intended to avoid the negative connotations of intuitive lens design, the newly modern precision lens industry came to heavily rely on the assurances of reputation that had, ironically, been more closely associated with the artisanal production of lenses. In general, a quality objective was often labelled with a maker name while lower quality lenses had no marking. In response to a question about why maker's names were put on objectives in *The American Monthly Microscopial Journal* (1889), a series of optical companies provided statements. The United States optical company Bausch and Lomb, an affiliate of Zeiss, contended that:

> All reputable makers of objectives both in this country and abroad have their names engraved on objectives, which is a guarantee for the quality of the lens. There are some microscope objectives made in England and France which are sold with the cheap imported microscopes brought into this market by importers of optical instruments which bear no inscription as to who the maker is.[286]

Another contributor, Fr. J. Emmerich, made special note about Zeiss, whose tendency was to engrave their firm name on each of their objectives in order to ensure a belief in quality. However, Emmerich also wrote a caution: that buyers should "beware of counterfeits" that

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[285] Charles Fabre, *Traité encyclopédique de photographie. Complément D* (1906), 32.
[286] "Queries," 279.

simply adopted the Zeiss name.[287] The tendency in the US and Germany was to place the name on the objectives, but the European custom – particularly with France – was to place the name on the box.[288] This tendency spoke to the state of the French industry as one that was either not well known enough or not well aligned with the firms to guarantee quality. Like the term anastigmat, though, the proscription of lens makers names did not necessarily mean that the names were of a high quality: the brand name merely identified the (mostly) reliable national provenance of a lens' production, which increasingly took on more significance than the promise of scientific measurement alone. Lenses, as technologies of vision, were organized on the market according to corporate reputations more than individual craftsmen or the science behind the lens.

The imagination of lens quality and standardization was strongly influenced by the origin of where a lens company was located – not because of an inherent technological or national superiority, but because of how lenses circulated across international lines. As Williams writes, because the cost of importing basic materials was so low in France, German companies had a tendency to set up subsidiaries where they could send raw materials that could be worked into instruments and "sold at prices which undercut those of the indigenous French industry."[289] These price discrepancies often served to reinforce the imagined quality of the Zeiss lenses. Zeiss lenses were frequently more expensive than other lenses. In many cases, the difference in price was due to the customs duties on foreign goods rather than an inherent difference in build quality.[290] As *Motion Picture News* (1916) similarly suggests, in most instances "the Tessar lenses made by Bausch and Lomb, Ross, and Krauss are equal in performances to the genuine

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[287] "Queries," 278-279.
[288] Ibid. 279.
[289] Williams, *The Precision Makers,* 79.
[290] Vial, "Un grand constructeur francais," 521.

Carl Zeiss objectives."[291] However, despite being largely equivalent, lens quality was accompanied by a pervasive doubt closely aligned with national origin. Because imported Zeiss lenses were more expensive than the more cheaply produced domestic E. Krauss lenses, the 'genuine' Zeiss lenses were imagined to be of a higher quality.

It is likely that the lower domestic price of E. Krauss lenses is the reason that so many E. Krauss lenses were included with Pathé Frères motion picture cameras. Pathé Professional Cameras were the most popular cameras that emerged from the pre-1913 era, and remained the standard camera for many years afterwards.[292] In the years before World War I, Pathé cameras were some of the most widely used cameras for motion picture work until the introduction of the 1911 Bell & Howell 2709 cine camera, and even after the war the Pathé studio cameras were often used as second cameras. It's been estimated that, before 1918, 60% of all films in both Europe and the United States were shot with a Pathé camera.[293]

A number of documents indicate that the Pathé Professional was sold with Krauss-Zeiss Tessars. In their 1902 Catalogue, E. Krauss indicated that Pathé Frères cinematographes could be purchased with Krauss-Zeiss lenses. As late as a 1920 Pathé Consortium advertisement, the camera is also listed as including a 50mm Tessar-Krauss lens.[294] While a number of advertisements indicate that Krauss lenses were used on Pathé cameras, they were not the only lenses included with the Pathé cameras. In a 1913 French language catalogue and in a 1915 English language catalogue, the Pathé Professional Camera was provided with a Voigtländer 51mm f/4.5 Helier [Heliar] lens, although the 1915 catalogue also offered the option of adding a

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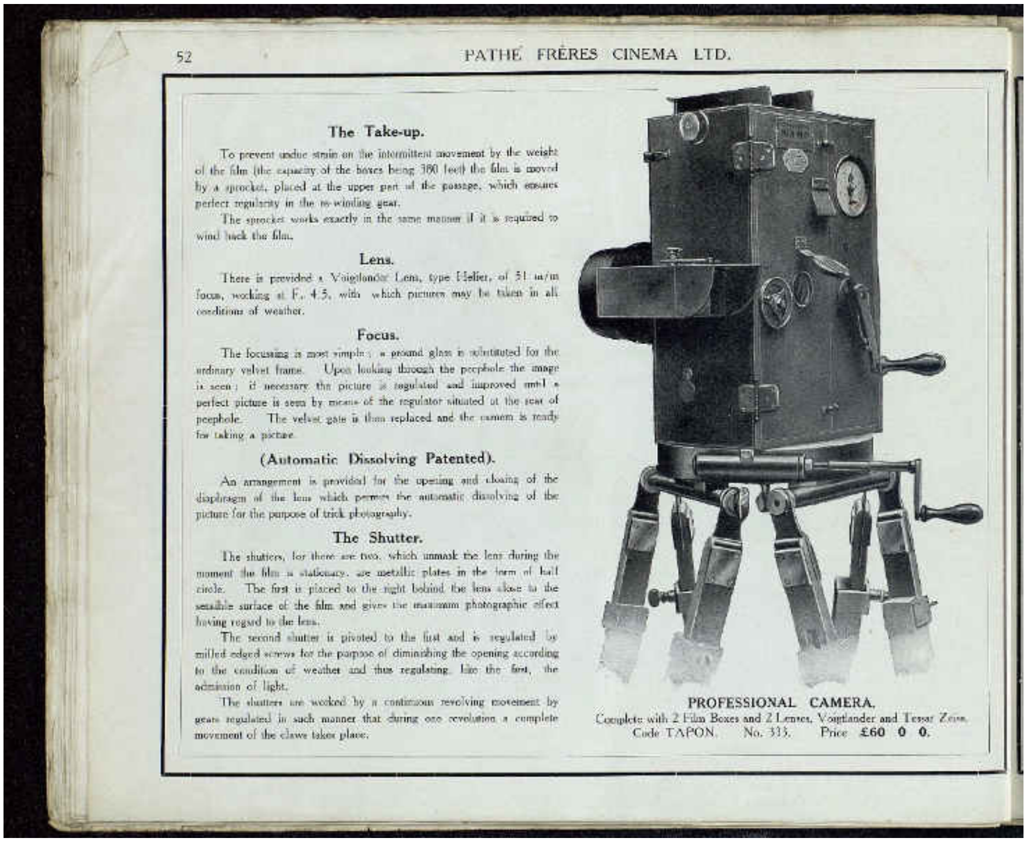
[291] "Picture Lenses are Ultra-Rapid Anastigmats," *Motion Picture News* 13, no. 19 (May 13, 1916): 2948.
[292] David Bordwell, Janet Staiger, and Kristin Thompson. *The Classical Hollywood Cinema: Film Style & Mode of Production to 1960* (New York: Columbia University Press, 1985), 266.
[293] David A. Cook and Robert Sklar, "History of the Motion Picture," *Encyclopædia Britannica,* April 27, 2018. https://www.britannica.com/art/history-of-the-motion-picture
[294] "Appareil prise de vues professionnel." Pathé-Consortium-Cinema. 1920.



52 PATHÉ FRÈRES CINEMA LTD.

The Take-up.

To prevent undue strain on the intermittent movement by the weight of the film (the capacity of the boxes being 380 feet) the film is moved by a sprocket, placed at the upper part of the passage, which ensures perfect regularity in the re-winding gear.

The sprocket works exactly in the same manner if it is required to wind back the film.

Lens.

There is provided a Voigtlander Lens, type Helier, of 51 m/m focus, working at F. 4.5, with which pictures may be taken in all conditions of weather.

Focus.

The focussing is most simple; a ground glass is substituted for the ordinary velvet frame. Upon looking through the peephole the image is seen; if necessary the picture is regulated and improved until a perfect picture is seen by means of the regulator situated at the rear of peephole. The velvet gate is then replaced and the camera is ready for taking a picture.

(Automatic Dissolving Patented).

An arrangement is provided for the opening and closing of the diaphragm of the lens which permits the automatic dissolving of the picture for the purpose of trick photography.

The Shutter.

The shutters, for there are two, which unmask the lens during the moment the film is stationary, are metallic plates in the form of half circle. The first is placed to the right behind the lens close to the sensible surface of the film and gives the maximum photographic effect having regard to the lens.

The second shutter is pivoted to the first and is regulated by milled edged screws for the purpose of diminishing the opening according to the condition of weather and thus regulating, like the first, the admission of light.

The shutters are worked by a continuous revolving movement by gears regulated in such manner that during one revolution a complete movement of the claws takes place.

PROFESSIONAL CAMERA.
Complete with 2 Film Boxes and 2 Lenses, Voigtlander and Tessar Zeiss.
Code TAPON. No. 333. Price £60 0 0.

Figure 12 Pathé Freres Catalogue 1915. 5.

Zeiss Tessar 50mm f/3.5 lens.[295] The inclusion of these multiple lenses suggests that, depending on where the camera was distributed, different lenses were attached or built into the sale of a camera. Technological distribution, rather than companies alone, had a strong influence on which kinds of lenses were used and available for purchase with certain cameras.

While there is little evidence to concretely track the use of E. Krauss lenses on specific films or by specific filmmakers, the saturation of Pathé cameras in combination with the active inclusion of E. Krauss lenses in the product literature is suggestive, at the very least, of how much these lenses were used in cinematic practice. Again, this is no guarantee that these lenses continued to be used with the cameras. But they did indicate a baseline imagination of what kind of lenses were idealized and valued as necessary for the capture of motion pictures. Camera

[295] Pathé Frères. Catalog. 1915. 52-54.

makers would not have had to tell consumers which kind of lens – and, if the lens was often of a particularly poor make, they often did not include this information. But the names of Krauss, Zeiss, Voigtländer, and other 'prestige' lens companies helped to assure consumers of the perceived value and quality of the cameras.

Lenses may have left the laboratories, but lenses did not really ever leave the city. Instead of an upper class market of scientists, lenses shifted to another distinctly urban market: the mass market of amateur photographers and a growing field of cinematographers. On one hand, the explosion of lens manufacturers dubiously branding their lenses as anastigmats was a practice of commercial exploitation that attempted to capture this wider market. But, on the other hand, we can also think of the rise of questionable lenses as an example of cultural continuity: where the aesthetic opulence of French instruments migrated into the mystification of scientific branding. Connecting both was a consumer a desire for aesthetic pleasure in technologies of vision: one baroque, one modern.

Conclusion

Urban commercial culture influenced how optical commodities came to be identified and standardized against the commercial expansion of the international optics industry. In their invisibility, lenses demonstrated the potential – both real and imagined – of technology's capacity to express reality without distortion. It was not a technological realism where lenses were 'truly' able to represent reality. Rather, in their invisibility – especially in the cinema – the use of lenses affirmed the reality of an increasingly human-built world where technology did more than simply reproduce or imitate nature. The increased naturalization and invisibility of lenses in the cinema spoke to an emerging imagination of a certain kind of technological realism

– the reality of commercial culture, where the functioning of technology was obscured and mystified and nonetheless experienced as real in those processes.

Much like the cinema industry as a whole, the broad range of applications that characterized early instrument culture began to shift towards specialization in the 1900s and 1910s. The early years of the twentieth century resulted in increasingly standardized and specialized production needs. However, as was the case with cinema, the ideals and goals of lens design did not develop in isolation of their broader historical contexts. As Williams summarizes the changes in the French industry between 1907 and 1915:

> Overlap of interest between the industry and government concerns increased; organised research, within universities, under the auspices of government, and within science-based industry generally became more widespread; the union movement gathered momentum; the question of science education at different levels moved back on to the agenda; and, of increasing and eventually overwhelming significance, the international political and military situation worsened.[296]

For E. Krauss, the eventual advent of the Great War meant that its photographic lens applications became wholly dedicated to France's war effort. As E. Krauss wrote in its 1919 catalogue, during the war, "all the fabrication of our workshops on photographic objectives was reserved to aviation. Thanks to the precision of our methods of calculation, thanks to the perfection of our industrial realization, French photography planes were able to obtain, at more than 1,000 meters of altitude, admirable shots."[297] Following the war, E. Krauss returned to its "peaceful work" and resumed manufacture of all its former series of photographic lenses for "amateurs, for professionals, for scientists, for all the varied works of the Arts, Sciences, and Industry."[298]

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[296] Williams, *The Precision Makers,* 42-43.
[297] E. Krauss. Catalog. Paris, 1919.
[298] Ibid. In the 1920s, E. Krauss began to specialize in the production of still photography cameras. Of particular note was the 1924 L'Eka, a photography camera that used nonperforated 35mm cinema film. Released a year before the Leica, the still photography camera perhaps most responsible for the use of 35mm celluloid film for still photography, the name and reputation of Krauss was enough to warrant Leitz naming its camera Lei-ca rather than Le-ca (for the first letters of Leitz and camera, a common practice of abbreviation used in lens and camera

World War I would prove to mark significant changes for the design, production, and use of lenses at an international scale – changes that will be specifically discussed in the following chapter. While some international optical companies benefitted from the war, in France, the war aggressively reshaped the instrument industry. As Brenni writes, after World War I:

> the increasing salaries and costs of raw materials, the reorganization of industry and labor, the evolution of instruments, and the growing rationalization and mechanization production, completely transformed the landscape of the French instrument industry. Most of the glorious 19th century firms disappeared or merged, others were absorbed by larger companies, and the workshops left Paris.[299]

Much like the French instrument industry as a whole, E. Krauss never quite achieved the same level of prominence that it did in its golden era. In 1934, E. Krauss was purchased and absorbed by the Barbier, Bénard and Turenne (BBT), a company internationally renowned for its construction of lighthouses and later for systems used to illuminate operating rooms, aviation, and streets.[300] While Krauss maintained production longer than other turn-of-the-century French optical companies, as of 1934, it appeared that "the Krauss empire collapsed overnight. No more lenses, no more apparatuses, no more catalogues."[301]

The century-long survival of precision lens companies like Zeiss, Bausch and Lomb, and Cooke is the exception rather than the rule, and their endurance in the popular imagination of quality or historical lenses was not necessarily the result of inherently superior lens design. How we understand failure is contingent on the way that progress is measured against history. When assessed as a commodity, rather than as a tool, lenses clearly developed around and in response

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branding) for worry of confusing it with the E. Krauss L'Eka. However, in comparison to the other prominent cinema lens designers addressed in this project, E. Krauss did not maintain the same level of historical aura that accompanied Leica. Krauss' lenses and cameras were made in a small series, and was not supported by a huge advertising campaign like the one that accompanied Leitz apparatuses. Vial, "Un grand constructeur francais," 523.

[299] Brenni, "Artist and Engineer," 10.

[300] "BBT," Bibliothèque des Phares, consulté le 30 août 2018, http://bibliothequedesphares.fr/acteurs/BBT.

[301] Vial, "Un grand constructeur francais," 526.

to a variety of commercial and cultural contexts that were often more complicated than an objective valuation of technical merit. Technological spectacle was experienced as its own form of reality, and lenses came to be shaped and designed around emerging practices of representing the reality of urban living, technological modernity, and soon, war.

Chapter 3 | "The End of a Foreign Monopoly:" Bausch and Lomb and the Wartime Expansion of Optical Glass Production

The camera lens is the eye of the Army.
Moving Picture World (1917)

In the February 1920 issue of *Popular Science*, Bausch and Lomb Optical Company ran a full-page advertisement titled "The End of a Foreign Monopoly." Below a large illustration of a heavily-muscled man pulling a large core of hot optical glass from a low fire, the advertisement describes a dramatic tale of wartime peril:

> Optical glass assumed, over night, a new and terrible importance, when the world went to war with Germany. For the world, so far as it knew, was largely dependent on Germany for the higher grades, dependent on an *enemy* for the very eyes of fleets and armies -- periscopes, aeroplane camera-lenses, searchlights, field glasses, range-finders. And optical glass cannot be made over night.[302]

While many countries had robust commercial capabilities for manufacturing optical instruments, the war revealed that the glass necessary to construct those precision instruments was almost exclusively supplied by Germany.[303] As Chapter 1 discussed, Zeiss became the dominant global supplier of optical glass and precision lenses in the late 19th century as a result of its nationally supported industrialization and its advertising campaigns, which convinced practitioners of the practical applications of scientifically designed optics. Photographers found Zeiss' distortionless lenses extremely useful, and as Chapter 2 discussed in the context of Paris, optical firms increasingly designed and sold lenses for commercial markets rather than specialized professional markets. As the practices of photography and cinema became more ubiquitous,

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[302] "The End of A Foreign Monopoly," Bausch and Lomb Optical Company Advertisement, *Popular Science*, February 1920, 2.
[303] Stewart Wills, "How the Great War Changed the Optics Industry," *Optics and Photonics News* 27, no. 1 (2016): 40-47. https://www.osapublishing.org/opn/abstract.cfm?uri=opn-27-1-40.

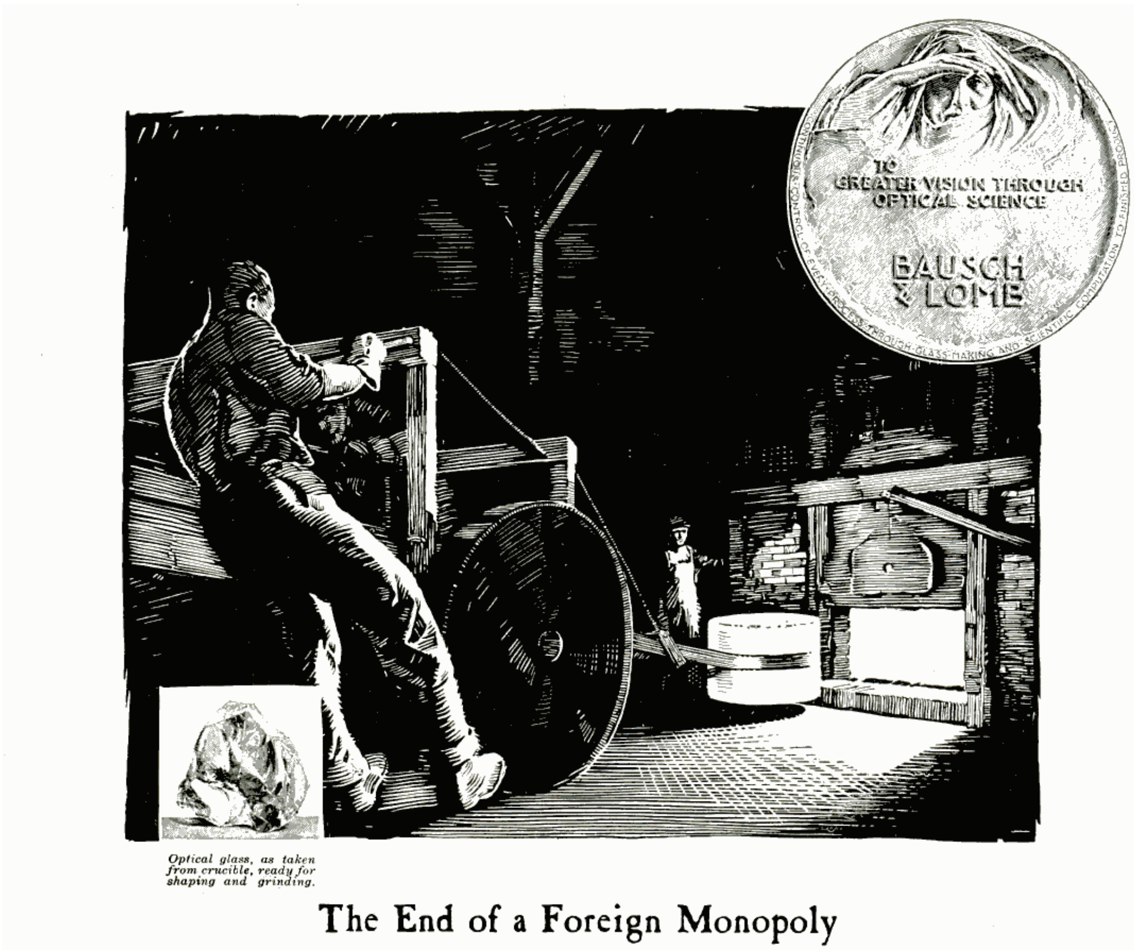

Figure 13 Bausch and Lomb Optical Company Advertisement, Popular Science, February 1920.

lenses became increasingly invisible. After the beginning of World War I in 1914, though, the optical glass industries of France, England, and America were cut off from German optical glass supply – with no existing infrastructure to support an immediate wartime need for optical glass.[304] Glass, which had begun to fade from view, became abruptly visible.

To illustrate how the uneven development of national optical industries influenced photographic lenses, this chapter will examine the American production and circulation of photographic lenses from 1914-1918. World War I has been discussed in relationship to the military's use of cinema, the war's systematization of perception as a form of violence, and the

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[304] Wills, "How the Great War Changed the Optics Industry."

development of motion picture technical standards.[305] However, less attention has been paid to how the war also dramatically rearranged the manufacture and circulation of photographic lenses. The production of precision lenses for photography and cinema – both in the United States and abroad – was significantly affected by the ways in which Allied optical manufacturers addressed abrupt changes in the origin and circulation of materials from which photographic lenses were made.

While the war affected optical industries across the world, this chapter will largely focus on the United States. The American industry is a useful case study in understanding how the industrialization of vision proceeded across both national and international fronts, as well as how these design practices were motivated by xenophobia and national security. Additionally, America began to develop professional institutions and literature on optics that established a history of technological development that was told through decidedly nationalist genealogies. The development of optical glass communities, in terms of both production and professionalization, expanded optical infrastructure and helped support the growing technological needs of an expanding motion picture industry.

Specifically, this chapter examines the effect of a wartime shortage of optical glass on the production of photographic lenses at Bausch and Lomb, an optical company based in Rochester, N.Y. While Bausch and Lomb is more widely historicized in cinema studies for their production of Cinemascope lenses in the 1950s, I center this chapter on Bausch and Lomb's relationship to a broader network of optical markets and suppliers during the first World War.[306] If, as David

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[305] *Cinema's Military Industrial Complex*, ed. Haidee Wasson and Lee Grieveson (Berkeley: University of California Press, 2018); Paul Virilio, *War and Cinema: The Logistics of Perception* (London: Verso, 1989); Janet Staiger, "Historical Note: Standardization and Independence: The Founding Objectives of the SMPTE," *SMPTE Journal* 96, no.6 (June 1987): 536.

[306] Bordwell, Staiger, and Thompson, *The Classical Hollywood Cinema,* 252; J.F. Taylor, "Skouras: "Impossible" Is Unknown," *The Film Daily*, September 16, 1954, 10.

Noble suggests in *America by Design: Science, Technology, and the Rise of Corporate Capitalism*, "the history of modern technology in America is of a piece with that of the rise of corporate capitalism," then the history of precision lenses in America is also of a piece with the wartime expansion of Bausch and Lomb. Although these industrial networks were not directly preoccupied with motion picture production, they were nonetheless a vital part of the technological infrastructure that studios and exhibitors drew upon in their efforts to create and distribute films.[307] By examining the wartime development of Bausch and Lomb, I ultimately argue that national anxieties about the provenance of optical glass played a key role in expanding international optical industries in ways that were unintentionally beneficial to the industrialization of film production.

At the same time that multiple nations were developing their optical infrastructure, the film industry was also undergoing its own industrialization process. 'Early' cinema is traditionally recognized as ending in 1915, a threshold year in film history that marks the increased normalization of industrial cinema practices.[308] By 1915, the tendency towards multi-reel films, a consolidated producer system, and the articulation of professional roles and responsibilities meant that the growing cinema industry had a great need for a support infrastructure that was regular and standardized. While 1915 marks a formal threshold of the Classical period with the consolidation and standardization of classical narration, the Great War also had significant effects on the circulation of motion picture materials. Recent scholarship has

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[307] The wartime development of the optical industry also has striking parallels and intersections with developments in engineering, higher education, and manufacturing discussed in the history of science and technology. See David Noble, *American by Design*, Olivier Zunz, *Why The American Century?*, and David A. Hounshell, *From the American System to Mass Production: 1800-1932.*

[308] Kaveh Askari, Scott Curtis, Frank Gray, et al., *Performing New Media, 1890-1915* (Bloomington: Indiana University Press, 2014), 1-3.

begun to consider this time as a period of institutionalization.[309] Institutionalization emphasizes that the broad shift to narrative production was strongly attached to infrastructural changes in the film industry (rather than an inevitable maturation or progression of film form). Due to decreased European film production, a ban on shipping film stock, and the replacement of London by New York as the center of film distribution, the motion picture industry began to change in ways that was closely linked to its conditions of production.[310]

Film lenses were not as visibly affected by the war in comparison to changes in film distribution, which more directly affected programming. Nonetheless, the wartime circulation of lenses had lasting repercussions for the ways in which motion pictures came to be produced. The most obvious effect was an increased scarcity of photographic lenses. During the war, photographic lens production was predominantly restricted to the wartime operations of the United States Signal Corps. Yet, the scarcity of lenses was only a symptom of a more significant effect of the war: a cessation of imported foreign glass. Optical companies, both in the United States and abroad, practically ceased the production of photographic lenses for motion picture use as these optical companies were engaged with the production of instruments used in warfare by several branches of the US government.[311] Professional knowledge of lens design became divided along national lines with few existing institutions that could support an immediate need for optical research. Often behind the scenes, these changes reevaluated what counted as development in optical design.

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[309] Joel Frykholm, *George Kleine and American Cinema: The Movie Business and Film Culture in the Silent Era* (London: BFI, 2015), 11.
[310] Kristen Whissel, *Picturing American Modernity: Traffic, Technology, and the Silent Cinema* (Durham: Duke University Press, 2008), 223.
[311] "Cinema Camera Objectives," *Motion Picture News*, October 12, 1918, 2432-3434.

In analyzing the wartime movements of American glass industries, I historicize how World War I accelerated both the material and conceptual infrastructure of glass production that was significant in supporting an expanding cinema culture. In doing so, I will build on early film history and argue that the end of early cinema, and the rise of industrial production, ought to be considered in relation to parallel changes that were occurring in optical production. The supply crisis of World War One significantly motivated the nationalizing of optical industries that were capable of producing the kinds of high-quality lenses necessary to industrial film production on a large scale. The aggressive expansion of optical glass production was also accompanied by the organization and publication of optical science outside of Germany. Ultimately, the wartime optical glass supply crisis revealed that visual space was not simply something to be captured: visual space was something that had to be manufactured.

"*To Greater Vision Through Optical Science*:" *Bausch and Lomb Optical Company*

Bausch and Lomb Optical Company began in 1853 when John Jacob Bausch, a German immigrant, set up a tiny optical goods shop in Rochester, NY. The crop failures and rampant poverty of 1848 Europe resulted in the emigration of numerous skilled German workers to the United States, including Joseph Zentmayer (a prominent microscope maker based in Philadephia), the Grunow brothers (microscope makers based in New Haven and New York), and John Jacob Bausch.[312] Bausch had originally taken up a position in Rochester as a wood turner, but lost two fingers when his hand was drawn into a buzz saw. Afterwards, Bausch fell back on his secondary trade in the spectacle business and set up a small optical workshop.[313] The

[312] Donald Padgitt, *A Short History of the Early American Microscopes* (London: Microscope Publications, 1975), 83
[313] Ibid. 85.

shop sold eyeglasses, microscopes, and other imported optical products from Europe.[314] Henry Lomb, another German immigrant who lent Bausch sixty dollars to begin his shop, managed sales for the company. Following an embargo on European imports during the American Civil War, Bausch and Lomb became successful selling spectacle frames and diversified to produce a variety of optical products, particularly those that required a high degree of precision.[315] Following its success in supplying optical supplies during the Civil War, the company expanded and opened a sales office in New York City.[316] Building on its successful eyeglass business, Bausch and Lomb diversified to produce a variety of optical products, particularly those that required a high degree of precision.

Figure 14 Bausch & Lomb's Store, 1853. Undated newspaper clipping, JJ Bausch Scrapbook. Courtesy of Bausch and Lomb Archives.

Bausch and Lomb's position as an American optical company was historically defined by its capacity to provide a domestic supply of goods that were classically imagined as European. Much like the dye industry, optical glass was regarded as "one of the exclusive, industrial heritages of a few European countries" and "Popular prejudices decreed that everything optical must come out of Europe."[317] Prior to the 1880s, most lenses for microscopy, astronomy, and

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[314] "John Jacob Bausch and Henry Lomb," *German-American History and Heritage.* http://www.germanheritage.com/biographies/atol/bausch.html
[315] Padgitt, *A Short History*, 86-88.
[316] Ibid. 86-88
[317] Hugh A. Smith, "America's Optical Emancipation: How a Dreamer of 66 Years' Standing Has Seen His Vision Realized," *Scientific American,* May 3, 1919, 454.

photography were imported from English, French, and German manufacturers.[318] The European origin of a lens was not a guarantee of quality. Rather, it was a shorthand used to describe a tradition of European lens craft that largely did not exist in the United States. As late as 1916, there were no schools in the United States where the practical foundations of a lens grinder's trade were taught.[319] The American institutional matrix of science, industry, and education that had led to economic success in agriculture, manufacturing, and electricity had yet to extend to the production of precision optics in the United States.[320] While the optics were designed, shaped, ground, and polished at the Bausch and Lomb plant, all the rough glass blanks still originated from Europe.[321] The German provenance of optical glass meant that U.S. lens production was fundamentally an international enterprise – even if the overseas origins of optical glass tended to overemphasize the national craft of lens production.

While Bausch and Lomb is better known in the current era for its eye health products and contact lenses, the company has a rich history in photographic lens development. The company began making photographic lenses in 1883. Beginning in 1888, Bausch and Lomb became the primary lens provider for another famous Rochester company, Eastman Kodak, and Bausch and Lomb lenses were used to outfit Kodak's first camera.[322] During World War I, Bausch and Lomb became the primary site of production for the military's optical glass needs and the first American manufacturer of optical glass in the United States. In the 1950s, Bausch and Lomb was also responsible for the redesign and accelerated production of the Cinemascope projection

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318 Bausch & Lomb Optical Company, "Introducing Ourselves," *Photographic Lenses* (Rochester: Bausch & Lomb Optical Company, 1912): 5.
319 Carl Louis Gregory, "Motion Picture Photography," *The Moving Picture World* 27, no. 8 (February 26, 1916): 1300.
320 Zunz, *Why The American Century*, ix-xvi.
321 Smith, "America's Optical Emancipation,"454.
322 Michael Pritchard, "Bausch and Lomb," in *Encyclopedia of Nineteenth-Century Photography,* ed. John Hannavy (New York: Routledge, 2008), 121.

lenses by rebuilding machinery used to produce wide-beamed Navy searchlights in World War I.[323] Bausch and Lomb richly intersects optical history, photography, cinema, and the military, and serves as a useful case study in understanding how nationalism was a key influence on the industrialization and professionalization of lens production.

In the prewar years, Bausch and Lomb were not well known for their motion picture lenses or even their own domestically designed photographic lenses. Rather, a significant part of Bausch and Lomb's pre-war success in lens production and distribution was due to its close business relationship with Zeiss. Bausch and Lomb, like E. Krauss in France, was exclusively licensed by Carl Zeiss in 1892 to make Zeiss Anastigmats and other lenses for the American market. [324] The production of Zeiss products in the U.S. enabled Zeiss to bypass costly import tariffs and establish a bigger business in the United States.[325] Bausch and Lomb began to produce a newly patented series of anastigmat lenses designed by Abbe and Rudolph of Zeiss. Although Bausch and Lomb domestically distributed Zeiss lenses, the designs and supplies of high-quality optical glass remained attached to their German provenance.

It was the mass-manufacturing of photographic lenses in the tradition and name of Zeiss that made Bausch and Lomb a prosperous company at the turn of the century.[326] By 1903, the company had produced 500,000 photographic lenses, and by 1910, the company reported that it had produced over a million photographic lenses.[327] After the formation of "The Triple Alliance" in 1908, Zeiss moved from a licensing relationship to a partnership with Bausch and Lomb and

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[323] J.F. Taylor, "Skouras," 10.
[324] Pritchard, "Bausch and Lomb," 121.
[325] "Triple Alliance: Zeiss - Bausch & Lomb – Saegmuller," *Collection of Historical Scientific Instruments: Harvard University.* http://waywiser.fas.harvard.edu/people/7108/triple-alliance--zeiss--bausch--lomb--saegmuller
[326] Bordwell, Staiger, and Thompson, *The Classical Hollywood Cinema,* 252.
[327] Pritchard, "Bausch and Lomb," 121; Bausch & Lomb Optical Co, "Photographic Lenses," *Catalog H* (Bausch and Lomb Optical Company: Rochester, 1910), 7.

one of Bausch and Lomb's subsidiary partners, the Saegmuller Company, which was the primary producer of gunsights for the U.S. Navy. The Triple Alliance was formed in part by personal relationships cultivated by Henry Lomb's son, Adolph Lomb, who had spent considerable time studying at the Carl Zeiss Works in Jena.[328] As Bausch and Lomb wrote in a preface to their 1912 catalog, The Triple Alliance was an international partnership that "concentrated the resources, the experience and the energies of the two leading optical firms of the Old and New World."[329]

The narrative of an Old and New World of optics consistently structured the popular imaginations of American optical glass. These imaginations sustained the belief that German lens production was synonymous with quality design long after industrial optical practices were globally adopted. European optical glass, particularly German glass, was held as the international standard of quality, and nearly all optical-quality glass was imported from Europe in the 19th and early 20th century.[330] Optical glass was intertwined with multiple professional practices and discourses that were not necessarily limited to photography or photographic images. For example, the association of Germany with optical quality was assisted by the travel patterns of American doctors, who often finished their education in German universities and were familiar with those instruments. American post-graduates who studied abroad used, often for the first time, optical equipment in their research. Upon returning to the United States, many felt that the American system lacked the professional education and scientific instruments available in

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[328] Victoria N. Meyer, "Adolph Lomb: Patronage, Industry and Optics in Early 20th-Century America," *Optics & Photonics News* (January 2013): 37.
[329] Bausch and Lomb Optical Co., "Introducing Ourselves," in *Photographic Lenses* (Rochester: Bausch & Lomb Optical Company, 1912), 5.
[330] "John Jacob Bausch and Henry Lomb," *German-American History and Heritage.* http://www.germanheritage.com/biographies/atol/bausch.html

England and Germany.[331] The educational systems for professional practices like medicine served to reinforce a broader belief in the high fidelity and scientific superiority of European glass.[332]

Consumers closely associated lens quality with Europe because, for most of the 19th century, precision lens production was predominantly an artisanal practice. Nearly all workers engaged in the production of optical instruments in the early and middle 19th century were "tradesmen with training in metalwork and the construction of small machines who had picked up their optical skills after gaining employment in a shop engaged in building and selling optical instruments."[333] The quality of a lens was closely tied to the individual reputation of an optician, a relationship reflected in the practice of engraving lenses with maker names like (Johann) Voigtländer, (Carl) Zeiss, (Andrew) Ross, and (John Henry) Dallmeyer. As one New York dealer phrased it, "we would have more confidence in a lens bearing the name of its maker than in one without it, because the latter would not dare to put his name on a bad or objectionable article if he cares for his reputation."[334] Furthermore, the professional craft of melting, grinding, and polishing optical glass was historically passed down through apprenticeship rather than in schools. A belief in lens quality was implicitly a belief in technology as technique, and in the 19th century, the professional infrastructure for optical craft was largely limited to England, France, and Germany. The provenance of a lens implied its quality on the basis of these material practices.

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[331] Rayton, "The Status of Lens Making in America," 428.
[332] In summer of 1916, Bausch and Lomb exhibited some of their products at the American Medical Association and American Optical Association "to allay the somewhat panicky fears of the trade and the professions at large." Bausch + Lomb Optical Glass Catalog, 1919.
[333] Feffer, "Ernst Abbe," 25.
[334] "Queries," 279.

Bausch and Lomb's relationship to Zeiss complicated the imagined division of optics along national levels of supply, production, and distribution. The Triple Alliance unified the corporations' interests and, according to a 1908 booklet titled *A Triple Alliance in Optics* published by Bausch & Lomb, the "interests of the firm of Zeiss in the United States therefore become one with those of the Bausch & Lomb Optical Company."[335] The association was more than just a marketing scheme: Zeiss owned about 20% of Bausch & Lomb's shares, and the companies worked closely together towards mutual business interests.[336] The firms were effectively aligned as one entity, and the companies proceeded to publish materials with the Alliance logo, a set of three prisms with the initials of the participating entities (B-L, Z, and S).[337]

Figure 15 The Triple Alliance logo. Courtesy of Bausch and Lomb Archives.

The international growth and expansion of optical manufacturing – the combination of the Old and New Worlds – found a growing market for precision lenses in the motion picture industry. While any lens could hypothetically be used for film production, the lenses generally used in taking motion pictures were "ultra-rapid anastigmats."[338] Or, more simply put: camera operators desired corrected lenses that were fast enough to capture crisp, clear detail for when

[335] *A Triple Alliance in Optics*. Rochester: Bausch & Lomb Optical Co,, 1908, p4.
[336] Triple Alliance: Zeiss - Bausch & Lomb - Saegmuller. http://waywiser.fas.harvard.edu/people/7108/triple-alliance--zeiss--bausch--lomb--saegmuller
[337] Ibid.
[338] "Picture Lenses are Ultra-Rapid Anastigmats," 2948.

the negative was projected in theaters. According to *Motion Picture News*, *American Cinematographer*, and *The Handbook of Kinematography,* the most popular anastigmatic lens with cameramen during the prewar period was the Zeiss Tessar.[339] It was not quite as sharp as the Voigtländer Heliar, another ideal lens for cinematography at the time, but the Tessar was twice as fast and offered “reserve speed in case of emergency.”[340] Bausch and Lomb manufactured Tessars in the United States, and while there was debate over whether domestically produced lenses were equivalent to ‘genuine’ Zeiss lenses from Germany, they were largely accepted as equal. Assurances of optical quality implied by the national provenance of Zeiss lenses helped facilitate the increasingly international exchange of film technologies, and by the early 20th century, cinema had become a strong influence on the development and design of photographic lenses.[341]

A Lack of Glass

Beginning in 1914, the predominant influence on the manufacture of photographic lenses shifted from cinema and photography to war. The first rumblings of this change were felt in Britain, but the effects quickly rippled out to the rest of the Allied nations. In August of 1914, Britain's Navy blockaded the German Imperial Fleet in its ports to restrict the mainland’s access to supplies. Though the blockage eventually cut off Germany's food supplies and starved the German people into food riots, it also “created an immediate economic crisis in the British empire,” particularly in the instrument industry.[342] Prior to the war, Jena-Zeiss supplied between

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[339] “Picture Lenses are Ultra-Rapid Anastigmats,” 2948; Brown, “Modern Lenses: Section Three,” 4-5; Bennett, *The Handbook of Kinematography*.
[340] “Picture Lenses are Ultra-Rapid Anastigmats,” 2948.
[341] W. Taylor and H.W. Lee, "The Development of the Photographic Lens," *Proceedings of the Physical Society* 47, no. 3 (1935): 509.
[342] Choate, *Dangerous Business,* 105.

60 and 90% of Britain's optical glass supply.[343] The Chance Brothers, Britain's largest domestic supplier, were only able to provide about 10% of Britain's wartime optical glass demand. Britain's only other substantial alternative supplier of optical glass, the French company Parra-Mantois, was quickly overwhelmed by orders from other European instrument makers whose German optical glass supply was also compromised.[344] While many countries had robust commercial capacities for the production of producing optical instruments, the glass for those instruments came almost entirely from Germany.[345] The United States was beginning to develop an optical glass industry, both because of the threat of losing access to German optical glass and for the promise of supplying Europe. However, the United States wasn't able to fill these shortages until late in the war. Because the Allied nations were so heavily dependent on German supply, the war created an immediate shortage of glass with no domestic industry capable of immediately satisfying that deficit on either a national or international scale.

One of greatest wartime challenges for the United States was the manufacture of visual space. This was true not only of the photographers and cinematographers who struggled to represent the reality of life at the warfront, but also for the optical companies who faced new challenges in manufacturing the optics that helped the military visualize the battlefield. The most pressing reason for the growth of optical glass industries was the use of optical glass in military weaponry. High quality optical glass was an essential part of early 20th century military logistics. The expansion of precision optical production was part of a broader initiative to create domestic technological infrastructures for national defense. In comparison to the American Civil War,

[343] Choate marks this as closer to 90%. Choate, *Dangerous Business*, 105. Simmonds marks this as closer to 60%. Alan G.V. Simmonds, *Britain and World War I* (New York, NY: Routledge, 2012), 76-77.
[344] Stephen Sambrook, *No Gunnery Without Glass: Optical Glass Supply and Production Problems in Britain and the USA, 1914-1918*."
[345] Wills, "How the Great War Changed the Optics Industry," 40-47.

which generally relied on sighting by eye, advances in artillery power and precision had increased target ranges to as high as 60,000 yards. To fire accurately over such distances, guns required optical rangefinders, panoramic sites, field glasses and other fire-control devices "which were only as precise as the optical glass in them."[346] Military weapons were not just tools of destruction, but also of perception.

The war shortage was so significant that both the US and the British governments requisitioned lenses from the public. At first, the British government satisfied the need by purchasing German lenses from its citizens, but in November of 1915, all unsold optical instruments in private or commercial hands were commandeered. The British War Office was also forced to open secret negotiations with the German government for a supply of optical glass through a Swiss intermediary.[347] In 1917, the US Signal Corps of the Army also asked for individual owners to sell lenses. While the article assured that England and the United States were working to correct the shortage and "making lenses better than the German ones formerly imported," suitable lenses were not being produced fast enough for national use.[348] The call for lenses asked specially for the Zeiss Tessars, Bausch and Lomb Zeiss Tessars, and Voigtlander Heliars: all German glass. At theater screenings, "four-minute speakers" urged audiences to "loan whatever glasses they might have to Uncle Sam."[349] These were temporary measures, though, and served to address a short term lack of lenses while the government invested in long term infrastructural development continued to expand.

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[346] "The British Glass Scramble." *Optics and Photonics News,* January 2016. https://www.osa-opn.org/home/articles/volume_27/january_2016/features/how_the_great_war_changed_the_optics_industry/the_british_glass_scramble/
[347] George Robb, *British Culture and the First World War* (New York: Palgrave Macmillan, 2002), 190.
[348] Gregory, "Motion Picture Photography" (1916), 1330.
[349] "How Simplex Met Lens Shortage: A Human Interest Story of Industrial Achievement During the World War of Nations," *Motion Picture News* 19, no. 1 (January 4, 1919): 114.

A lack of both material and professional optical glass infrastructure, combined with increasing needs for military applications, led to American, English, and French companies cutting production of optical needs for any other reason than military applications. During the wartime period, companies like Kodak sought alliances with other optical glass companies as their own optical supply for both business and government supply was at risk. As early as August of 1915, Kodak's optical division Hawk-Eye Works informed Eastman that the French optical company Parra-Mantois "cannot guarantee any deliveries whatsoever" and that catalogue prices were increasing by 60%.[350] Kodak also reported that the optical Works of Taylor-Hobson "have been almost entirely commandeered by the British Government for the manufacture of clinometers, gun sights, and other instruments used in warfare" and that as a result, Kodak was for some time unable to receive lens deliveries. Taylor-Hobson were also experiencing difficulties in obtaining glass from Parra-Mantois.[351] In 1917, French authorities were largely opposed to shipping optical glass across the Atlantic for war purposes and firmly stated that "no glass will be allowed to go out for any commercial purposes."[352] While Parra-Mantois provided some limited shipments of optical glass, it seems that later they were provided under the express stipulation that it was only to be used for the production of optical parts for the US Army and Navy. [353]As a result of the British Government commandeering the Taylor-Hobson glass works, along with Taylor's difficulty in obtaining glass from Parra-Mantois, Kodak found itself with a shortage of lenses.[354]

[350] F.W. Barnes to George Eastman, August 12, 1915. Courtesy of Eastman Kodak Archives.
[351] Brackenbury to F.W. Barnes, April 22, 1915, F.W. Barnes to A.K. Whitnet, May 3, 1915. Courtesy of Eastman Kodak Archives.
[352] Gilbert Dey to George Eastman. November 2, 1917. Courtesy of Eastman Kodak Archives.
[353] S.A. Hand, "The Manufacture of Optical Glass," American Machinist 49, no. 0 (August 29, 1918): 368.
[354] Brackenbury to F.W. Barnes, April 22, 1915, F.W. Barnes to A.K. Whitnet, May 3, 1915. Courtesy of Eastman Kodak Archives.

The war affected French and British optical industries in similar ways. France and Britain were heavily reliant on imported optical glass, and both national optical industries were heavily subsidized during the war. In France, the optical glass producer Parra-Mantois took over the majority of optical glass supplies; in 1916, the laboratory of Armand de Gramont at Levallois-Perret was transformed into a workshop for the production of wartime optics; and a large factory was built by La Société française d'Optique, which was formed in conjunction with the firm Lacour-Berthiot, to meet foreign competition.[355] In June of 1915, the UK's Optical Munitions and Glass Department offered the optical company Chance Brothers a deal which offered funding for plant expansion, scientific expertise, and "guaranteed exclusivity in military contracts for ten years" in exchange for increases in optical glass production for the British military.[356] In Germany, Zeiss' operations were similarly dedicated to government production, although the company lacked rubber rather than optical glass. In nearly all cases, the war resulted in governments directing, subsidizing, and expanding national optical industries. Military applications fostered significant government intervention and investment in the precision instruments industry. As Mari Williams writes, "it was during the First World War itself that the longest strides were taken with respect to government intervention in science generally and in the precision instruments industry in particular...As munitions of war, however, certain types of scientific instrument underwent transformations during the First World War in ways which seemed impossible in peacetime."[357]

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[355] Jean-Pierre Sirois Trahan, "Un Spectre Passa: Marcel Proust retrouve," *Revue d'études proustiennes* 4, no.2 (2016): 19-30. "Quotations," 612-613.
[356] "The British Glass Scramble."
[357] Williams, *The Precision Makers*, 9.

World War I immediately reframed the partnership between Zeiss and Bausch and Lomb as threatening to the interests of the German military.[358] While America did not formally enter the war until 1917, Zeiss severed its alliance with Bausch and Lomb in November of 1915 after Bausch and Lomb took on contracts for the manufacture of field glasses for the British, French, and Russian governments.[359] On November 20th, 1915, Zeiss sent a letter to Eastman Kodak Co informing them that Zeiss had been "compelled to dissolve our agreement with Messrs. Bausch and Lomb Optical Co, Rochester, and to stop the community of interests with them because they have been supplying military instruments to countries being at war with Germany."[360] As Bausch and Lomb had been producing Zeiss lenses and would continue to supply Kodak with lenses, Eastman Kodak would ask Bausch and Lomb to make a statement that they would protect Kodak from any claims of unlawfully using Zeiss products following the dissolution of The Triple Alliance.

Both because of the fear of losing access to German glass and because of the economic promise of supplying a Europe at war, the United States began to industrialize its precision optical industry in 1914. Bausch and Lomb had been experimenting with melting new kinds of optical glass as early as 1903, but it was only in the winter of 1914-1915 that multiple buildings were specifically constructed at Bausch and Lomb for the purposes of creating a national supply of precision optical glass. [361] These experiments took on new urgency when Zeiss dissolved The

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[358] The Alliance was a close partnership, and it interesting to speculate whether this merger would have been a more complete unification of international interests without Schott's stipulation that Zeiss was to remain a German company and stay in Jena (This would come to pass in the Cold War, when Zeiss was split into two companies due to the division of West and East Germany.) Zeiss was legally bound "to maintain in perpetuity their entity at Jena" according to the conditions laid down by Abbe in the Carl Zeiss Stiftung. The Stiftung ensured that Zeiss would remain attached to its national origins and encouraged the kind of national division that would remain between Zeiss and other optical glass industries up to, and including, the war.
[359] Benedict Cromwell, *America's Munitions 1917-1918* (Washington: Government Printing Office, 1919), 578.
[360] Zeiss to Eastman Kodak Corporation. November 20, 1915. Courtesy of Eastman Kodak Archives.
[361] Smith, "America's Optical Emancipation," 455.

Triple Alliance in 1915. Although Bausch and Lomb and other domestic glass companies were beginning to research how to create optical glass at a mass scale, by the time the United States entered the war in 1917, the domestic production of optical glass was still inadequate to the standards and volume required by military.[362] Much like Pittsburgh, the other newly industrial city in the United States where wartime glass production took place, Rochester was able to fulfill the wartime need for optical glass production because of its access to waterway transportation. Precision optics required a constellation of materials, many of which needed to be sourced from far off distances. To sustain a domestic precision optical industry, the United States needed to vitalize three material industries: fuel, clay, and sand.

Lower quality glass melting was typically fueled by coal, but precision glass required significant amounts of gas heating. The regularity and control of temperature was crucial to effectively melting the glass. City gas, supplied by the Rochester Gas and Electric Company, was the only fuel used for the many necessary heating operations.[363] The 1912 Bausch & Lomb glass plant was said to have "used more gas at a time than a thousand homes," and Bausch & Lomb was the Rochester Gas & Electric Company's largest customer.[364] Glassmaking in cities like Rochester and Pittsburgh benefitted from adjacency to steel producers, who had similar infrastructural needs for fuel.

To melt the glass, Bausch and Lomb also needed to secure new sources of clay for their melting pots. A persistent problem prior to the war had been the composition of the glass melting pots, which contained impurities that reacted poorly with the glass melts.[365] As British geologist P.G. Boswell wrote about his trip to America, a combination of three or four different raw clay

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[362] In part, the delay was also due to the idea that the war would be over much earlier than 1918.
[363] H.O. Andrew, "Our New Optical Glass Industry and Its Fuel" (n.d.). Courtesy of Bausch and Lomb Archives.
[364] Donovan A. Schilling, *A Photographic History of Bausch + Lomb* (Victor: Pancoast Publishing, 2011) 35-36.
[365] Wills, "How the Great War Changed the Optics Industry," 40-47.

sources had enabled Americans to make glasshouse-pots which had "superseded almost entirely the Grossalmerode [Großalmerode] clay upon which they had relied in the pre-war days upon Germany."[366]

When the importation of foreign sand was found to be impossible during the war, surveys found that "abundant quantities" of silica suited for the manufacturing of precision lenses were located in Pennsylvania, West Virginia, Illinois, Missouri, New Jersey, Massachusetts, Ohio, New York, Maryland, and many other states.[367] Although the U.S. had formerly imported better grades of potassium carbonate from Germany, sand that was suitable for optical glass was located at Rockwood, Michigan, Hancock, Maryland, and Ottowa, Illinois.[368] While the best European sand was located in Fontainebleau, in France, the sand at Rockwood was found to be "even freer from iron than that of Fontainebleau."[369] The Sylvania Sandstone quarry at Rockwood, located just south of Detroit, was also ideally positioned for easy transportation to Rochester and Pittsburgh via the Great Lakes.

The United States' lack of optical glass was not due to a fundamental lack of resources or an inherent German superiority. The fuel, clay, and sand necessary for the manufacture of precision optical glass were all present in the United States. The problem was that, prior to the war, manufacturers and inventors were chiefly concerned with increasing production volume and lowering labor costs. According to Colonel F.E. Wright's 1921 analysis, one of the biggest problems facing optical production during the war was "precision and factory control."[370] The

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[366] "Lessons from the Visit to America: Report of the Sheffield Meeting, October 20th, 1920," *Journal of the Society of Glass Technology* 4 (1920): 374.
[367] Department of Commerce: Bureau of Foreign and Domestic Commerce, EE Pratt, Chief, *The Glass Industry: Report on the Cost of Production of Glass in the United States* (Washington: Government Printing Office, 1917), 55.
[368] F.E. Wright, *The Manufacture of Optical Glass and of Optical Systems: A War-Time Problem* (Washington: Government Printing Office, 1921), 84.
[369] Charles Greeley Abbot, *Great Inventions* (Smithsonian Scientific Series 12, 1932), 323-324.
[370] Wright, *The Manufacture of Optical Glass*, 82.

primary difficulty for the Geophysical Laboratory, which coordinated the American initiatives to scale up domestic glass production, was establishing methods of high precision with sand manufacturers to obtain the desired chemical purity.[371] As F.E. Wright reflected in his 1921 report, *The Manufacture of Optical Glass and of Optical Systems: A Wartime Problem*:

> the making of modern optical glasses does not consist solely in the mixing together of a secret batch, handed down from father to son, in melting this down in a furnace, and in allowing the melt to cool properly...The problem is essentially one of precision and factory control; and although the glassmaker's experience is not to be disregarded, optical glass of high quality can not be produced by it alone.[372]

As the United States found itself without access to foreign materials, it became clear that while the domestic industry had invested heavily in machinery improvements, "a knowledge of the glass itself, its behavior, the ingredients that go to make up the batch [of glass]" had been neglected in domestic industrial development.[373] In the same way that Zeiss's lenses required microscopists to both understand and believe in the benefits of scientifically designed lenses, it was necessary for the Geophysical Laboratory to educate and convince silica manufacturers to accept a shared definition of what criteria constituted high chemical purity.[374] The problem was not a fundamental lack of resources, but rather, an investment in refinement and quality control.

What is significant about the material shortages of the war are the ways that they reveal how optical corporations functioned as a force that efficiently managed and transformed the material world. A photographic lens typically doesn't contain inscriptions of its optical glass; we don't see markers of Michigan quarries or the silica of Fontainebleau if we look at a lens. Lenses prominently display inscriptions of corporate management and scientific standardization: the Bausch and Lomb logo, the Kodak logo, the f-stop, a particular brand name like the Tessar or the

[371] Wright, *The Manufacture of Optical Glass*, 82-85.
[372] Ibid. 82.
[373] Department of Commerce, *The Glass Industry*, 22.
[374] Wright, *The Manufacture of Optical Glass*, 84.

Heliar. Lenses had long carried engravings of their creators, but during the war, what these names and technical specifications meant began to shift. Faced with a crisis of production, a lens' quality was increasingly constituted not by physics or natural laws of light, but by industrial management. If modern vision was characterized by increasingly abstract practices of representing the world, precision lenses embodied industrial modernity's transcendent process of transforming the material world into the ephemerality of vision, melting all that is solid into air.

The war divided lens supply along national lines, and this division complicated existing alignments between the belief in optical fidelity and its national origin. The practical capacities of optical representation – lens correction – could not be abstracted from the national contexts of the material and professional infrastructures required to produce such representations. Despite vocal advertisements by American companies that domestic lenses were equal to European lenses, popular and professional thought maintained the belief that the best optical glass must be purchased from either Zeiss or Parra-Mantois.[375] Zeiss lenses retained their association with quality, and the association of Germany with optical quality was often used as a rallying cry to encourage glass production as a form of wartime nationalism.

Wartime Expansion at Bausch and Lomb

To support the aerial surveillance of the Signal Corps and long-range weaponry, the United States required a domestic optical glass industry – and they needed to develop it quickly. Following the optical glass supply crisis, Bausch and Lomb became the primary site of the United States military's investment in domestic glass production. In 1917, a research lab was

[375] "The Making of a Photographic Objective," *The Moving Picture World*, February 26, 1916, 1300.

established at the Bausch and Lomb factory on advice of the council of National Defense.[376] The task of the lab was not only to reproduce the kind of optical glass that had long been produced in Europe, but also to develop information about the process of its manufacture.[377] After seven months of work at the Bausch and Lomb plant, by the end of 1917, the essential details of the manufacturing process had been developed. The amount of usable optical glass produced across the United States increased from about 3,000 pounds per month in April of 1917 to 79,000 pounds per month in October of 1918. As Wright reflected in his 1921 report, "the records show that in the short period of 19 months, we did accomplish much to overtake decades of German experience."[378]

While the prominence of German glass prior to the war was repeated ad nauseum in press coverage of the optical shortage, there is reason to believe that Germany's prominence was over-narrated as a way to foster a sense of dire need for domestic optical glass production in the wartime years. In the 1916 *Revue generale des sciences,* M.A. Boutaric, faculty member at the University of Montpellier, suggests that Zeiss "surrounded its products with scientific propaganda" and that Zeiss' success was largely due to these perceptions rather than a fundamental superiority.[379] As suggested in *Nature*, in the fifteen years leading up to the war, British manufacturers of optical glass were "confronted with a more serious competition from Mantois than from Schott."[380] In affirming the superiority of foreign glass, these wartime scare narratives motivated national security on the basis of national insecurity.

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[376] "America's Conquest of Optical Glass: Our War Time Emancipation from Germany in a Small Thing But as Vital as Dyes and Chemicals," *Manufacturing and Industrial Management* (August 5, 1919): 174.
[377] Wright, *The Manufacture of Optical Glass,* 11.
[378] Ibid. 5.
[379] "Quotations," 612.
[380] "Scientific Glassware," *Nature*, November 16, 1916, 210.

Although the underdevelopment of domestic optics was due to a lack of investment in professional training and material refinement, both during and after the outbreak of the war in 1914, domestic optical glass production in the United States was frequently juxtaposed against the threat of German superiority and technological advancements. As a 1920 Bausch & Lomb advertisement suggested, "a favorite dream of our founders was of emancipation from foreign control of raw material; and for some years we had been quietly experimenting. When war came, we were ready - and ready not merely with methods and formulae, but with a modern and complete glass plant - the first in America for making optical glass on a commercial scale."[381] The 1920 Pathé Review No. 37 also featured a short film titled "Another Worry for Fritz." The film included views taken at the Bureau of Standards in Washington and illustrated experts "showing the manner in which the rough blocks of glass are ground out and polished."[382] In the description for the film in *The Moving Picture World*, wartime needs "gave government experts opportunity to develop the science of lens making which was monopolized by Germany before the war."[383] Nationalism was a way to motivate the aggressive expansion of the domestic industry, but it was also a logic that sought to celebrate technological innovation as the (inevitable) result of ongoing American labors.

The idea that Bausch and Lomb had been historically fighting for independence from Germany was not entirely true. Bausch & Lomb had been experimenting with different optical glass materials some years prior to the war, but these experiments were not as significant as many postwar articles made them out to be. In 1903 William Bausch, son of JJ Bausch, had

[381] "The End of A Foreign Monopoly," 2.
[382] "Zoology and Science in Current Pathé Review," *The Moving Picture World*, February 7, 1920, 909. Given that the review was dated in 1920, a year and a half after the war's end, it is likely that the film was produced during the war but later distributed.
[383] Ibid. 909.

performed some experiments on synthesizing optical glass in a small glass-pressing plant erected on the Genesee River flats behind the Bausch and Lomb factory, but these tests largely failed. These tests were taken up again in 1912 when Bausch privately funded Victor Martin, a Belgian glasscutter, to begin additional tests. After the advent of the war in July of 1914, a second building was constructed on the river flats in the winter of 1914-1915. It was only at the end of May 1915 that the experiments produced their first batch of usable light crown and dense flint glass.[384] Independence from German glass supply was an ongoing concern for Bausch & Lomb, but postwar publications often re-narrated this historical progress along more sharply divided national lines than the material practices suggested.

By the time the United States entered the war in 1917, the quality and quantity of domestic optical glass was still inadequate to the standard or volume necessary for the military. This was true not only of Bausch & Lomb, but also of all other American optical companies. Bausch & Lomb's narrative indicates a proud nationalism that had become vital to the identity of the optical glass industry in the Great War, and one that was taken up by many optical glass industries such as the Pittsburgh Plate Glass Company, Keuffel & Esser in Hoboken, and the Spencer Lens Company at Buffalo.[385] The production conditions underlying the supply of lenses and motion pictures became enmeshed in a broader constellation of visual technologies that were "the very eyes of fleets and armies."[386]

It was not just the supply of optical glass, but the *quality* of glass that guided the American wartime effort. As Germany held such a high reputation for optical glass quality prior to the war, American optical industries needed to reassure the military and other domestic

[384] Smith, "America's Optical Emancipation," 455.
[385] Wright. *The Manufacture of Optical Glass,* 9.
[386] "The End of A Foreign Monopoly," 2.

industries of the equality, if not the superiority, of domestic glass. In summer of 1916, Bausch and Lomb exhibited some of their products at the American Medical Association and American Optical Association "to allay the somewhat panicky fears of the trade and the professions at large."[387] In another example, in the winter of 1916-1917, Bausch and Lomb produced a batch of optical glass that was used in "the manufacture of several hundred high-priced anastigmat photographic lenses" which had previously only been created using the "highest grade Jena glass."[388] The lenses were fitted to speed cameras and, after being subjected to "exacting tests," the testing manufacturers wrote that the tests demonstrated that the new Bausch and Lomb lenses were "not only equal, but superior to the same type of lenses heretofore made from the imported glass."[389] Regardless of whether the lenses were, in fact, superior, the publication of this information in Bausch and Lomb's 1919 catalog indicates that lens suppliers were as much concerned with proving that domestic lenses were superior to foreign lenses as they were concerned with meeting supply numbers. The technical accomplishment of crisp, clear images demonstrated not only good design, but a particularly national form of success that continued to be defined against a history of German provenance.

The production of optical glass quickly became a question of both national security and insecurity. In 1917, a research lab at the Bausch and Lomb factory was started on advice of the council of National Defense, headed by Arthur L Day and Captain FE Wright.[390] As Wright observes in his book-length report, everything involved in the American war-time production of optical glass, including expense, was subordinated to speed.[391] The government's support of raw

[387] Bausch + Lomb Optical Glass Catalog, 1919.
[388] "Excerpt from Bausch & Lomb Optical Glass Catalog of 1919," Bausch and Lomb Archives (Rochester): 4.
[389] "Excerpt from Bausch & Lomb Optical Glass Catalog of 1919," 4.
[390] EA Schiebe, "America's Conquest of Optical Glass," *Purchasing Agent*, July 19, 1919, 174.
[391] Wright, *The Manufacture of Optical Glass,* 287.

materials, the construction of new glass plants, expanded professionalization, and the exchange of professional information across industries fueled an aggressive expansion and industrialization of an industry largely dependent on foreign goods. Following seven months of work at the Bausch and Lomb plant, at the end of 1917, the essential details of the manufacture had been developed and glass in considerable quantities was being produced. The efforts at the Rochester site were then extended to the Spencer Lens Company and the Pittsburgh Plate Glass Company, companies which had achieved significantly less success the production of optical glass. From 1915 to 1917, American companies like Bausch and Lomb aggressively increased optical glass production, in some cases transitioning from producing 2,000 to 20,000 pounds of glass per month.[392]

From the supply crisis of 1914 until the end of the war in 1918, the American optics industry expanded in a concerted effort to not only produce an adequate infrastructure for the production and supply of optical glass, but to strengthen the professional reputation of specifically American glass. While Zeiss' industrialization in the late 19th century emphasized the fidelity that theoretical science lent lenses, World War I revealed that science and progress was intimately connected to national provenance and emphasized fidelity as a question of production conditions and professional reputation. As Germany held such a high reputation for optical glass quality, it became important to the industries to also promote the equality, if not the superiority, of American glass as a way to emphasize the integrity and technological progress of the United States.

[392] Wills, "How the Great War Changed the Optics Industry," 40-47.

Wartime Visions

The wartime period from 1914 to 1918 demonstrated the incredible, and devastating, effects of technologically enhanced vision. The invention and deployment of submarines, poison gas, and aerial bombardment "severed notions of modern progress from machine culture and linked the latter instead to mass death and unparalleled human suffering."[393] The use of artillery that could devastate targets beyond direct human perception, the increasingly immediate relationship between vision and death, and the use of photography in aerial warfare made it so that representations of the world were equally as vital as the realities they depicted. As Paul Virilio suggests in *War and Cinema*, the landscape of war, through the use of increasingly visual forms of warfare, "became cinematic."[394]

Despite Virilio's claim that that war became cinematic, photographers and cinematographers frequently struggled to represent the war. The difficulty in representing the war was both a material and a conceptual struggle. At a material level, photographers found it difficult to capture images of action. Battles often took place at distances too far to be captured, or at dawn or dusk when a low amount of daylight made photographic capture impossible with existing recording formats. The act of holding a camera was itself a dangerous act. In the case of one Austrian photographer, upon arriving at the front, an enemy "spotted his lens and thought it was an observation telescope and directed all fire on that spot. So getting shots at the front was not really possible, and the film people limited themselves to shots of engineers, field bakeries, airfields, and so forth."[395] The confusion of the photographic lens and the observation lens is a

393 Whissel, *Picturing American Modernity*, 223.
394 Paul Virilio, *War and Cinema*, 70.
395 James W. Castellan, Ron van Dopperen, Cooper C. Graham, *American Cinematographers in the Great War, 1914-1918* (Bloomington: Indiana University Press, 2016), 6.

poetic example of how vision was synonymous with danger in the war: to see, or be seen, was to enter a position of death.

The difficulty in representing the war was also a conceptual struggle. Photographs and film recordings of the period were often at odds with the experience and scale of violence enacted by the war. In July of 1917, while filming the war drama *Hearts of the World* (1918), D.W. Griffith declared that "it is only possible to film snatches of a battle, and these could not be pieced together to give the public a sufficiently comprehensive idea of what a battle is like."[396] By November of 1917, though, Griffith had changed his tune, proclaiming that "Only the modern motion picture camera makes it possible to give both the scope and the intimate details of modern warfare."[397] On these shoots Griffith had been using a new telephoto lens which had been developed by French designers, which according to Griffith, "makes it possible to secure long shots that heretofore could never have been taken."[398] Griffith overstated the authenticity of his production, and while some footage and newsreel scenes were used in the film, a number of the battle scenes were staged in Los Angeles. In combining original footage and modern acting, cinema popularized an image of the war where it was difficult to distinguish between authentic and staged shots, where the blurring between artifice and reality was an image of the war "*as it really was*."[399]

The objective 'truth' of the war exceeded traditional models of a distortionless, corrected vision of the natural world. As Huppauf writes in "Experiences of Modern Warfare and the Crisis of Representation," World War I was a culmination of ongoing aesthetic practices of

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[396] "Griffith Cannot Get Battle Scenes on French Firing Line, He Declares," *Exhibitors Herald* 5, no. 2 (July 7, 1917): 13.
[397] "D.W. Griffith Back from War With Big Scenes for Spectacle," *Exhibitors Herald* (November 3, 1917): 38.
[398] Ibid. 38.
[399] Bernd Huppauf, "Experiences of Modern Warfare and the Crisis of Representation," *New German Critique* 59 (1993): 52.

abstracting humanity by modern technological means. War photography and films, in 'failing' to represent experience, revealed that "human perception was changing and adapting to the view of the camera lens…the model of the new relationship between man's hardened senses and his world."[400] While images from *The Battle of the Somme* (1916), *Hearts of the World* (1918), or photographs by Ernest Brooks have become lodged in the historical imaginary of the war, the images that best expressed the new cinematic quality of the war were the aerial photographs taken by the Signal Corps.

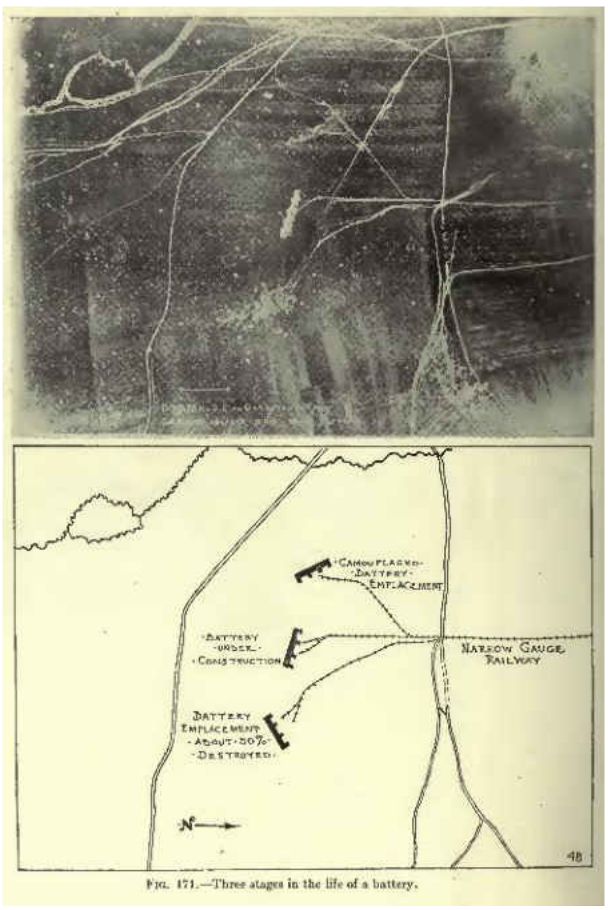

Figure 16 The abstract image from the warfront often required decoding and interpretation to make sense of their depicted reality. Ives. Airplane Photography 1920. 362.

If war became cinematic, it became cinematic in the tradition of the avant-garde cinema that emerged over the following decade. While synthetic rather than dialectical, functional rather than transcendent, the images of reality that emerged from aerial surveys relied on the interpretation of abstract and fragmented scenes of reality. Aerial shots did not represent "sensuous or moral experiences of space;" rather, in order to be understood, "the code of the visible landscape of destruction has to be decodified and recodified in military terms."[401] Aerial photography was

[400] Ibid. 42.
[401] Huppauf, "Experiences of Modern Warfare and the Crisis of Representation," 57-58.

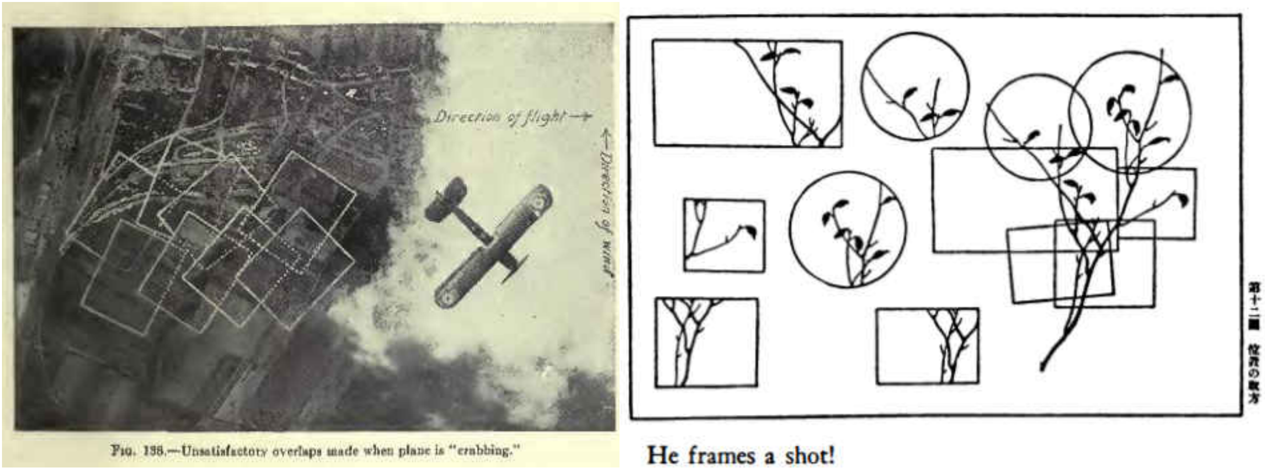

Figure 17 Diagrams of ineffective aerial photography bear a striking resemblance to Sergei Eisenstein's diagram of Japanese illustrations. Ives. Airplane Photography (1920). Page 309. Eisenstein. Film Form (1977). 41.

important to gather information about the battlefield, guide artillery attacks, and assess the progress of the war. In its displacement of bodily perception through virtual technologies, the wartime photographers rent apart classical ideas of time and perception. The lived experience of soldiers was displaced by new technological worlds that shifted truth and meaning to "an abstract and enigmatic virtual realm."[402]

The violence of the war was not just physical, but also phenomenological: it shifted the legitimacy of what counted as the field of the visible and sensible.[403] Visual abstraction began to systematically take place at a scale of inhuman perception that was only sensible through the levels of management and protocol of the state. What was visible, or sensible, was designed around the needs of nations at war. As Nadia Bozak writes, "it is the image, personalized point of view, and culturally inscribed vision that have formulated landscape as a specific way of seeing and thinking about nature and, by extension, managing it."[404] As an advertisement calling for

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[402] Douglas Kellner, "Virilio, War and Technology: Some Critical Reflection," *Theory, Culture & Society* 5-6 (1999): 116-117.

[403] Anne Friedberg suggests that the aerial balloonists of the late 18th century were responsible for reconceptualizing ideas of horizon and perspective, which were important to the ideology of representation sustained by panoramas. Friedberg, *Window Shopping*, 22.

[404] Nadia Bozak, *The Cinematic Footprint: Lights, Cameras, Natural Resources* (New Brunswick: Rutgers, 2011), 90.

citizens to donate their photographic war effort similarly suggested, “the camera lens is the eye of the Army.”[405]

And yet, while these images were brought to life by military codes of orientation and interpretation, the lenses required to capture these aerial views had their own material life. As Lisa Parks writes on the use of drones, aerial media do not just represent the natural world, but also demonstrate “materializing capacities and effects” where aerial photography’s relation to the material world “becomes intelligible, vivid, palpable, and contestable.”[406] The optical glass of gunsights, binoculars, aerial photography, and wartime cinematographers helped to represent the war in its various forms, but lenses were not external to these various practices. Like a person recognizing that their photograph is being taken, the optical infrastructure of the war rearranged how people moved and were moved in war. While unmanned drones and manned aerial photography should be recognized as historically distinct, both reveal the ways in which lens-based imagery manifests an embedded series of professional and material power relations that inform how images are made, circulated, and understood.

While photographic lenses were increasingly produced in France, Britain, and the United States during the war, commercial cinematographers and photographers had limited access to these supplies. Many optical companies made a reserve stock of motion picture camera objectives, but nearly all optical companies who formerly made photographic objectives were limited to military production.[407] When the scarcity of precision lenses for aerial surveying led the US Signal Corps to requisition photographic lenses from the public in 1917, they asked specially for Zeiss Tessars and Voigtländer Heliars – German lenses that were also preferred in

[405] Carl Louis Gregory, “Motion Picture Photography,” *The Moving Picture World,* December 1, 1917, 1330.
[406] Lisa Parks and Caren Kaplan, *Life in the Age of Drone Warfare* (Durham: Duke University Press, 2017), 136.
[407] "Cinema Camera Objectives," 2432.

cinematography for their speed and sharpness. As Karl Brown noted in *American Cinematographer*, “No greater tribute could be paid a lens than the willingness of cameramen to pay fancy prices for the Tessar when importations were impossible during the war.”[408] In comparison to prewar catalog prices of 25.00 for a Bausch and Lomb Tessar f/3.5, prices for a f/3.5 Zeiss lens ranged from 40.00 to 100.00 at the beginning of the war. [409]

Both still and motion picture camera lenses were in short supply, and the war had extensive effects on the field of photography, particularly in New York. The last photo exhibit at 291, Alfred Stieglitz’ famous art gallery, was shown in 1916, and with the last issue of Camera Work in 1917, the Photo-Secessionist movement came to a quiet close. Aggravating these changes were economic changes that made it difficult for photographers to secure equipment, but as McCandless writes, “art photography began to seem not only more difficult but less important as many photographers began to concentrate more on the wartime needs of the country.”[410] Photographers like Edward Steichen and Karl Struss sought out employment in the Signal Corps, and both the military and the art scene’s suspicion of Struss’ pro-German allegiances would ultimately lead him to abandon New York and pursue a career as a cinematographer in Hollywood, where he would eventually film Murnau’s *Sunrise: A Song of Two Humans* (1927).[411]

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[408] Brown, “Modern Lenses: Section Three,” 5.

[409] Carl Louis Gregory, "Motion Picture Photography," *The Moving Picture World*, June 3, 1916, 1688. Bausch and Lomb Lens Catalogue, dated between 1913 and 1915. http://www.piercevaubel.com/cam/catalogs/1915b&llp569.htm

[410] Barbara McCandless, "A Commitment to Beauty," In *New York to Hollywood: The Photography of Karl Struss*, Barbara McCandless, Bonnie Yochelson and Richard Koszarski (Fort Worth: Amon Carter Museum, 1995), 34.

[411] For a more extensive discussion of Struss’ life as both a photographer and a cinematographer, see *New York to Hollywood: The Photography of Karl Struss*.

The government's control over optical supply also caused dramatic shortages in the supply of motion picture projector lenses.[412] According to *The Moving Picture World*, many exhibitors changed their screen size immediately in order to accommodate impending restrictions on lenses.[413] Manufacturers became concerned that distributing projectors with missing or incorrect lenses would "require the exhibitor opening a new house to use a different size picture from that which his screen and stage had been designed for."[414] The trade press expressed a fear about the effects that a lens shortage would have on the broader business of motion pictures. Smaller exhibitors might have entertained the idea of moving location, but it was unlikely that larger scale exhibitors would change their location as a result of improper lenses, particularly given how important location was becoming in theatrical exhibition in the late 1910s. As Gomery observes, location was frequently more important than the quality of the films themselves. Balaban & Katz's 1917 and 1918 theaters were specifically located along the terminus of the Chicago 'el' lines, and the buildings were constructed not only for motion pictures, but also for adjoining small vaudeville acts.[415] The right kind of projector lens may not have been essential to the practice of movie exhibition, but the shortage of lenses revealed that a certain level of standardization and quality in projector lenses was nonetheless becoming valuable in the emerging motion picture industry.

These fears also indicate how important the quality of cinematic exhibition was becoming to film theaters. Lenses were treated not just as technical tools, but as an integrated part of

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[412] At the Government's request, projector manufacturers "agreed to restrict the purchasing of lenses with equipment to three sizes – four, five and six inches on projector and sixteen, twenty and twenty-four inches on stereopticon lenses." "How the Lens War Situation Was Met: The Precision Machine Company Takes the Bull by the Horns and Then Converts It Into Beef," *The Moving Picture World*, January 4, 1919, 73.

[413] "How Simplex Met Lens Shortage," 114.

[414] "How the Lens War Situation Was Met," 73.

[415] Douglas Gomery, *Shared Pleasures: A History of Movie Presentation in the United States* (Madison: University of Wisconsin Press, 1992), 40-48.

motion picture exhibition. In a 1919 presentation to the Optical Society of Great Britain, Charles Gamble further affirmed the idea that the comfort of the theater was, in fact, a concern of optics. "Comfort is not alone, as many might think, the services of polite attendants, quietude, soft chairs and pleasing decorations," Gamble argued, and contended that comfort was "largely conditioned by the degree to which all causes of visual fatigue or irritation are eliminated."[416] To change a lens was also to change a whole slew of other interconnected practices. Hypothetically, theaters could function with lower quality lenses. But in practice, the fear of losing exhibition quality spurred initiatives to counter such a possible situation. The development of cinema as an industry relied upon the design and distribution of lenses for cinema's claim to quality.

The wartime expansion of The Precision Machine Company, which sold the Simplex projectors used in a wide number of theaters, suggests the extent to which a stable lens supply was valuable for exhibition. During the war, one of the optical companies that was under contract to supply the Precision Machine Company with lenses stopped making projector lenses as a consequence of their new government obligations.[417] Under the direction of Edwin S. Porter, who became an active manager of the Precision Machine Company in September of 1916 when his brother, Edwin M. Porter, took over as acting general manager of the company, the company sought to establish their own lens factory. Edwin S. Porter, better known for *The Great Train Robbery* (1903) and his films for the Edison Manufacturing Company, established a $25,000 plant at Morris Park, Long Island, which was specifically dedicated to the production of projection lenses for Precision Machine Company's Simplex projectors. [418] Much like Bausch & Lomb, Simplex promoted the fact that their lenses were tested by optical experts who declared

[416] Charles W. Gamble, "On Projection Screens," *Transactions of the Optical Society* (1919): 34.
[417] "How the Lens War Situation Was Met," 73.
[418] Ibid. 73.

that these lenses were "superior to the commercial lenses now in use, each of them measuring up to the standard."[419]

The material history of cinema lenses during the war was often disconnected from its formal and aesthetic tendencies – at least, on the surface. The shortage of lenses did not have a direct influence on film form. But, the material shortage did have an indirect influence on the photography and cinema's infrastructure: its supply companies, its exhibition spaces, its laborers, its internal notions of value and quality. If the wartime period presents something of a lacuna between the rise of narrative of the 1910s and the rise of the studio system of the 1920s, in looking at how and why lenses were used during the war, we can see that lenses served as sites where manufacturers, practitioners, and exhibitors continued to reimagine their practices of lens-based representation and optical quality.

The Optical Society of America

In addition to expanding its material infrastructures, America needed to develop a professional optics community that could sustain and grow precision optical glass production. In the same way that Germany had a virtual monopoly on the supply of optical glass, prior to the war, Germany also had the most robust body of professional literature and training in the field of optical design. By and large, the dedicated communities and libraries of optical research were located in Germany.[420] While there were ongoing efforts to build a professional optics community in the United States, educational opportunities for optical design were slower to

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[419] "How the Lens War Situation Was Met," 73.

[420] The Optical Society of England was founded in 1899. The OSE's 1900 presidential address was in regards to the problems of optics in the Boer War. Hilda Kingslake, "History of the Optical Society of America, Journal of the Optical Society of America: 1916-1966," *Journal of the Optical Society of America* 56, no. 3 (1966): 275. It is worth noting that many of these organizations shared two common characteristics: many were interested in standardization, and many were invested in standardization for the reasons of war.

develop. One of the first courses took place at Ohio State University in 1916, where Astronomy professor H.C. Lorde ran a course on applied optics, but it wasn't until 1929 that the University of Rochester founded its Institute of Optics, the first educational program dedicated to optics in the United States. [421] The Institute was founded through a grant from Eastman Kodak and Bausch and Lomb, and its founding faculty member was optical designer Rudolph Kingslake.[422]

The war led to an acute and urgent need for increased optical skills and knowledge. As Hilda Kingslake, prominent historian of the Optical Society of America (OSA), writes, "No center in the country felt this more than Rochester."[423] There were many scientific societies in Rochester including a microscopical society, a chemical society, and an optometric group, but "none of these provided a scientific home for those interested in the relatively new study of applied optics."[424] The Optical Society of America, begun by 30 optical scientists and instrument makers in Rochester, was founded in 1916.[425] Under the direction of Perley G. Nutting, who worked at the first Optical Division at the U.S. Bureau of Standards in 1903 and later for Kodak in 1910, the OSA focused primarily on increased professionalization and bringing American optical instruments to the level of quality of German instruments.[426] The organization tended to distance itself from the entertainment business, which was largely seen as the province of the Society of Motion Picture Engineers (SMPE).[427] The SMPE was also founded in 1916 as a way to advance "the theory and practice of motion picture engineering and the allied arts and

[421] "The Making of a Photographic Objective," 1300.
[422] Hilda Kingslake, Rudolph Kingslake's wife, was also an active member of the optics community and wrote an extensive history of the Institute and the Optical Society of America.
[423] Hilda Kingslake, "History of the Optical Society of America," 276.
[424] Ibid. 276.
[425] Nutting made efforts to found an optical society in 1910, but due to his shift of employment from the Goverment to Kodak in 1910, there was a gap in efforts. See Kingslake, "History of the Optical Society of America," 276.
[426] Hankins, How the Magic Lantern Lost Its Magic, p.40.
[427] Thomas L. Hankins, "How the Magic Lantern Lost Its Magic," *Optics and Photonics News* 14, no. 1 (2003): 40.

sciences, the standardization of the mechanism and practices employed therein and the dissemination of scientific knowledge by publication."[428] According to Jonah Horwitz, the SMPE came from two impetuses: the federal government was increasing its use of motion picture technology and was invested in its standardization, and the emergent studio system sought a "permanent forum" for the coordination of film industry technologies.[429] While SMPE worked towards the aims of studio support, only a few of its engineers were truly from the studios. Many SMPE members came from research and manufacturing firms that serviced the industry like Bausch and Lomb, Eastman Kodak, and General Electric. The SMPE was one of the more notable professional organizations that emerged from the war that was dedicated to cinema's technological infrastructure.[430]

While the OSA was not as directly concerned with motion picture production as the SMPE, they nonetheless were responsible for cultivating a strong academic and professional infrastructure for the publication and circulation of optical scholarship. Notably, one of the first major initiatives of the OSA was to create an English translation of Helmholtz' *Physiological Optics,* which was first published in 1867. As noted in Chapter 1, Helmholtz' theories of energy and vision were crucial to Germany's efforts to expand its scientific infrastructure in the late 19th century. The English translation of the 1911 third edition of *Physiological Optics*, as Hilda Kingslake writes, was "one of the great publications of the Optical Society.[431] The translation project was begun in 1921, and the three parts of the volume were published between 1924 and

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[428] "The Society of Motion Picture Engineers: Its Aims and Accomplishments," *The Society of Motion Picture Engineers* (New York: Society of Motion Picture Engineers, 1930), iii.
[429] Jonah Horwitz, "Journal of The Society of Motion Picture and Television Engineers | SMPTE Motion Imaging Journal," *Velvet Light Trap*, no. 76 (Fall 2015): 62.
[430] See especially Luci Marzola, "Better Pictures Through Chemistry."
[431] Kingslake, "History of the Optical Society of America," 297.

1926.[432] The translation effort was financed heavily by Bausch & Lomb vice-president Adolph Lomb, who was Bausch and Lomb co-founder Henry Lomb's son. A foundational text "which marked the dawn of a new era in the science of the physiology of the senses," the translation of *Physiological Optics* was seen as a necessary step for the creations of new scientific treatises and textbooks in the American field of applied optics.[433]

The English language circulation of scientific treaties and journals supported the education of new generations of non-German speaking optical engineers who came to fill positions in the expanding American optical industry. Helmholtz' theories, as Jocelyn Szczepaniak-Gillece writes, had a lasting influence on exhibition technicians and engineers well into the 1930s. The continued influence of Helmholtz "illustrated a fixation on the optical impact of the motion picture screen and the physiological dimensions of the cinematic experience."[434] The migration of these ideas through societies like the OSA and the SMPE was largely due to the wartime effort to develop professional optical societies. Under Nutting's tenure, the OSA also worked closely with the International Commission on Illumination (CIE), a French organization that established fundamental standards in the measurement of light and color, and the International Congress of Photography.[435] While societies like the OSA rarely engaged with cinema during the war, as Chapter 4 will discuss, professional research in optical science was aggressively redirected to peacetime areas of development, like cinema, in the early 1920s. Although not concerned explicitly with cinema, the OSA was nonetheless a crucial agent in forming the optical infrastructure from which cinema benefitted.

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432 Kingslake, "History of the Optical Society of America," 297

433 W. Peddie, "Physiological Optics (Review)," *Nature* 114, no. 2877 (December 20, 1924): 887-889.

434 Szczepaniak-Gillece, *The Optical Vacuum,* 67.

435 Kingslake, "History of the Optical Society of America," 327.

The OSA and SMPE were not connected by a shared interest in cinema, but rather, a shared interest in the organization and publication of optical science by corporate engineers. The wartime development of electrical and chemical industries carried the scientific revolution into a broader array of industries. As David Noble argues, through patents, control over scientific research, and corporate support for institutions that produced both "scientific knowledge and knowledgeable people," modern science-based industry emerged from the "growing willingness of the capitalist to embark upon the costly, time-consuming, and uncertain path of research and development."[436] Following the war, corporations came to believe that "large-scale continuous operation and extensive organized research and development were the essentials of financial success…these demanded big companies, corporate organization, and stable markets." While Noble develops his argument through an analysis of the electrical and chemical industries, the same patterns of corporate progressivism supported the development of optical organizations like the OSA and Bausch & Lomb. Indeed, during the 1920s, the OSA operated on a continual deficit, and Adolph Lomb donated somewhere between $2,000 and $3,000 every year to support the organization.[437] Corporate progressivism was motivated not by greed, but by "a shared dream, a compelling vision of an affluent, humane, tranquil, and powerful America."[438] Or, as a 1908 Bausch and Lomb pamphlet proclaimed, the industrial spirit "aims to subserve the good of mankind as a whole. To give to science the best instruments…is surely to advance the welfare of humanity."[439]

The blurred lines between the corporate engineer and scientist indicated the extent to which science and corporate capitalism had become intimately intertwined in the late 1910s and

[436] Noble, *America By Design*, 5-6.
[437] Meyer, "Adolph Lomb," 40.
[438] Noble, *America By Design,* 64.
[439] Meyer, "Adolph Lomb," 38-39.

early 1920s – a connection that influenced the technology industries that supported the growing film industry (regardless of the extent to which they were explicitly concerned with cinema). The OSA and SMPE emerged out of a growing interest in standardization and optical fidelity, and both organizations came to strongly influence the direction of optical development in the United States and abroad. While prewar literature and professionalization was strongly divided along national lines, in these optical communities, there was a shift from a nationalist position to an internationalist attitude in optical design which saw international agreement and standardization as essential to trust in knowledge.[440]

Conclusion

Optical manufacturers quickly found themselves with a surplus of optical glass following the end of the war in 1918. Without the military demand, many of these cottage industries were forced to redirect their investments or fold.[441] As F. Twyman suggests, the greatest innovations in the optical industries occurred during the postwar conditions of austerity.[442] Camera lenses introduced during the war found alternative uses in photographing theatrical productions with ordinary theater lighting, projecting images in larger moving picture halls, and capturing increasingly fast movement on cinematographs.[443] While Bausch and Lomb were renowned for their photographic lenses prior to the war, afterwards, they were more well regarded for their cinematographic lenses. Much like the Precision Machine Company, Bausch and Lomb also turned their wartime optics to projector lenses, and Bausch and Lomb Cinephor projector lenses

440 Canales, *A Tenth of a Second*, 126.
441 Sambrook. *No Gunnery Without Glass.*
442 F. Twyman, "The Vitality of the British Optical Industry," *Journal of Scientific Instruments* 2, no. 12 (September 1925): 370.
443 Twyman, "The Vitality of the British Optical Industry," 371-372.

were held to be an industry standard in motion picture projection. Wartime innovations in optics were increasingly applied to the motion picture industry, and as *The Moving Picture World* proudly declared in 1919:

> The lenses which make possible motion picture photography and projection, have until recently all been made from optical glass imported from Europe. The glass for the cameras being made in America is now being turned out by the Bosch [sic] and Lomb plant, among the largest customers of the company being the Eastman Kodak Company, who buy all their lenses from Bausch and Lomb.[444]

The Moving Picture World's nationalist sentiment was characteristic of a postwar tendency to narrate optical history as a singularly national endeavor. In comparison to the OSA and the SMPE, who were both vocal in their support for international collaboration and support, there was a very strong tendency in the popular press to claim lens progress along decidedly national genealogies. Many postwar articles on lenses invoke a specifically *American* history of optical glass in a way that is absent from many earlier trade articles. With titles like "America's Optical Emancipation," (1919) "America's Conquest of Optical Glass" (1919), "Breaking A German Monopoly" (1919), and "Make Lenses Better Than Germans" (1919), articles in both the popular press and professional trade journals framed Bausch and Lomb as a triumphant example of American industry. This continued on as late as 1939 with Bausch and Lomb engineer W.B. Rayton's article "The Status of Lens Making in America," where he claims that early European success in lens production was due to the fact that the US was largely preoccupied with agriculture and industrial transportation, and that "the production of instruments for the projection of pictures has been preeminently "an American achievement."[445] Given anti-German sentiments in the United States, one might also speculate about how a company founded by

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[444] "Make Lenses Better Than Germans: Bausch & Lomb Optical Company Now Produces Glass That Excels the Boche Jena Product," *The Moving Picture World* 40, no.8 (May 24, 1919): 1178.
[445] Rayton, "The Status of Lens Making in America," 426, 429.

German immigrants may have felt particularly compelled to demonstrate its national character.[446]

Perhaps nothing demonstrated this nationalist mythology more than a Bausch and Lomb advertisement in *The Book of the Rochester Centennial* (1934). A full page advertisement on the inside of the book's cover, bookending the history of Rochester along with a rear inside cover advertisement from Eastman Kodak, framed the success of Bausch and Lomb as a mythical story of individual triumph:

> Motherless, fatherless, friendless and jobless, John J. Bausch landed in the United States in the rude, roaring days of '49. No financial assets were ever lower than his. His vicissitudes read like the trials of Job. But he had ideas, courage, honesty and energy. And he soon found a wonderful friend – Henry Lomb. Today the world beats a path to the doorway of an institution whose name is known wherever science throws its light…Industry, education, government – all rely on its fidelity to the standards that have governed it for more than eighty years.[447]

[446] Smith, "America's Optical Emancipation;" "America's Conquest;" "Breaking a German Monopoly," *The Trader* (July 1919): 63-64; "Make Lenses Better Than Germans," 1178.
[447] "A Jobless Immigrant Boy Made the World Beat A Path To His Door," *The Book of the Rochester Centennial: A Century on Parade* (The Rochester Centennial, Inc., 1934), Inside Cover.

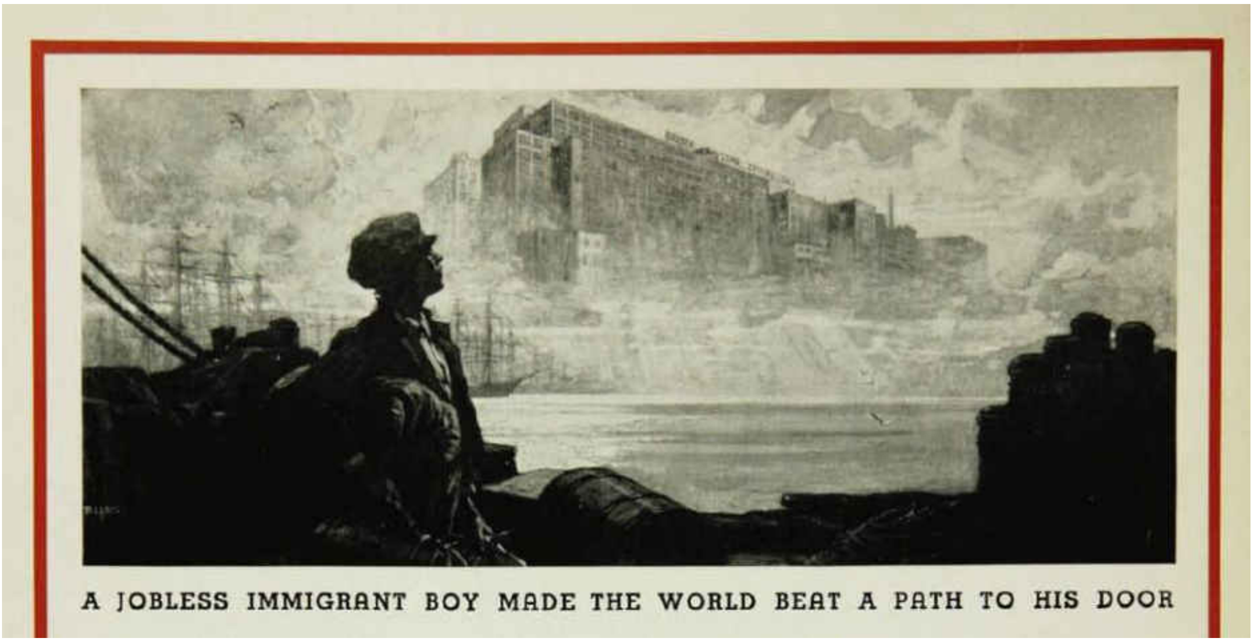

Figure 18 John J. Bausch illustrated as a visionary immigrant, looking out at an image of Bausch and Lomb on the horizon.

Depicting a waif on the docks, gazing up at a massive building hovering dreamlike in the clouds, the advertisement collapsed the mythology of the immigrant story with a dream of corporate expansion. The advertisement invoked the success of the land upon which Bausch began his business: one that rewarded individual tenacity and spirit.

The postwar tendency to write nationally-traced histories of lens development presents an interesting paradox. While the history of optics became closely aligned with questions of national heritage and identity (much in the same way that the 'origins' of cinema have been falsely divided along distinct national lines), the international expansions of optical industries ultimately unsettled the historical relationship between optical quality and national origin. Although Europe was seen to be the provenance of all things optical prior to the war, afterwards, practitioner beliefs in the quality of precision lenses were more firmly based on the reputation of large optical corporations. If, as Noble suggests, scientific engineers reproduced corporate logic in scientific research – a field whose interests in objectivity and knowledge were seemingly antithetical to modern capitalism – this was due in no small part to the replacement of nation with corporation. Although the expansion of corporate power was done in the spirit of progressivism, it had the effect of securing the power of corporate logic in American life, which proved to have more dubiously progressive effects over time.

The corporatization of technological production, examined in this chapter in relationship to lens production, was constitutive of a broader ideological shift in technological modernity. In *The Culture of Time and Space: 1880-1918*, Stephen Kern argues that new ideas about the nature of space brought about by transit and communication technologies challenged the popular notion that space could be objectively homogeneous – the idea that had motivated Helmholtz' measurement initiatives in the 1880s. Faced with a rapid and unevenly accelerating world, philosophers, physicists, and artists embraced the idea that space was not simply a void where objects existed, but rather, that space was "a multitude of qualitatively different spaces that varied with the shifting moods and perspectives of human consciousness."[448] Rather than thinking of lenses as passive tools that were used to represent the "pluralism and confusion of the modern age," lens production was itself co-constitutive of a world that was increasingly seeing and being seen through different lenses.[449]

The national expansion of optical production across the globe affirmed the potential of industry, rather than nation, to advance and progress technology – which, through the linkage of science and industry, was itself a form of social production. The rapid development of national optics – both as an industry and a professional community of knowledge – broke down the uncontested place that objective science held in the popular and professional imaginations of optical glass quality. If Zeiss established the field of expectations about optical fidelity in the late 19th and early 20th century, the war destabilized the firm association of nation with objective

[448] Stephen Kern, *The Culture of Time and Space: 1880-1914* (Cambridge: Harvard University Press, 1983), 149.
[449] Ibid. 147-153.

scientific progress. The national development of optical industries like Bausch and Lomb made high quality lenses more available and, significantly, visual fidelity became more easily accessible by photographers and cinematographers. Alongside a widespread industrialization of lens production, emerging professional communities of optics began to consider lens development not as a question of universally objective science, but as a design process with multiple definitions of correct (and distorted) perspective.

The dramatic wartime expansion of optical glass industries created an industrial base ideally suited to business relationships with the motion picture industry, especially following the cessation of wartime demands for military applications. The industrialization of glass did not have an immediate or direct impact on the ways in which films represented reality and motion. Neither the deep focus style of the silent period nor the soft focus style of the 1920s resulted from the use of "crude" or dedicated soft focus lenses alone.[450] More significantly, the national push for optics industries expanded the study, writing, and professional organization of optical knowledge, among which included the cinema (which came to occupy a particularly prestigious place in precision optics design). The motion picture industry, in turn, shaped the ways in which lenses became designed for seeing the world in terms of the studio.

[450] Bordwell, Staiger, and Thompson, *The Classical Hollywood Cinema*, 223.

Chapter 4 | Fast Glass: Cooke and the Cinematic Lenses of 1920s Hollywood

> Agriculture, steel, oil, transportation – all indispensable weapons. But there is another weapon to be fittingly grouped with them – a weapon of the heart – motion pictures!
> *Famous Players-Lasky (1918)*

Perhaps more than any other lens, the Cooke Speed Panchro is entangled in the history of Classical Hollywood. Designed by the British optical company Taylor, Taylor, and Hobson, the lens was first introduced to cinema studios as the F/2 Opic lens in 1924 and formally branded as the Speed Panchro in 1930.[451] Cooke's fast lenses were used extensively in the 1920s film industry – particularly by the Famous Players-Lasky/Paramount Corporation. In 1926, *Kinematograph Weekly* reported that over a hundred Cooke lenses were in use by the photographic department of the Famous Players-Lasky studios.[452] In 1928, *The Kinematograph Year Book* reported that Paramount had standardized the use of Cooke's F/2 lenses on all of their cinema cameras.[453] The wide apertures made Cooke's cine-lenses a useful tool for cinematographers who were grappling with a wide range of industry-wide changes that occurred throughout the 1920s, such as the adoption of panchromatic stock, incandescent lighting, and sound filmmaking. While these technological changes have often been historicized in relationship to their aesthetic consequences for film form, these changes also created new challenges for optical suppliers who sought to manufacture lenses for studio practice. From film to lighting to sound, the speed of Cooke lenses helped cinematographers address changes that formed the technological foundations of Hollywood's golden era.

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[451] R. Fawn Mitchell, "Historical Background of the Speed Panchro Lens," *The International Photographer,* November 1935, 17. The Opic succeeded Cooke's other fast lenses that were used for cine production: the f/3.5 IIa, which was produced between 1912-1914, and the f/3.1 Kinic, which was produced between 1921-1924.
[452] "The Observation Window," *Supplement to Kinematograph Weekly*, September 9, 1926, 71.
[453] "Lenses," *The Kinematograph Year Book 1928*, 300.

In the 21st century, Cooke has used their historical involvement with the studios to cultivate an aura of film history around its lenses. Most notably, in 2016, Cooke Optics resumed manufacture of their Speed Panchro lenses. Speed Panchros had not been manufactured since 1965 – the year that Cooke stopped producing these lenses to focus more specifically on television production. Cooke resumed manufacture of the Speed Panchros in an attempt to capitalize on contemporary desires for classic Cooke lenses. As Cooke Optics CEO Les Zellan mused in a 2018 interview, the Speed Panchro Classic line was produced to supply cinematographers who were using old lenses as a way to capture a specifically 'cinematic' look on digital recording formats. Many of the Speed Panchros being used were old and required multiple look-up tables (LUTs) for each lens to function effectively on set. [454] When Zellan described the history of Cooke at the 2019 British Society of Cinematographers Exposition, he emphasized that the quality of Cooke was built on a Taylor-Hobson's long tradition of solving problems for studio production:

> [W]hen sound movies came in, it's the Speed Panchros that we developed that made sound movies possible, to be sure, because all the lenses were just too slow…when Technicolor was a three-strip camera process…the lens had to throw out of the back of the lens through a prism, and so it had to go a long way. Nobody could figure that out. Then Technicolor sent their engineers to Cooke, and we solved that problem, and these principles that we developed along the way are used in every lens today…at a lot of turns in the industry, when there was a problem, Cooke solved it.[455]

[454] Interview with Les Zellan, Cinec 2018. https://www.thecineeye.tv/interview-with-les-zellan-cooke-optics-at-cinec-2018/

[455] Interview with Les Zellan of Cooke Optics at BSC Expo 2019. https://www.youtube.com/watch?v=wLwdqsrUu9s

Figure 19 November 1930 Announcement for the Speed-Panchro Lenses. American Cinematographer.

The lens, from the perspective of Cooke, was central to the development of Classical Hollywood's technical infrastructure. Zellan uses Cooke's historic involvement with the studios to suggest that the quality of Cooke lenses comes not only from exceptional construction, but also from a long tradition of successfully addressing technical problems in cinematic practice. As a lens that gained fame from its use in Hollywood's golden era and eventually became a casualty of rising television production in 1965, the Speed Panchro has played a central role in the guiding corporate mythology of Cooke: that Cooke lenses are cinema lenses, and that these lenses revive cinema's technological aura in an era when celluloid film is increasingly displaced by digital formats. Like so many corporate narratives, though, the success of Cooke occurred at the intersection of multiple cultural influences – not just corporate research and development – that constituted cinema in the 1920s.

Focusing on Taylor-Hobson and their Cooke lenses, this chapter examines how and why Cooke lenses became so closely linked to cinematic practice.[456] As I've demonstrated in the previous three chapters, the modernization of the precision lens industry was historically defined by the scientific production of distortionless lenses. Zeiss, E. Krauss and Bausch & Lomb – who were all corporate affiliates – made up the industrial infrastructure of the "anastigmat era," an era where distortionless photographic lenses became mass produced and internationally distributed. In many ways, the national initiatives to industrialize domestic optical industries during World War I marked a shift in the anastigmat era. Anastigmats were still used in production, and practitioners continued to extol the importance of corrected, distortionless lenses. However, in the wake of the war, lenses were increasingly manufactured for more clearly defined markets and communities of practice. Lens correction was an important quality, but correction became one of many criteria that constituted lenses as a specifically cinematic technology in the emerging 1920s cinema.

When the Opic was redesigned and rebranded as the Speed Panchro in 1930, the year that Taylor-Hobson was purchased by motion picture camera company Bell & Howell, the release of the Speed Panchro revealed the extent to which studio production desired technologies that were specifically designed for the integrated systems of studio production. Optical companies, much like the engineering and professional societies that Luci Marzola examines in *Engineering Hollywood: Technology, Technicians, and the Science of Building the Studio System, 1915-1930*, were becoming part of a horizontally integrated network of technologies that supported the emergent film industry. While Hollywood's success in the 1920s is frequently historicized as a

[456] For the purpose of brevity, I will refer to Taylor, Taylor & Hobson as "Taylor-Hobson" for the remainder of this chapter. According to a 1910 issue of *Camera Craft*, Taylor, Taylor & Hobson began to operate under the name of "Taylor-Hobson in 1910." However, both the company and the trade press often used these names interchangeably and with little consistency. "Change of Name," *Camera Craft* 17, 1910, 128.

product of the studios' vertical integration, as Marzola argues, it was the "horizontally organized trade associations and collaborative endeavors around technology which allowed the system to dominate motion picture production for decades."[457] The success of the Speed Panchro was due to how the lens – as both a material object and commercial commodity – worked efficiently and reliably across the multiple and growing departments that constituted cinema's horizontal infrastructure. Furthermore, Cooke's brand reputation helped foster a strong imagined connection between amateur movie makers and studio practice, which was especially beneficial to vendors selling equipment to an emerging consumer class of semi-professional filmmakers.

In addition to capitalizing on the growth and profitable mythology of studio production, Cooke's cinema lenses were also the product of an increasingly corporate engineering culture. Following the war, electrical, chemical, dye, and optical industries began to adopt a "corporate system of science-based industry" as a way to maintain more extensive control over research and production processes.[458] The expansion of the scientific-industrial matrix was motivated by the economic possibilities of mass consumption – a practice of commercial expansion that many wartime industries pursued during peacetime.[459] The consequence of these industrial shifts was a rise in engineering culture that instituted technology not simply as tools or objects, but rather, a "fundamental social development in itself" constituted by "the preparation, mobilization, and habituation of people for new types of productive activity, the reorientation of the pattern of social investment, the restructuring of social institutions, and, potentially, the redefinition of social relationships.[460] This is to say: these infrastructural rearrangements changed not only the

[457] Luci Marzola, *Engineering Hollywood: Technology, Technicians, and the Science of Building the Studio System, 1915-1930*, Dissertation (August 2016).
[458] Noble, *America By Design,* 6-18.
[459] Zunz, *Why The American Century,* 22.
[460] Noble, *America By Design,* xxii.

design of lenses, but the broader corporate industrial structure necessary for the production of lenses. As Bausch & Lomb director W.B. Rayton mused in *Cinematographic Annual* (1930), although the optician might be tempted to think that "without optics there could be not cinematography," such an "idle and superficial" impulse immediately gives way to the contributions of the chemist and the precision mechanic.[461] While Rayton's 1930 observation frames cinematic development as a technocentric process – not dissimilar from Les Zellan's 2019 logic – Rayton's statement reveals the extent to which optical engineers conceived of the cinema as a system of production.

I argue that the studio use of Cooke's fast glass – a term that neatly expressed modernity's ideals of speed and visibility – both reflected and constituted a wider shift towards the manufacturing of visual space rather than its objective capture. First, I will illustrate how Cooke's optical reputation was strongly influenced by its national reputation following World War I. Second, I will illustrate how Taylor-Hobson migrated these wartime optical innovations into the commercial market of the cinema, particularly in the field of projector lenses. Third, I will examine how Cooke cinema lenses were defined not only by their use in studio production, but also in relationship to a growing semi-professional camera market. Finally, I will examine the Cooke Speed Panchro to demonstrate how lens design became predicated on studio-specific needs for the manufacture of visual space. In examining the entanglement of Taylor-Hobson lenses with 1920s Hollywood, we can better understand how cinema lenses became defined as such on the basis of studio-specific practices.

Cinema lenses became defined by their capacity to function in the studios: they manufactured an environment built to conceal its technological construction. Rather than simply

[461] W.B. Rayton, "Optical Science in Cinematography Bibliography," in *Cinematographic Annual*, *Vol. 1*, ed. Hal Hall (Hollywood: American Society of Cinematographers, 1930), 41.

representing or simulating the world, studios were themselves constitutive of a broader modern tendency to manufacture the world. As Brian Jacobson contends, studios were models of the "human-built" world where "modern technologies came not so much to dominate the natural environment as to replace it with artificial alternatives."[462] Ensconced within the technology of the studio, "the real becomes more artificial than fiction itself, accessible only, and paradoxically, through the camera's lens, the single location from which one can imagine the artificial scene free of illusion."[463] Jacobson echoes Walter Benjamin, who similarly writes that studio production manufactures an environment where it is "impossible to assign to a spectator a viewpoint which would exclude from the actual scene such extraneous accessories as camera equipment, lighting machinery, staff assistants, etc. – unless his eye were on a line parallel with the lens."[464] The impossible viewpoint of the cinema mystifies a reality effect of the lens that was also shared with microscopy and photography: the lens reveals a world that can only be perceived as such from the perspective of the technology.

Benjamin's impossible viewpoint is reflected by the dearth of behind the scenes photography that look directly at the lens. Behind the scenes photos of Hollywood production are rarely positioned from the perspective of the actor, and if so, they never look directly at the lens. On an economic level, this makes sense: the space of the actor is at the center of a constellation of labors that have been carefully coordinated to ensure "the thoroughgoing permeation of reality with mechanical equipment, an aspect of reality which is free of all equipment."[465] Positioning a behind-the-scenes camera in the place of the actor runs the risk of interrupting a series of

[462] Jacobson, *Studios Before the System,* 17-57.
[463] Ibid. 19.
[464] Walter Benjamin, "The Work of Art in the Age of Mechanical Reproduction," in *Illuminations,* ed. Hannah Arendt, trans. Harry Zohn (New York: Schocken Books, 1935), 11.
[465] Ibid. 12.

expensive labors. On a somewhat more mystical level, though, the absence of photographs that look directly down the barrel of the lens also serves an ideological function. As Benjamin suggests, to replace the aura of art, studios manufactured an aura around technology. While the 1920s entrenched classical Hollywood cinema form as "timeless and natural," as Miriam Bratu Hansen contends, the seemingly natural form of classical cinema was a "regime of productivity and intelligibility that is both historically and culturally specific."[466] Despite being elegantly inscribed with lens maker names, focal lengths, and apertures, the lens is an empty space of archival record: as though it is taboo to look directly at the location from which artifice becomes reality. In the human built world of the cinema – both in the vertically aligned studios and the horizontally aligned technology industry – the auratic absence of the lens naturalized and humanized increasingly artificial practices of manufacturing visual space.

Taylor-Hobson and the Postwar British Optical Industry

By the end of World War I, Taylor-Hobson had cultivated a reputation as a particularly prestigious British optical manufacturer and were well known for their photographic objectives. By 1930, Taylor-Hobson's Cooke lenses had become a standard name in both professional and amateur cinematography in nearly all the Hollywood trade press. How, exactly, did Taylor-Hobson come to be associated so strongly with the cinema in the 1920s? The adoption of Taylor-Hobson's lenses in the studios was not based solely on the basis of Cooke lenses being the 'best' or fastest lenses available, nor was their use in the cinema based on an inevitable or progressive 'evolution' of photographic technologies for cinematic use. Cooke's reputation as a precision

[466] Hansen, "The Mass Production of the Senses," 334.

instrument maker was intertwined with its role in the war and with the promise that its 'British' products provided for postwar optics – both on a professional and commercial level.

Taylor-Hobson, like many lens designers of the late 19th century, became commercially successful on the basis of designing lenses with minimal distortion. In 1886, the same year that the Jena Glass Works began to distribute its scientifically designed optical glass, engineer William Taylor and optician T. Smithies Taylor created a company that produced and sold a variety of optical instruments. In 1887, Herbert Hobson joined and became the sales face of the company; although his name is carried on in the company, he left in 1896. Based in Leicester, Taylor-Hobson built its reputation on the basis of its high-end, precision instruments.

The Cooke lenses produced by Taylor-Hobson take their brand name from an acquisition made in the 1890s. Thomas Cooke was a scientific instrument manufacturer based in York, and Cooke had a factory from 1837 to 1868 that produced spectacles, telescopes, and surveying equipment to sundials, clocks, and lathes.[467] In 1893, one of Cooke's engineers, H. Dennis Taylor (no relation to any of the Taylor brothers) designed and patented the Cooke Triplet, a distortionless photographic lens. In 1894, Thomas Cooke offered the Taylor-Hobson the manufacturing rights to the Triplet photographic lens design and the Cooke name. Taylor-Hobson made a wide variety of optical instruments, but the Cooke Triplet was one its most successful products. Rather than layering more and more glass elements to reduce optical distortion, the Triplet was made of three optical elements. Photographers were widely enamored of the Triplet's sharpness and the simplicity of its design, and its simple construction resulted in many optical companies adopting a triplet design for lens construction.[468]

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[467] "T. Cooke and Sons," *Grace's Guide to British Industrial History.* https://www.gracesguide.co.uk/T._Cooke_and_Sons

[468] The Triplet was one of the few lenses that undermined Zeiss' claim to optical authority at the turn of the 20th century. There was a debate about whether Zeiss' famous Tessar – which was used most frequently by

From Leicester, Taylor-Hobson both sourced the necessary materials for precision glass manufacture and supplied a growing network of international photographers. In 1899, Taylor-Hobson's business had grown to the extent that they moved from the Slate Street Works and erected a new factory and office building, known as the Stoughton Street Works, with "every modern convenience."[469] By 1902, a New York Office was established by a J. Ronald Taylor, a third Taylor brother, and the New York office was primarily set up to supply Eastman Kodak.[470] Although the precision optics industry was not nearly as large as other more classically modern industries – such as the textile industry or the machine tool industry – precision instruments were a significant and often emblematic marker of British industrial progress.[471] Prior to the war, British makers often showed little concern for foreign competition. As Mari Williams writes, it wasn't that British makers were unaware of this competition: many makers sold German products, and several used parts manufactured in Germany.[472] The British industry largely operated on the basis of keeping costs low, and these cost-saving measures resulted in a lack of domestic investment in worker training and a significant dependence on imported materials.

British indifference to German optics quickly shifted to nationalist hostility when Britain declared war on Germany. While arguments about British industrial performance were generally carried out outside the precision instruments industry, at the outbreak of the Great War,

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cinematographers – was, in fact, derivative of the Cooke Triplet. The designs are quite similar, but the Cooke Triplet was designed and patented in 1893: the Tessar was designed and patented in 1902. Those defending the Triplet pointed to the similarities in design; those defending the Tessar pointed to the Tessar's design as an advance on the existing Protar and Unar lens designs. The most likely explanation, as HH Nasse writes, is that if there is a relationship between the Zeiss Tessar and the Cooke Triplet, it is because "usable solutions to lens correction problems are similar." Nonetheless, the debate over whether Cooke or Zeiss could lay claim to optical inventions illustrated a common lens culture that engineered lenses out of readily available devices and concepts. Nasse, "From the Series of Articles on Lens Names," 3.

[469] "Trade Jottings," *The Photographic Dealer and Optical and Scientific Apparatus Trades Journal* 7, no. 38 (July 1899): 6.

[470] Jess Jenkins "Taylor, Taylor and Hobson Ltd. - Leicester's contribution to precision engineering," 2008.

[471] Williams, *The Precision Makers,* 15.

[472] Ibid. 34.

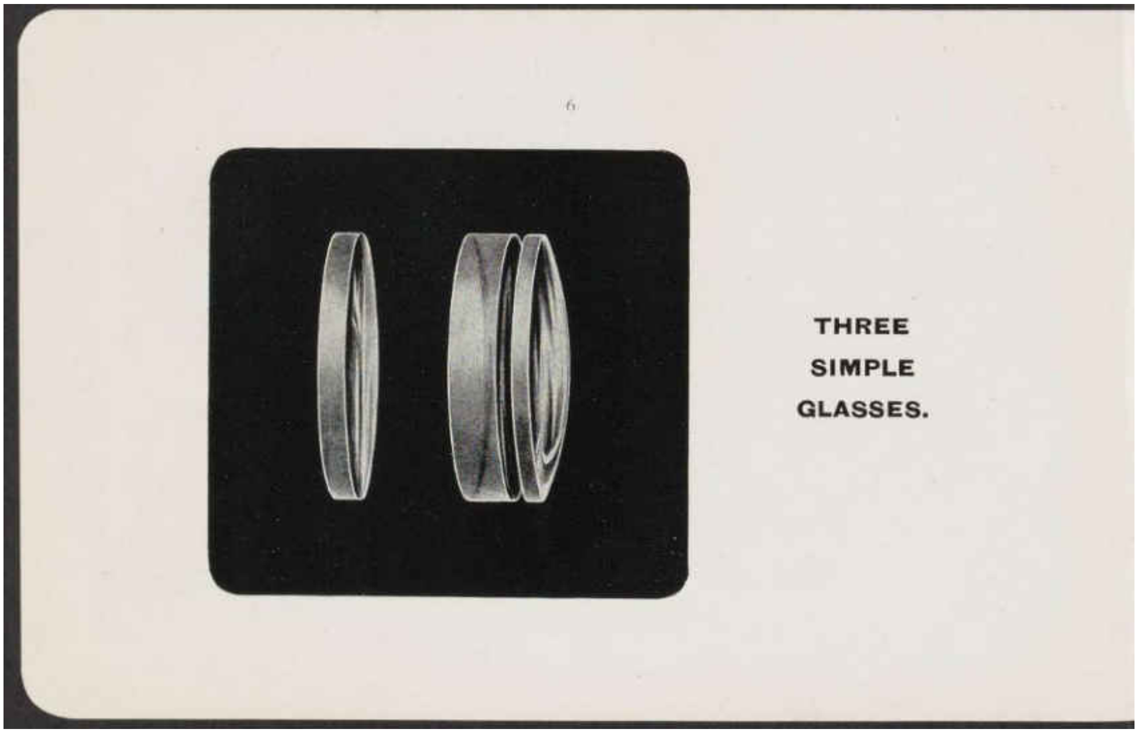

Figure 20 Cooke 1902 Catalog. 10.

Germany's optical superiority played into fears of national degeneration that had been endemic to British culture since the late 19th century.[473] Nationalism proved to be an effective rallying cry for the massive mobilization required to sustain the British war effort on both a material and ideological level. Although optical discourse was strongly focused on German antagonists, one of the strongest reasons for the optical crisis was a lack of suitable silica from France. British manufacturers had generally used sand obtained from Fontainebleau, just south of Paris. In addition to its chemical purity, even grade, and suitable size and shape, Fontainebleau sand was widely used because it could "be transported cheaply and conveniently to most British glass-making districts. This is partly due to the insular position of Britain, and partly to the fact that the

[473] Williams, *The Precision Makers,* 34. Robb, *British Culture and the First World War*, 190.

sand can be directly shipped from Rouen."[474] The war emphasized the sharp limits of the modern promise of industry built upon international practices of resource extraction.

The sand necessary for precision optics was often discussed in terms of its chemical and material purity, even though the most significant barrier to sourcing British silica was a lack of adequate domestic refinement and processing. As Boswell wrote in 1915, "There does not appear to be anywhere in the British Isles a sand so suitable, from all points of view, as either the Fontainebleau or Lippe sands…This does not mean that sands as pure and well-graded as those cannot be found."[475] Although these discussions described material qualities necessary to the construction of precision optical glass, the scientific emphasis on purity and homogeneity obscured the economic incentives that encouraged British glassmakers to build an industry on the basis of cheaper foreign materials in the first place. These discussions were only further reinforced by nationalist discussions of optical labor. Despite a long tradition of foreign workers, postwar discussions about the preservation of the British optical industry emphasized the economic threats of "unfair foreign underpaid labor" and routine labor "best suited to the German worker."[476] Together, anxieties about the underdevelopment of both material resources and domestic labor were used by optical companies to rationalize a nationalist push for the invigoration of a specifically British optical industry.

Although Taylor-Hobson had been producing lenses since 1894, they achieved national recognition for their manufacture of photographic lenses during World War I. Much like France and America, Britain's optical industry rapidly expanded during the war to compensate for an

[474] P.G.H. Boswell, "Sands for glass-making, with especial reference to optical glass," *Transactions of the Optical Society* 16. (1915): 245.
[475] Ibid. 248.
[476] "The Glass Industry After the War," *Journal of the Society of Glass Technology* II (1918): 103. H Dennis Taylor, "Optical Designing as an Art," *Transactions of the Optical Society* 24 (1923): 162.

abrupt loss of access to German optical glass, which had become immediately vital for a wide range of military applications. The British manufacture of optical glass was undertaken by Chance Brothers, a British glass company who, once upon a time, supplied the glass for the Crystal Palace of the 1851 exhibition. The Chance Brothers was offered some of the most significant state financing to increase their production, which increased from 70,000 lbs of optical glass in 1916 to 92,000 lbs in 1918 – somewhere close to fifty times its normal pre-War quantity.[477] Taylor-Hobson were largely responsible for manufacturing photographic lenses for aerial surveillance. Similar to Bausch & Lomb in the United States, Taylor-Hobson received special recognition for their work in the war for the construction of precision optics. While secondary to the wartime need for range-finders, gun sights, and binoculars, precision photographic optics functioned as a highly visible example of Britain's wartime technology effort.

Most notably, the Cooke Aviar visibly affirmed the success of the British industrial effort. The Aviar was a lens designed for use in aerial photography and adopted by the Royal Air Force in 1916. As aerial photographers were, out of necessity, often working with a hodge-podge of requisitioned lenses, refinements in the clarity and supply of aerial photography reinforced beliefs in Britain's domestic independence, the perceived technological supremacy of Britain's rapidly developing air force, and its actual viability in surveying, photographing, and representing the war. English optical glass makers juxtaposed the quality of their glass against a German standard, and the war-driven embargo intensified practices of legitimating optical glass along national lines. We can see this explicitly in a review of a 1916 test of the Aviar, which

[477] Alan G.V. Simmonds, *Britain and WWI* (New York: Routledge, 2012), 77. "Where Britain Leads," *Cooke Lens Catalog,* (Taylor Hobson, 1930).

strongly parallels a similar 1916 lens test by Bausch and Lomb.[478] A blind test was made between a Zeiss lens and the Cooke Aviar. Plates were exposed simultaneously at a high altitude, and plates received identical exposures and development. John H. Gear, president of the Photographic Society, made an address about this test:

> I was subsequently asked to give an opinion upon the quality of the lenses used in making the negatives, not knowing what lenses had been used. Very little examination was necessary before I unhesitatingly selected one negative as being superior to the other—that one was made with the British Lens.[479]

Regardless of whether this test was purely for publicity, the comparison between English and German glass was symptomatic of efforts to remove the stigma from British industry and to prove that English lenses were superior to German lenses. The test also linked the Royal Air Force with British science and manufacturing, creating an explicit link between technological progress and military might. The Aviar was lauded as a symbol of Britain's optical industry managing to create lenses that not only equaled, but surpassed, lenses of German construction. William Taylor was awarded an OBE (Order of the British Empire), and the King visited the Taylor-Hobson Stoughton Street Works in June of 1919. As a way to concretely measure Britain against Germany, Cooke's precision lenses produced and affirmed images of domestic technological progress.[480]

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[478] As written in an excerpt from the Bausch and Lomb Optical Glass Catalog (1919): "In the winter of 1916-17, we produced glass which was used in the manufacture of several hundred high-priced anastigmat photographic lenses, hitherto employing only the highest grade Jena glass. These lenses were fitted to speed cameras and subjected to the most exacting tests. In subsequently congratulating our plant on its achievment [sic], the camera manufacturer wrote: "Our critical tests of these lenses show them to be not only equal, but superior to the same type of lenses heretofore made from the imported glass." *Bausch and Lomb Optical Glass Catalog* (Bausch and Lomb Optical Company, 1919).

[479] Cooke Catalog (Taylor Hobson, 1930).

[480] The practice of aligning lens technologies with British technological progress continued long after the war. Advertising was good for nationalism, but nationalism was also good for advertising. For example, Cooke would later advertise the use of its Speed Panchro lens for a 1936 underwater documentation of the Lusitania wreck, a British ocean liner sunk by Germans in 1915. Dudley Darby, "A Tale of Technical Excellence and Endurance," *ZERB* (Autumn 2011): 32-35.

Taylor-Hobson's wartime innovations were one of a growing network of scientifically driven industrialization projects in Britain. While arguments about British industrial performance and its links to technical training and education were largely carried out outside the precision instruments industry prior to 1914, these conversations became central to optics in the war.[481] Much like the American OSA (Optical Society of America) and the French OPL (Optique et précision Lavallois), the British Society of Glass Technology grew out of a wartime lack of knowledge about the infrastructure of optical glass production. It also mirrored the emergence of dedicated motion picture standards organizations such as the Society of Motion Picture Engineers (1916) and the Deutschen Kinotechnische Gesellschaft (1920).[482] Inaugurated in 1916, in the midst of the war, the British Society of Glass Technology was founded for the general advancement of knowledge and practices in glass technology. The Society was a means by which English manufacturers and scientists could share knowledge about a wide range of glass crafts. At the Inaugural Meeting on November 9th, 1916, Society Secretary W.E.S. Turner – a chemist who had established a Department of Glass Manufacture at the University College of Sheffield in 1915 – noted that there was a desire for manufacturers to be more closely associated with both each other and with men of science "by which means alone the deadening influences of generations past could be overcome."[483] These organizations helped glassmakers build a body of professional knowledge that could circulate outside of the traditional apprenticeship models of knowledge that had led to the abrupt scarcity of optical glass. In its early years, the Society's journal was dedicated to surveying literature relevant to glass in both British and foreign journals

[481] Williams, *The Precision Makers,* 34.
[482] "Report of S.M.P.E. Progress Committee," *American Cinematographer*, April 1925, 18.
[483] "The Inaugural Meeting," *Journal of the Society of Glass Technology* 1 (1917): 3.

since 1915, and following the war, the journal served as a site of emergent discussion about what the future would hold for the newly formed British optical industry.[484]

On May 15th, 1918 – six months prior to the end of the war – The Society of Glass Technology held a general discussion in London around the topic of "The Glass Industry After The War." The wartime expansion the optical industry suggested the rich benefits of national science and research, but these utopian visions were met with the immediate fear that this impetus would not sustain in the postwar era. Opticians and glassmakers were anxious about whether the newly expanded domestic optical industry would be protected against German glass, which was soon to enter the market after the cessation of the war. A number of members advocated for government protections from foreign imports, particularly as the *Sheffield Telegraph* had reported that German glass-manufacturing had been taken over by the government and been "amalgamated into one great company."[485] The amalgamation of the German industry was not entirely true, and neither was it significantly different from the government subsidies provided to the British industry. What the fear of German industry did tap into, though, was a domestic anxiety about the quality of British products. Although members were optimistic about the newly vitalized British glass industry, members were fearful that the British market would "undoubtably be deluged with foreign glass during a period of time when we shall all, more or less, feel we ought to have a rest and a holiday."[486] Other members of the Glass Society quickly noted that unless the British glass industry became more equitable for its workmen – the same economic inequalities that had contributed to Britain's underdeveloped glass industry in the first place – Britain's glass industry would immediately collapse.

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484 "The Society of Glass Technology," *Journal of the Society of Glass Technology* 1 (1917): 1.
485 "The Glass Industry After the War," 105.
486 Ibid. 103.

Following the war, the British optical industry replaced the stimulus that the war provided with "national prestige" and "the stimulus of good, honest pride in ourselves."[487] In concert with their efforts to distinguish their industry, British optical engineers began discussing cinema in more explicit terms after the war. For example, while The Optical Society of Great Britain had published a number of articles about photographic lenses and shutters since its initial proceedings in 1899, these articles rarely identified the application of photographic lenses for cinematography. It was only in 1919 that The Optical Society of Greaat Britain explicitly engaged with cinema in the form of Charles W. Gamble's article, "On Projection Screens." In the article, Gamble argued that opticians should approach the improvement of image projection more systematically. He contended:

> Although screens for receiving projected images may be regarded as optical devices, and, reasonably, devices of a delicate nature, it is perhaps singular that there has been until recently little or no attention paid to investigating the conditions which determine their efficiency. By far the largest use of projection screens occurs in the cinematograph theatres, which are so widely distributed.[488]

Unhappy that experiments on improving the screen had thus far been the result of practical tests rather than "quantitative methodological investigation," Gamble suggested that considering both the screen and the lens as an optical system would increase the comfort and value of exhibition, particularly in relationship to cinematograph theaters which were the largest use of projector screens.

Gamble's article picked up a conversation about optical projection that had been largely forestalled by the war. After the 1909 Cinematograph Act, which regulated film exhibition at a national level, cinema-building boomed in London.[489] While scholarship has primarily focused

[487] "The Glass Industry After the War," 112.
[488] Gamble, "On Projection Screens," 34.
[489] "History," *London's Silent Cinemas.* http://www.londonssilentcinemas.com/history/#fn-11-11

on how the Cinematograph Act established censorship precedents, the Act also served as a powerful impetus for British exhibitors to standardize and improve the quality of exhibition spaces.[490] As F.H. Richardson wrote in 1915, in contrast to British exhibitors, American film manufacturers were paying for a highly corrected camera lens and then proceeding to "wipe out the good effects of the high grade camera lens by projecting the picture with the cheapest thing we can get."[491] As *Kinematograph Weekly* staff member Collin N. Bennett bemoaned, had the European war not switched the lens companies Dallmeyer, Ross, R&J Beck, and Taylor-Hobson to government work, "the effect of what they are doing for the motion picture exhibitor would by this time be considerably more apparent than it is."[492] Following the war, optical companies committed to government work turned back to the cinema as a site to sell higher quality optical equipment, and the industrial focus on cinema as a potential market was also reflected in professional optical publications.

The discussion about Gamble's article was minimal in the published Optical Society proceedings, but over the following decade, the Optical Society published more articles and proceedings that directly examined cinematic applications.[493] Of particular note is a lecture delivered by W. Day on "The Birth of Kinematography, and Its Antecedents" on January 25, 1923. It is extremely likely that W. Day was Will Day (Wilfred Ernest Lytton Day), an early amateur British film historian and author of the unpublished *25,000 Years to Trap a Shadow.*

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[490] David R. Williams, "The 'Cinematograph Act' of 1909: An Introduction to the Impetus behind the Legislation and Some Early Effects," *Film History* 9, no. 4 (1997): 341-350.
[491] F.H. Richardson, "Projection Department, Subsection: High Grade Lenses" in *The Moving Picture World* 4 (September 1915): 1639.
[492] Ibid. 1639.
[493] In the 1920s, these articles were: R.J. Trump, "A Shutterless, continuous-feed kinematograph," *Transactions of the Optical Society* 22 (1921): 75-83; W. Day, "The Birth of Kinematography, and its Antecedents," *Transactions of the Optical Society* 24 (1923) 69-71; Taylor "Optical Designing as an Art," 143-167; H. Dennis Taylor, "The feasibility of cinema projection from a continuously moving film" *Transactions of the Optical Society* 25 (1924): 149-176; H.W. Lee, "The Taylor-Hobson F/2 Anastigmat," *Transactions of the Optical Society* 25 (1924): 240-248.

Day's lecture at the Optical Society suggested the extent to which optical societies were directly focusing on cinematic practice in the 1920s as means of building up the prestige and popularity of their craft – particularly in an era where many optical companies were forced to redirect their wartime innovations into other markets or fold. Shortly after Day's January lecture, H. Dennis Taylor, designer of the original Cooke Triplet, gave an address in March 1923 to The Society of Glass Technology, "Optical Designing as an Art." Taylor had been in retirement since 1920, and in 1923, was returning publishing after an fourteen year hiatus.[494] In his address, Taylor argued against the prevailing idea that science and engineering held the definitive solution for lens production. Taylor stated:

> I regard the work of optical designing to be much more analogous to the work of the sculptor than to that of the mechanical engineer…I regard the best optical designing as more of the nature of an art than the mere calculation and carrying out of a mathematically prescribed specification.[495]

In opposition to the prevailing professional tendency to align optical design with increasingly scientific and mechanical forms of labor, Taylor argued strongly for a return to experimentation. Taylor argued for the benefits of trial and error, rather than scientific analysis, as a way to "sharpen" rather than "atrophy" intelligence, inventiveness, and artistic faculties. [496] By reframing the future of optical design away from the standing tradition of Zeiss and towards the seemingly neglected British school of optics established by Airy and Coddington, Taylor mobilized national history for the support of science and industry. Taylor's address, mired in nationalism, redefined the postwar narrative of glass production in terms of quality and prestige – language that was strongly drawn from the nationalist sentiments of the wartime years.

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494 Peter Abrahams, "H. Dennis Taylor, Optical Designer for T. Cooke & Sons." 2000. http://www.europa.com/~telscope/hdtaylor.txt
495 Taylor, "Optical Designing as an Art," 156-157.
496 Ibid. 157.

Technological change never occurs in a vacuum, and the development of cinema lenses was not solely the product of Cooke's internal reputation with the cinema industry. Rather, Cooke's prestige was intertwined with its broader industrial reputation, which itself was predicated on a nationalist desire to expand British glass production into broader markets. The wartime development of the optical industry, which shored up both Britain's infrastructural base and its cultural belief in the quality of British lenses, encouraged the continued expansion of precision optics.[497] The film industry's use of Taylor-Hobson's lenses was based on these technical qualities, but these qualities were never inherently central to film practice. These technical qualities became valuable because studios and theatres began to widely enact technical standards – a horizontal synchronization that especially benefitted 1920s motion picture studios, who were beginning to vertically integrate motion picture production and motion picture exhibition.

Taylor-Hobson Moves into the Movies

The optical industry of the early 1920s was increasingly defined by scientific exchange, the migration of wartime optical innovations into alternate markets, and a desire to re-energize the glass industry on the basis of national prestige. As optics developed into a more international and scientifically coordinated community of study, they sought to circulate, and sell, the product of their research in new commercial markets.

One such market was the growing market of motion picture exhibition. The Berlin picture palaces that Siegfried Kracauer analyzes in *The Mass Ornament* grew out of an industrial shift towards opulent exhibition in the 1920s In the years following the war, "movie exhibition

[497] "Where Britain Leads."

replaced big-time vaudeville as the mass entertainment form preferred by Americans."[498] The rise of cinema in the 1920s was by no means an immediate or evenly distributed process, but a wide range of businesses concerned with the film production began to approach cinema as an industry with its own distinct set of technical and professional needs. While elevating the quality of the pictures themselves was part of this strategy, as Douglas Gomery writes in *Shared Pleasures: A History of Movie Presentation in the United States*, the individual movie "typically matters little to exhibition."[499] Exhibitors didn't sell movies; they sold escape, comfort, and quality. By adopting the strategy of chain stores like Sears and S&P, the U.S. film industry used theatre ownership to support its broader business of studio production.[500] The creation of an integrated motion-picture production system involved more than the studio acquisition of multiple chains; rather, as Marzola writes, "there was a whole other side of the industry that made production possible and that needed to be incorporated for the system to function."[501] As motion picture exhibition became increasingly central to the studio profit model, standardization across taking and projection was seen as a key criteria for quality, which was essential for profit.

Taylor-Hobson advertised itself in ways that the emerging 'quality' motion picture industry sought to both promote and identify itself with. As much as story and stars were the promoted cores of the motion picture industry, as the Players-Lasky wrote in a short 1919 corporate overview, *The Story of the Famous Players-Lasky*, "Every picture produced by this organization is the fruit of the labor of a thousand experts, experts whose entire energies are bent

[498] Gomery, *Shared Pleasures,* 36.
[499] David Bordwell, "Foreword," in *Shared pleasures: a history of movie presentation in the United States*, Douglas Gomery (Madison: University of Wisconsin Press, 1992), xii.
[500] Douglas Gomery, "The Movies Become Big Business: Publix Theatres and the Chain Store Strategy," *Cinema Journal* 18, no. 2 (Spring 1979): 26-27.
[501] Luci Marzola, "A Society Apart: The Early Years of the Society of Motion Picture Engineers," *Film History* 28, no. 4 (2016): 23.

to one task – the making of the best motion pictures."[502] Optics' language of scientific testing, quality assurance, and engineering spoke strongly to studio and exhibitor efforts to increase both public and industry-internal perceptions of cinema quality. While not exclusive to the optical industry, optical catalogues and advertisements actively used narratives of scientific engineering and design to translate technical quality into practical quality.

From 1919 to 1922, Taylor-Hobson began to aggressively mobilize their wartime lens production into photography and cinema markets. They promoted the use of their lenses for aerial photography in the war; they published a letter from Ernest Shackleton about the use of their lenses on the Antarctic Expedition; they emphasized the use of their lenses to film royalty. These international accomplishments helped Cooke advertise their growing distribution offices. In 1921, after a period of displaying their wartime accomplishments, Taylor-Hobson released a catalog with their new lenses. The catalog included lenses for astronomical photography and cinema taking and projection lenses, including lenses with apertures as large as f/2.5, f/2, and f/1.9.[503] Although manufacture was "not sufficiently advanced for these ultra-fast objectives to be listed in detail," consumers were notified that they could have further information directed to them. In October of 1921, Taylor-Hobson also moved their primary sales department from Leicester to London.[504] Although Taylor-Hobson had maintained an office at 1135 Broadway in New York, at some point between 1915 and 1922, they discontinued operations at this location – likely due to the war.

Taylor-Hobson distributed a new F/2 type of lens as early as 1920, which was introduced to kinematograph studios as the "Kinic" lens.[505] According to R. Fawn Mitchell, Technical

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[502] *The Story of the Famous Players-Lasky Corporation* (Famous Players-Lasky Corporation, 1919), 9.
[503] "Cooke Lenses," *The British Journal of Photography* (April 22, 1921): 242.
[504] "News and Notes," *The British Journal of Photography* 68 (October 14, 1921): 617.
[505] Mitchell, "Historical Background of the Speed Panchro Lens," 17.

TAYLOR-HOBSON COOKE ANASTIGMATS 27

Taylor-Hobson Cinema Projection Lenses

THE LATEST ADVANCE IN THE MOTION PICTURE FIELD

Compare the picture to right with the same picture below and the great superiority of the new Taylor-Hobson Cinema Projection Lens will be instantly apparent. The National Physical Laboratory (London), reports that the Taylor-Hobson lens transmits 52% more light than the next best lens on the English Market fitting the standard 2⅛-inch jacket.

TAYLOR-HOBSON LENS

This wonderful luminosity is obtained by using the largest diameter lenses that can be used in a standard jacket and by a patented formula which permits of the rear lens being brought close up to the film gate.

All the light passing through the gate is transmitted by this wonderful lens to the screen resulting in pictures of sparkling brilliancy.

The lens is made from the highest grade optical glass, scientifically ground and polished and beautifully finished.

It is especially recommended for use with Mazda installation. The increased clearness and brilliance of the projected image will prove the greatest drawing card for the progressive exhibitor.

THE NEXT BEST LENS

Supplied in Mounts fitting directly the standard American Projection Machines, such as Simplex or Powers.

Focal Length	F. Value	Focal Length	F. Value	Price
3½ inches	F/1.8	5 inches	F/2.6	$60.00
3¾ inches	F/2.0	5¼ inches	F/2.8	60.00
4 inches	F/2.1	5½ inches	F/2.9	60.00
4¼ inches	F/2.2	5¾ inches	F/3.0	60.00
4½ inches	F/2.4	6 inches	F/3.1	60.00
4¾ inches	F/2.5			

Figure 21 1922 Burke & James Cooke Lens Catalog.

Service Manager for Bell & Howell, while cinematographers had "preliminary hesitation" about using lenses of such wide aperture, "the superior definition and quality of these lenses won acceptance under the most rigid tests and the use of really fast lenses came into general use in the studios for the first time."[506] Mitchell's statement about the studios echoed similar claims made by Bausch & Lomb and Taylor-Hobson about the use of their lenses for military. The sale of lenses, whether it was for war or cinema, was frequently embedded in a demonstration of scientifically-grounded quality (and often with a story or claim to rigid scientific testing). Faster lenses did not inherently mean better pictures. As Kristin Thompson writes, we should dismiss the notion that "the silent period used only a crude, unintentional deep focus resulting from 'contrasty' orthochromatic film or from crude, slow lenses."[507] Rather, if faster lenses became valuable over the course of the 1920s, it was because fast glass was connected to Hollywood's specific desire for quality and standardization.

The value of a lens was cultivated in more places that just the material lens itself: lenses also became valuable through circulated trade articles that convinced technicians and business operators of the value of more expensive lenses. In 1922, Taylor-Hobson began to distribute their

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[506] Ibid. 17.

[507] Bordwell, Staiger, and Thompson, *The Classical Hollywood Cinema,* 223.

lenses through Chicago-based camera accessories company, Burke & James.[508] In 1922 Burke & James released a catalog dedicated to their new offering of Cooke lenses. Listed first in the catalogue were the Series I lenses, F/3.1, designated "For Motion Picture Taking." The catalogue was, per its introduction, "not merely a catalog of the famous Taylor-Hobson Cooke Anastigmats" but also "a treatise on applied photographic optics."[509] With full page articles such as "Which Lens to Choose," "What is An Anastigmat?," "How to Test Lenses," "How to Focus," and "What Depth of Focus Really Means," Burke & James sought to educate consumers on the multiple reasons – and perceived value gained – from purchasing more expensive and higher quality lenses.

Although Taylor-Hobson was beginning to sell camera lenses to the film industry, their reputation for quality lenses grew the most in the field of cinema projection. In 1922, Taylor-Hobson also received a fête for their lens being chosen as the projector lens for the London premiere of D.W. Griffith's *Orphans of the Storm* (1921). The Taylor-Hobson lens apparently won after a competitive test, and a note in the *Exhibitors Trade Review* remarked on how the new lens gives "52% more light than others and saves 50% on current bills." [510] A July 1922 advertisement for Taylor-Hobson projection lenses forthcoming from Burke & James similarly promoted the lenses' greater efficiency – rather than the lack of distortion that was classically advertised in lens advertisements.[511]

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[508] See Burke & James 1908/9 catalog; 1911 catalog. Prior to the war, Burke & James had been the sole US distributor for Dallmeyer lenses as early as 1908, and they were the exclusive Midwest agent for Goerz lenses beginning in 1911, and they also sold a number of Voigtlander lenses as well. Burke & James had also begun to manufacture their own amateur cinematograph camera, the Universal, in 1918, and advertised many of their lenses for this camera.

[509] "Introduction," *Taylor-Hobson Cooke Anastigmats*, Catalog, (Taylor-Hobson, 1922), 2.

[510] "New Accessories on the Market: Scraper and Patcher Appears; An English Lens Reported; Going Well and New Film," *Exhibitors Trade Review* 13, no. 1 (Dec 2, 1922): 52.

[511] "Expect Shipment of Taylor-Hobson Lens," *Exhibitors Herald,* July 1, 1922, 68.

Taylor-Hobson was not alone in the effort to sell the motion picture industry on improved projection quality: in the field of motion picture projection, they faced stiff competition from Bausch & Lomb. Bausch & Lomb, similarly mobilizing their wartime contributions to peacetime markets, released the Cinephor projection lens in 1921. In an advertisement in *Moving Picture World*, Bausch & Lomb proclaimed:

> [B]etter illumination alone did not satisfy the Scientific Staff of the Bausch & Lomb Optical Co. They were not content until they had devised a lens possessing as well *all* the elements necessary to real projection improvement – a *flatter field, sharper definition* to the very corners of the picture and *stronger contrasts* between light and shadow; a lens that will give the quality pictures expected by patrons of a quality house.[512]

Like Taylor-Hobson, Bausch & Lomb used advertisements to educate consumers on the criteria of what constituted a quality lens. The advertisement claimed that a greater aperture in the lens was not enough, and also emphasized that the lens quality was, on the judgment of "unbiased experts," "*uniformly reliable* in quality." By 1925, advertisements shifted to promote a "Cinephor Projection System" that promoted an increase in illumination with without additional expense, and depending on the type of light and operating conditions, "Illumination can be increased up to 25 percent."[513] In comparison to the discourse surrounding anastigmats, which emphasized the importance of faithfully reproducing an image, discussions of lens quality became predicated on discussions of efficiency, percentages, and systems: language that spoke to the manufacture, rather than capture, of visual reality.

It is unclear to what extent the Cinephor was used in theaters in comparison to Taylor-Hobson Cinema Projection Lenses. Both companies promoted their extensive use in the film industries. Regardless, both Bausch & Lomb and Taylor-Hobson mobilized a desire for quality

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[512] "Announcing – Bausch & Lomb Cinephor," *Moving Picture World,* August 27, 1921, 939.
[513] "Bausch & Lomb Cinephor Projection System," *Better Theaters Section of Exhibitors Herald,* November 7, 1925, 44.

Figure 22 Cinephor Ads 1921 and 1925.

in the motion picture industry that was based on the potential quality and profit values of a systemic approach to film technologies. By 1924, Taylor-Hobson had begun to establish a reputation as a lens company that could deliver not only technical standardization, but also the technical quality that so many film technology companies sought to cultivate.

While Taylor-Hobson was frequently discussed in British trade press such as *The Cinema News and Property Gazette* and *Kinematograph Weekly*, Taylor-Hobson was infrequently discussed in regular Hollywood trade press prior to 1925. One way that Taylor-Hobson became discussed and used by Hollywood was through professional trade societies, which were significantly preoccupied with improving projection quality from 1920 to 1924. Much like the Society of Glass, throughout the early 1920s, many SMPE papers became dedicated to improving projection and screen illumination. In addition to articles such as "Reflection Characteristics of Projection Screens" and "Absorption and Reflection Losses in Motion Picture

Objectives," in 1920 the Society convened committees to consider creating a correspondence course for educating projectionists and to test the effect of color in projection. In these papers, factors like interior illumination, the elimination of excessively bright surfaces, and proper screen brightness were suggested for consideration by the motion picture engineer "in order that the maximum of visual comfort may be obtained."[514] In L.C. Porter's 1922 President's Address, he identified projection lenses as a key problem for the SMPE:

> Many of us know that there is a difference in definition, or sharpness of picture projected with various lenses, yet no one knows how to measure it in exact terms, so that one lens may be compared with any other lens in quantitative units…At present only about five percent of the light generated for motion picture projection ultimately reaches the screen. What an enormously inefficient thing a projector is![515]

These sentiments were echoed by a number of other papers discussed by the SMPE in the early 1920s. A 1922 article by F.H. Richardson, "Projection and Its Importance to the Industry," observed that while a number of exhibitors were making good business on the basis of proper projection, "progressive exhibitors and theatre managers of this type are still very greatly in the minority."[516] Richardson connected the importance of projection not just to theatre managers, but studio production more broadly. Poor projection, in this respect, affected the reputation and quality of the director, the producer, and the actor. Richardson's paper positioned engineering and technology as a way to improve the quality and value of the motion picture industry not as a series of discrete and separate professional practices, but as an integrated and efficient system.

The optical engineers' embrace of cinema as an integrated system of production mirrored a shift that was also occurring in the field of cinematography. In January of 1925, *American*

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[514] Lloyd A. Jones and Milton F. Fillius, "Reflection Characteristics of Projection Screens," *Transactions of the Society of Motion Picture Engineers* 4, no. 11 (1920): 59-73.
[515] L.C. Porter, "Presidents Address," *Transactions of the Society of Motion Picture Engineers* 14 (May 1-4, 1922).
[516] F.H. Richardson, "Projection and Its Importance to the Industry," *Transactions of the Society of Motion Picture Engineers* 14 (1922): 55.

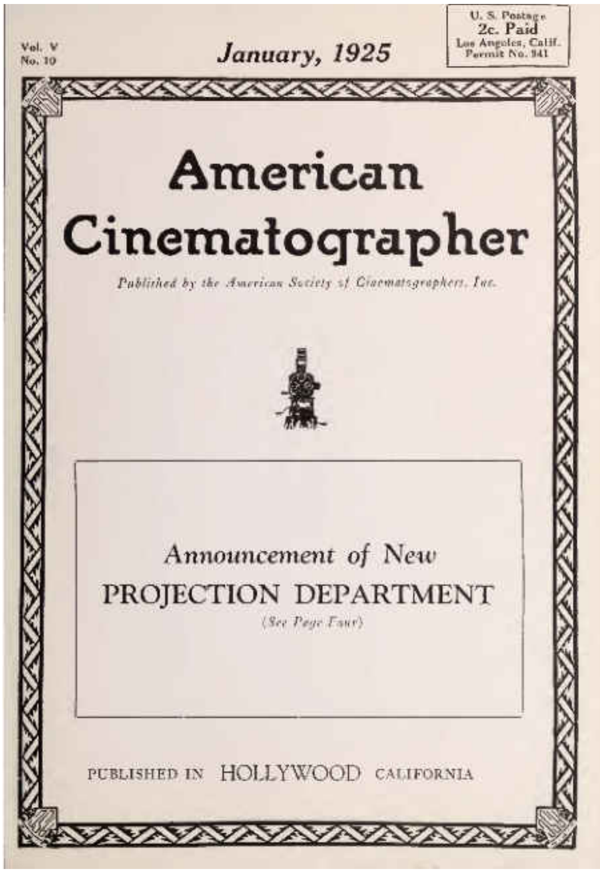

Figure 23 Cover of the January 1925 American Cinematographer.

Cinematographer announced that it would be regularly including a section on Projection in each of their issues. The creation of the Projection department was significant enough to merit a cover announcement. The goal of this new regular section was to bring about "the perfect screen presentation" by virtue of creating "the closest possible relationship" between the projectionist and the cinematographer.[517] *American Cinematographer* was not the first dedicated and regular publication about projection. Notable antecedents included James R. Cameron's *Motion Picture Projection* (1919), and F.H. Richardson's extensive columns in *Moving Picture World*. But, *American Cinematographer*'s Projection Department did precede a number of other dedicated projection journals like *The Motion Picture Projectionist* (1927), *Projection Engineering* (1929), and *International Projectionist* (1931). *American Cinematographer*'s decision to establish a Projection section in what was classically a journal for cinematographers placed motion picture production quality in an explicit conversation with motion picture distribution quality – an alignment significantly motivated by the vertical integration of the studios during this time.[518]

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[517] "American Cinematographer to Have Projection Department as Regular Part of Each Issue," *American Cinematographer* 5, no. 10 (January 1925): 4.

[518] Interestingly, right after the article about the new projection department was a small announcement about a new Bell & Howell camera that had gained the attention of ASC.

In this respect, the appointment of Earl J. Denison as Projection department section editor – and the extensive biographic review of his professional qualifications in the January 1925 announcement – was a decisively political choice. Denison, in addition to being an active member of the Society of Motion Picture Engineers, was also a longstanding motion picture engineer for the Famous Players-Lasky.[519] The article commemorating his appointment emphasized his long history in the testing and inspection of cinema projection technologies, noting that in his six years of work for Players-Lasky he had "invented and perfected a number of devices now in use by the Paramount organization in connection with inspection, splicing and projection of film."[520] The promotion of Denison and the Projection department highlighted the extreme importance of bringing together cinematographers and projectionists in service of establishing consistent quality for the studios.

As of 1925, aligning the quality of picture taking and picture projection had become paramount for the Players-Lasky. The Famous Players-Lasky was formed in 1916 as a merger of Adolph Zukor's Famous Players Film Company, the Jesse L. Lasky Feature Play Company, and the Paramount Pictures Corporation – which distributed Lasky and Famous Players films. Players-Lasky's investment in stars such as Mary Pickford, Rudolph Valentino, and Gloria Swanson led to escalating productions costs, but high-investment pictures appeared to be one of

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[519] In April 1925, AC published a scathing editorial and reprint of a column by F.H. Richardson, a regular contributor to the Moving Picture World, which had been originally submitted to AC in 1922. In Richardson's column, titled "Another Moses," Richardson castigates AC for cinematographers "discovering" the importance of projection. In addition to a number of editors note – one of which promised a yearly subscription to the Moving Picture World for any subscriber who could interpret the scrawled postscript on Richardson's January 1920 letter to AC – was a vicious takedown of Richardson's contention that AC had ignored and rarely encouraged projection in its five years of publication. The published battle suggested tensions between the institutionalization of projection discourse by a studio engineer such as Denison and a practitioner like Richardson. F.H. Richardson, "Another Moses," *American Cinematographer* (April 1925): 8-10, 15.

[520] "American Cinematographer to Have Projection Department as Regular Part of Each Issue," 4, 17-18.

the few reliable markers of financial success in the early 1920s. As Benjamin B. Hampton writes:

> Bigness–elaborateness–sumptuousness–lavishness–these seemed to constitute the elusive "quality" the public wanted. "Bigger and better" seemed to be the infallible recipe for success. These words were repeated so often in newspapers, trade journals, and fan magazines in 1922, that "bigger and better pictures" became the slogan of the studios.[521]

Illustrative of a broader tendency to sell "bigger and better pictures," Players-Lasky's coordination of production and exhibition was carried out under the corporate goal of "better motion pictures, better theaters, better business, and of continued growth and expansion of the entire industry."[522] To create higher quality pictures across production and distribution, in 1925, Famous Players-Lasky engaged in an alliance with the Balaban & Katz theater chain. The alliance meant that Balaban & Katz gained access to "the top Hollywood feature films" and the Famous Players-Lasky had dramatically expanded the extent of their vertically integrated studio model.[523] The alliance also spoke to the ever-increasing vertical integration that the Famous Players-Lasky, soon to be named Paramount, was enacting in film production. The concentration of theater control proceeded rapidly, and by 1924, "nearly all of the first-run houses in the United States and Canada had been acquired by Paramount, Loew's, Inc., the Stanley Company, and large circuits affiliated with the Zukor, Loew, Mastbaum and First National groups."[524] While the Players-Lasky emphasized the centrality of quality storytelling, the quality narrative product that it promoted was built on standardization, vertical integration, and the centralized creative control of the motion picture production process from conception to distribution.

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[521] Benjamin B. Hampton, *History of the American Film Industry from its Beginnings to 1931* (New York: Dover Publications, 1970): 305-306.
[522] *The Story of the Famous Players-Lasky Corporation*, 6.
[523] Gomery, *Shared Pleasures,* 43.
[524] Hampton, *History of the American Film Industry…,* 317.

The standardization of motion picture equipment, which included lenses, was an important part of this industrial push for 'quality' cinema. Taylor-Hobson's coordination of optical quality across taking and projection lent itself well to the Players-Lasky's efforts to harmonize technical quality across multiple stages of production. Between 1924 and 1926, Taylor-Hobson became very closely aligned with two of Hollywood's most central players: the Famous Players-Lasky and Bell & Howell. Frank E. Garbutt, a director of photography for Players-Lasky, wrote to Taylor-Hobson in 1926 to confirm that "Over 100 Cooke lenses of various focal lengths are used by the photographic department of Famous Players-Lasky Studios."[525] Garbutt was a special technical advisor to the Players-Lasky's new west coast film lab in 1922.[526] The use of Cooke lenses on a number of Bell & Howell professional cameras positioned Cooke lenses at the intersection of ongoing efforts to promote technological standardization in perhaps the largest vertically integrated studio of the time.

By 1925, Taylor-Hobson had firmly established itself as a lens maker that could cater specifically to the technical and quality requirements of the film industry. As suggested by *The Cinema News and Property Gazette* in the summer of 1925:

> Whether it be in connection with their now famous wide aperture and other high-grade cine-projector lenses, or with their equally fine cine-camera lenses, the name of Taylor-Hobson is becoming daily more closely associated with the picture-making and showing industry of this country.[527]

From their growing reputation in projection systems, Taylor-Hobson caught the eye of another technology company: Bell & Howell. It is through Cooke's industrial relationship to Bell &

[525] Darby, "A Tale of Technical Excellence and Endurance," 34.
[526] "World's Largest Private Film Laboratory Planned," *Paramount Pep* 6, no. 31 (February 6, 1922): 11.
[527] "About Lenses: Wonderful Oxford University Expedition Film," *Supplement to The Cinema News and Property Gazette*, June 25, 1925, 5.

Howell that Cooke lenses became most explicitly linked to the cinema in both the professional and the popular imagination.

Quality Lenses for Quality Cameras: Bell & Howell, Filmo, Eyemo, and Pioneer Cameras

Unsurprisingly, one reason that Cooke lenses became so closely associated with cinema production was due to their use on a wide number of Hollywood films. Indeed, the use of Cooke lenses in studio production was touted both by Cooke's own advertisements and by popular commentary around the company. As suggested in 1926 by "The Observation Window" of *Kinematograph Weekly*:

> It deserves to be better realized in the photographic world to what extent Taylor-Hobson lenses have come into favour in the sound-film and silent-film studios in England and in Hollywood. The Cooke lenses of very large aperture have been establishing themselves increasingly in film production for several years past…Frequenters of the movies may reckon therefore that most of the pictures which they see are both produced and projected by means of lenses made in the Leicester factories of Messrs. Taylor, Taylor of Hobson, Ltd., where so many photographic objectives have been originated and made.[528]

How and why Cooke lenses came to be used so regularly in cinema productions, though, was more complex than a simple question of objective technical quality. Rather, the reputation and perceived prestige quality of Cooke lenses – a reputation based strongly on their work on projection in the early 1920s – was a useful tool for camera manufacturers att empting to capture and create professional and amateur markets for motion picture equipment.

One of the primary reasons that Cooke lenses became so closely branded as "cinema lenses" was due to Bell & Howell's investment in the amateur film and photography market.[529]

[528] "The Observation Window," *Supplement to Kinematograph Weekly*, September 9, 1926, 71.
[529] It's difficult to know to what extent Bell & Howell and Cooke were affiliated – according to Patricia Zimmerman, the warehouse of Bell & Howell archives disappeared from Skokie, Illinois, in the 1980s. However, given that Bell & Howell took control of Taylor, Taylor & Hobson in 1930 until they sold TTH to Rank Organization – a British entertainment conglomerate – in 1946, there is strong evidence to suggest that Cooke lenses were an important part of Bell & Howell's technological environment.

Figure 24 An advertisement featuring Bell & Howell's three flagship cameras, the Filmo, the Eyemo, and the Professional Standard. McKay. Handbook of Motion Picture Photography 1927.

As the amateur market for lenses and cameras grew extensively during the 1920s, Bell and Howell mobilized the culture capital of Cooke lenses to sell amateur and semi-professional camera equipment.[530] As Marzola writes, "the amateur would use Bell & Howell cameras with Cooke lenses if the Hollywood cinematographer did."[531] Much like how the term "anastigmat" was first used to describe Zeiss' 1890 Anastigmat lens but was later used to sell lenses of dubious quality, the term cinema lens described a specific series of lenses manufactured for studio practice but also came to be used in a commercial effort to sell more mid-range equipment. In branding Cooke lenses as cinema lenses, Bell & Howell both differentiated their own studio-specific offerings while simultaneously using Cooke's prestige to better leverage the sale of motion picture equipment to amateur consumers.

In 1924, when Bell & Howell entered into a closer business arrangement with Cooke, Bell & Howell had dire need for the kind of technical quality that Cooke was known for. Bell and Howell had overtaken Pathé Professionals as the standard studio camera and, by 1920,

[530] Marzola, *Engineering Hollywood,* 140-141.
[531] Marzola, *Engineering Hollywood,* 140-141.

studios were almost "100% Bell and Howell equipped."[532] However, during the early 1920s, the Mitchell camera company increasingly challenged Bell & Howell for control over the motion picture camera supply. As Marzola writes, while Bell & Howell claimed that 95% of American feature films were shot on their cameras in 1922, between 1922 and 1925, Bell & Howell had begun to experience stiff competition from Mitchell.[533] Mitchells and Bell & Howell cameras remained the two standard studio cameras through the late silent period. However, by 1925, Bell & Howell were beginning to lose their prominent place in motion picture camera supply. Bell & Howell sought to differentiate itself as a technologically progressive company by drawing on Cooke's reputation as a high-end optical manufacturer.

Cooke lenses were advertised in conjunction with Bell & Howell as early as 1924 as part of a portable motion picture camera and companion projector. The portable camera, advertised with the note that "Bell and Howell creations give attention to professional and amateur alike," came with a Cooke 25mm F/3.5 anastigmat.[534] In a 1927 advertisement for the Filmo, Bell & Howell explained that the Cooke lens was the primary incentive for consumers to buy a more expensive Filmo camera. The advertisement, beginning with the header "Why it pays to pay more for this camera," immediately extols that the Filmo is "regularly equipped with a highest quality anastigmat, Taylor-Hobson Cooke, 25 m/m F 3.5 aperture lens. No lower-priced movie camera affords such a lens."[535] Inviting consumers to make edits, transitions, cartoons, and effects "familiar to you on the theatre screen," Bell & Howell sought to combine the allure of high-quality motion pictures with the perceived "future years of satisfaction" provided by a more

[532] Bordwell, Staiger, and Thompson, *The Classical Hollywood Cinema,* 268.
[533] Marzola, *Engineering Hollywood,* 130-136.
[534] "New Pair of Cinemachines," *American Cinematographer* (January 1924): 16.
[535] "Why it pays to pay more for this Camera," *Amateur Movie Makers* (February 1927): 42.

Figure 25 "Why it pays to pay more for this Camera." Amateur Movie Makers. February 1927. 42.

expensive lens.[536] The practice of connecting expensive technology to consumer quality to consumers would continue on throughout the late 1920s. For example, in a February 1927 advertisement in *Amateur Movie Makers*, Bell & Howell placed a two page advertisement with the heading "All the tricks used in Professional Movies Are made available to you through Bell & Howell equipment and accessories."[537] Bell & Howell used the glamour of Cooke and Hollywood to sell consumers on the value of a higher priced camera.

Bell & Howell's explicit emphasis on the Filmo's Cooke lenses was likely a commercial response to one of the notable postwar entries into the amateur motion picture camera market, the ICA Kinamo camera. ICA (Internationale Camera Aktiengesellschaft) was a subsidiary division of Zeiss that was created in 1909 for the consolidation of its camera manufacturing operations.[538] In 1921, ICA began marketing the Kinamo, a compact 35mm movie camera designed for handheld filming. Emanuel Goldberg, the designer of the camera, had originally been hired by Zeiss in the midst of World War I to develop military products. Following the war,

[536] Ibid. 42.
[537] "All the tricks used in Professional Movies Are made available to you through Bell & Howell equipment and accessories," *Amateur Movie Makers* (February 1927): 36-37.
[538] Michael Buckland, "The Kinamo Movie Camera, Emanuel Goldberg and Joris Ivens" *Film History* 20, no. 1 (2008): 49-51.

Goldberg shifted from working on military applications to small cameras.[539] The Kinamo N25, which was advertised from January 1924 to April 1924 in *American Cinematographer*, was described as a "semi-professional motion picture or cine camera" and was advertised as including "the Carl Zeiss Tessar f 3.5, the lens with which the best feature films have been made."[540] In an effort to increase Kinamo sales, short movies advertising the uses of the camera were also packaged with the Zeiss Ikon logo around 1926.[541] The inclusion of a Zeiss lens, and an emphasis on the connection between the lens and professional film productions, was a way for ICA to increase the perceived prestige and quality of the amateur camera. As Bell & Howell began to enter the amateur market, the Kinamo illustrated the potential that lens brands held for selling the perceived quality of amateur cameras.

In addition to the Filmo, Bell & Howell's diversified its camera options with the Eyemo camera. The Eyemo was released in 1925, around the same time that Bell & Howell began to advertise itself as the United States distributor of Cooke lenses. According to "A Cooke Look Back," "Every Eyemo camera was supplied with Cooke lenses made in Leicester, England. Bell & Howell wanted high-end, quality lenses at a reasonable cost and Taylor-Hobson became Bell & Howell's main supplier."[542] Similar to the Filmo, the Eyemo was marketed for semi-professional use. Designed as a handheld camera, the Eyemo was used extensively for newsreel footage, stunts, special effects shots, and rapid footage. Many Eyemo advertisements included

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[539] Ibid. 49-51. Goldberg's initial model was the Kinamo N25. A spring motor version was marketed in 1924, and in 1925 the N25 was modified and renamed the Universal Kinamo.
[540] "Ica Kinamo," *American Cinematographer* (January 1924): 23.
[541] Buckland, "The Kinamo Movie Camera," 53.
[542] Barbara Lowry, "A Cooke Look Back: Timeline of Cooke Cine Lens History," *Film and Digital Times* (January 2013): 5.

images of or comparisons to the Pioneer Professional Standard, further linking the Eyemo to Bell & Howell's professional reputation in studio production.[543]

Cooke's prestige was also used by equipment vendors to sell higher quality lenses to still photographers. On a commercial level, cinema's aura was used to upsell photographers on higher priced equipment. However, these lenses also served as a site of connection between photographers and the cinema. After Joseph DuBray visited the 1928 meeting of the Photographers Association of America as a representative of the ASC, he reflected that:

> All of the photographers told me that they were following very closely the results that the cinematographers are obtaining for the screen….I carried the investigation further, and learned that the photographer is not selling any larger number of pictures by asking the client to choose the style desired from an album; the client himself specifies this style referring to some motion picture that has apparently struck his fancy.[544]

Photographers were increasingly drawing on the cinema for aesthetic inspiration. As Karl Struss, cinematographer for Murnau's *Sunrise: A Song of Two Humans* (1927), similarly suggested in "Photographic Modernism and the Cinematographer," the tendency of 1920s photography to suggest motion in static compositions "in truth had its inspiration in the achievements of the silent cinema." [545] Struss observed that there were few examples of modernist or surrealist photography prior to the release of German or Russian silent films, notably *The Cabinet of Dr. Caligari* (1920), *Variety* (1925), and the Soviet films of Eisenstein and Tisse.[546] Somewhat cynically, Struss suggested that "More than a few of the modernists owe their success not so much to the understanding or application of pure photographic artistry as to an unusual knack of

[543] "The Greatest Producers use Bell & Howell Cameras," *Motion Picture News*, September 2, 1927, 650. "Bell & Howell Cameras," *American Cinematographer* (September 1926): 14-15. "A Friendly Sort of Camera!" *American Cinematographer* (February 1927) 14.
[544] Joseph A. DuBray, "Large Aperture Lenses in Cinematography," *Transactions of S.M.P.E.* 12, no. 33 (1928): 211.
[545] Karl Struss, "Photographic Modernism and the Cinematographer," *American Cinematographer* (November 1934): 297.
[546] Ibid. 297.

'freezing' motion with a speed camera" – speed cameras that used the same kinds of high speed lenses used for cinematography.[547] Cooke's fast lenses helped create the rapid, handheld, and accessible camerawork of the 1920s. But, the movement of equipment from studios to amateur markets should be seen as more complex than a technologically-driven change imposed by technology companies. The prestige associated with quality lenses, like Cooke, served as a site of access and identification for amateur practitioners to connect their photographic practices to those of the Hollywood studio.

Cooke's reputation served the particular kind of consumer that Bell & Howell sought to attract with the Filmo and Eyemo cameras: the semi-professional. As Bell & Howell engineer Joseph DuBray suggested in 1929, motion picture use was not solely divided between amateur and studio practice:

> [C]an we really call amateurs the number of researchers who today have recourse to motion picture photography as an aid to their investigation? The doctor who records in motion pictures the action of living organisms or the performance of operations? The industrialist who applies motion pictures to the precise recording of the functioning of the machines or products he manufactures, the educator who, more and more, realizes the great possibilities of motion pictures as a mighty collaborator?[548]

Doctors, industrialists, educators: this set of modern motion picture practitioners, which DuBray defined as the "semi-professional," desired more than just the ability to make "simple pictures" or to "rely solely on the interest they awaken just because they 'move' on the screen."[549] DuBray linked Bell & Howell's cameras to an imagined desire on the part of consumers to add "beauty to the picture, to express his artistic sentiments in them, to rival the cinematographic results that he

[547] Ibid. 297. As an established Hollywood cinematographer, Struss had some vested interest in claiming that photography was following from the work of cinema. However, his background as a still photographer suggests that Struss would have seen the two fields as interconnected rather than necessarily antagonistic.
[548] Joseph A. DuBray, "The Camera Intelligent," *American Cinematographer* (August 1929): 31.
[549] Ibid. 31-32.

daily sees on the thousands of theatre screens all over the country."[550] Given that George Eastman allegedly told William Taylor in the 1930s that "90% of the 16mm film used in America passed behind lenses made in Leicester," Cooke's reputation helped foster a strong imagined connection between semi-professional movie makers, quality, and studio practice.[551]

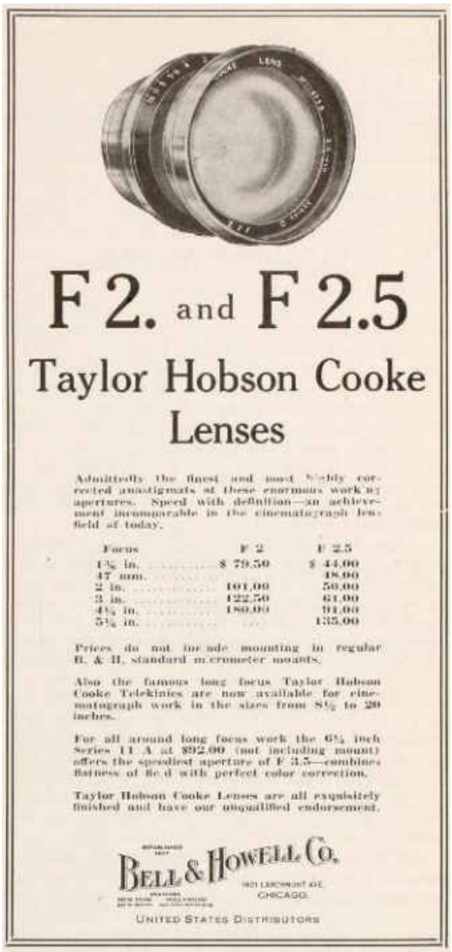

Figure 26 Bell & Howell begins advertising Cooke Lenses in 1925. American Cinematographer. August 1925. 17.

While Cooke's lenses may have begun as a way for Bell & Howell to convince consumers to buy more expensive cameras, the maintenance of this idea relied on Cooke lenses being used by professionals. As early as 1925, the same year that Bell & Howell was beginning to distribute its Filmo and Eyemo cameras, Bell & Howell succeeded Burke & James as the primary distributors for Cooke lenses in the United States.[552] In an August 1925 issue of *American Cinematographer*, Bell and Howell announced that it distributed "a complete line of Taylor Hobson Cooke lenses, including the F 2 and the F 2.5" and that Bell and Howell was the United States distributor for the Taylor-Hobson Cooke lenses.[553] Bell & Howell began to specifically advertise their sale of Cooke lenses with dedicated advertisements about their fast F/2 and F/2.5 lenses, which were used by studios. Given that Bell & Howell was increasingly branding its Pioneer Professional

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550 Ibid.. 31-32.
551 Darby, "A Tale of Technical Excellence and Endurance," 32-35.
552 "Bell and Howell Distributors for Taylor Hobson Cooke Lenses," *American Cinematographer* (August 1925): 25.
553 "Bell *and* Howell Distributors *for* Taylor Hobson Cooke Lenses," 25.

Standard cameras as the camera that "never grows obsolete no matter how old," Bell & Howell's sale of Cooke lenses enabled them to maintain a commercial relationship with camera owners long after they had purchased their camera.[554]

Through their association with Bell & Howell in the late 1920s, Cooke lenses became consistently associated with cinematic production, particularly in their use on Players-Lasky/Universal Pictures. In 1926, *Kinematograph Weekly* reported that over a hundred Cooke lenses were in use by the photographic department of the Famous Players-Lasky studios. In 1928, *The Kinematograph Year Book* reported that Paramount had standardized the use of Cooke's F/2 lenses on all of their cinema cameras.[555] Cooke lenses may have been advertised for their use on a number of motion picture cameras, but it is useful to remember that lenses were also interchangeable. Simply because a camera came equipped with a Cooke did not necessarily mean that cinematographers would use that lens, or use it for very long. Zeiss, Goerz, Voigtlander, and Astro lenses were widely in use during the 1920s. However, regardless of whether cinematographers used Cooke lenses, the clear attachment of Cooke lenses to Players-Lasky productions offered Taylor-Hobson a somewhat reliable business agreement with one of the more prolific studios of the era.

Quality Control: Fast Glass and Studio Practice

Cinematographers increasingly used large aperture lenses, or fast glass, through the 1920s. The desire for faster lenses in and of itself was not new. Since the 19th century, lens designers had been preoccupied with finding the optimal balance between high speed and low

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[554] See, for example, "Bell & Howell Cameras," *American Cinematographer* (September 1926): 14; "A Friendly Sort of Camera!" *American Cinematographer* (February 1927): 14.
[555] "Lenses," 300.

distortion. An effectively corrected lens often resulted in less light; greater light usually meant a decrease in the sharpness and clarity of the lens. What was new, though, was that beginning in the 1920s, there was a significant increase in what speeds were functional and viable in motion picture practice. Lenses that could work at f/1.9 and f/2, approximately four times faster than the typical speed of 3.5, enabled a significant increase in the amount of light available for motion picture capture. The speed in and of itself was not significant; as early as 1913, C.C. Minor was granted a patent for an f/.5 lens.[556] What was significant about the fast glass of the 1920s was that these lens could let in those levels of light while also exposing a 35mm field at a level of clarity and definition that was satisfactory and legible for studio production. Cinema lenses needed to be more than just technically fast: lenses needed to be practically functional on set.

There were many fast lenses produced for motion picture work from 1920 to 1925, such as the Minor f/1.7 (1920), the Dallmeyer F/1.9 (1920), the Gundlach-Manhattan f/1.9 Ultrastigmat (1922), the Bausch & Lomb Ultra f/2.7 Rapid Anastigmat (1922), the F/2 Kino Plasmat (1924), and the Astro Berlin f/2.3 Pan Tachar (1925). Many of these lenses were postwar refinements of existing lens designs. According to W.B. Rayton, optical designer at Bausch & Lomb, simply increasing the diameter of a lens did not result in a faster lens. But, some of the "old standard types of lenses" were found to "possess capabilities of expansion in speed in the short focal lengths employed in motion picture work."[557] Although fast lenses were frequently discussed in terms of technical merit, lenses were not adopted solely by the film industry on the basis of objective technical superiority or by virtue of the fastest lens. Rather, lenses were adopted on a wide range of criteria ranging from personal preference to distributor location to the latest wave of technical vogue. While Bordwell, Staiger, and Thompson suggest

[556] Rayton, "Optical Science in Cinematography Bibliography," 49.
[557] Rayton, "Optical Science in Cinematography Bibliography," 50.

that "We should not directly compare the aperture settings of the ultraspeed and soft-focus lenses of the twenties with the regular lenses in use at the time," the trade press often did.[558] As Karl Brown proclaimed in his 1922 article, "Super-speed Lenses," "The super-speed lenses are certainly equal in every way to the slower lenses, and there seems to be no reason why they should not become the standard, every-day utility lens."[559] This did not mean that cinematographers were necessarily using the lens at its widest aperture. Rather, these fast lenses presented the cinematographer with more control over a wider range of available light.

In addition to meeting professional expectations of fidelity, fast lenses provided another important affordance for practitioners working in the studio system: flexibility. Speed was perhaps the greatest quality of a lens for cinematographic flexibility. As Joseph A. DuBray wrote in 1930, "For Cinematographic Lenses, it may be stated that the ultimate goal of the optician is to minimize the effects of the various aberrations which are inherent with the physical properties of glass and at the same time reach the maximum possible luminosity or speed."[560] Correction of aberrations was a familiar expectation for lens design, but the emphasis on speed was driven by how studios framed light as a resource that needed to be effectively managed. Although cinema lenses were still often anastigmatic, the name shift from Zeiss Anastigmat to brand names like the Kino Hypar and Cooke Speed Panchro increasingly described motion picture lenses that were designed on the basis of cinema's industrial requirements. To design a cinema lens in the 1920s was to design a lens for increasingly manufactured and studio-specific lighting environments. In these artificial environments, light was a resource to be efficiently managed rather than objectively captured or recorded.

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[558] Bordwell, Staiger, and Thompson, *The Classical Hollywood Cinema,* 289.
[559] Karl Brown, "Super-speed Lenses," *American Cinematographer* (August 1922): 20.
[560] Joseph A. DuBray, "Color Correction in the 'Cooke,' 'Speed Panchro,' and 'Panchro' Lenses," *American Cinematographer* (November 1930): 10.

The Taylor-Hobson f/2 lenses, in particular, gained significant popularity in cinematography in the mid-1920s.[561] *Motion Picture News* reported on the use of Taylor-Hobson Series IIa lenses for motion picture photography as early as 1916, but higher praise was reserved for the lenses of Voigtlander, Goerz, Dallmeyer, Bausch & Lomb, and Zeiss.[562] The IIa was the primary lens for cinema use that Cooke produced prior to the war. Although it's less clear what motion picture lenses Cooke sold in the early 1920s, in a 1919 patent notice for the Opic in *The British Journal of Photography*, Taylor-Hobson described the optical glass construction for the Opic with specific reference to the optical glass supplied from the catalogues of Parra-Mantois and the Chance Brothers.[563] A 1935 article, "The Historical Background of the Speed Panchro Lens," suggests that Taylor-Hobson introduced an F/2 lens in 1920 as the "Kinic" lens.[564] A 1922 catalog explicitly lists a Series I f/3.1 lens "For Motion Picture Taking."[565] An earlier note in the 1921 *British Journal of Photography* suggests that Taylor-Hobson was manufacturing lenses with apertures as large as f/2.5, f/2, and f/1.9, but that manufacturing was "not sufficiently advanced for these ultra-fast objectives to be listed in detail."[566] While the early 1920s are murkier in regards to Cooke's dedicated camera lenses – and the extent to which they were used – the Cooke lens that gained a significant amount of use in the studios was the 1924 Series O F/2 lens.

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561 Rayton, "Optical Science in Cinematography Bibliography," 53.
562 "Picture Lenses are Ultra-Rapid Anastigmats," 2948.
563 "Improvements in Lenses. No 144,932. (September 22, 1919)," *The British Journal of Photography* 67, no. 3146 (August 20, 1920): 516-517; "F/2 Anastigmats with Improved Colour Correction," *The British Journal of Photography* Lxxvii, no. 3645 (March 14, 1930): 155. In the patent notice for the 1930 redesign of the F/2 lens, the Speed Panchro, the lens is described specifically in relationship to glass available from The Chance Brothers.
564 Mitchell, "Historical Background of the Speed Panchro Lens," 17.
565 Cooke 1922 Catalog, 9.
566 "News and Notes," *The British Journal of Photography* 68. (October 14, 1921): 617.

In 1924, H.W. Lee, from the Taylor-Hobson research department, gave a presentation to The Optical Society of Britain on "The Taylor-Hobson F/2 Anastigmat." In comparison to a decade earlier, where information about lens craft was closely restricted to private firms, the sharing and publication of this information made this information available to a much wider community of practice. Professional societies also functioned as a site for Taylor-Hobson to refine (and advertise) its investment in scientific design. Among Lee's suggested uses for the F/2 Anastigmat – which included its existing applications for low-light theatrical photography and its potential application in photographing meteors – was studio cinematography. As Lee wrote:

> In kinematography, the lens should be valuable, especially in the studio, permitting of photography with less intensely actinic light, which has been found so harmful to the actors' eyes. Fresh ground is being broken in other directions, though developments are not so far advanced as to permit of further reference at present.[567]

According to W. Taylor and H.W. Lee, while the large aperture lenses were initially rejected by practitioners, one of the primary reasons for the adoption of these fast lenses was "the recent development of fine-grain photographic emulsion for cinema film" that "stimulated a general demand for small cameras and lenses of proportionately short focal length, greater consequent depth of field, greater rapidity, and generally more critical definition."[568] As Cooke was about to enter into an agreement with Bell & Howell less than a year later, Lee's 1924 presentation to The Optical Society marked Taylor-Hobson's emphatic shift from focusing on projection lenses to focusing on camera lenses.

The industrial adoption of "fine-grain photographic emulsion" was one of the formative industrial shifts that defined the design and adoption of Cooke's flagship cinema lens, the Speed Panchro. In 1926, changes in motion picture stock supply promised potential problems across

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567 Lee, "The Taylor-Hobson F/2 Anastigmat," 246.
568 Taylor and Lee, "The Development of the Photographic Lens," 509.

exhibition and production. As Luci Marzola details in “Better Pictures Through Chemistry: DuPont and the Fight for the Hollywood Film Stock Market,” Eastman Kodak’s control over the supply of motion picture stock was challenged by the explosives company DuPont in the mid-1920s. Dupont, like Taylor-Hobson, had entered the motion picture market through a need to “create peacetime markets for its wartime facilities.”[569] Within a few short years – in no small part due to its corporate research structure – DuPont had begun to manufacture and distribute orthochromatic stock, and by the end of 1925, Dupont was manufacturing ortho negative in bulk. Orthochromatic stock was standard in the film industry, but as of 1926, Kodak began to promote and affordably supply panchromatic stock, which was faster and more sensitive to red light. While Kodak had created panchromatic stock as early as 1913, the company only began to make it functional and affordable in 1926 as a way to differentiate themselves from DuPont.[570] However, within a year, DuPont also began supplying panchromatic stock. Because panchromatic stock was more sensitive to the red spectrum of light, the wide adoption of panchro meant that studios needed to change their lighting systems from carbo arc lighting to incandescent lighting to better function with panchromatic stock.

The competition between Kodak and DuPont peaked with the 1928 Mazda tests. Over four months, tests comparing the use of Mazda incandescent lighting to carbon arc lighting were carried out on the Warner Bros. lot.[571] As Marzola writes, the 1928 Mazda tests were the first “great ‘scientific’ endeavor” of Hollywood.[572] While the Mazda tests were a benchmark demonstration for ongoing changes to lighting and stock, these changes also created both

[569] Luci Marzola, “Better Pictures Through Chemistry: DuPont and the Fight for the Hollywood Film Stock Market,” *The Velvet Light Trap* 76 (Fall 2015): 3.
[570] Marzola, “Better Pictures Through Chemistry,” 11-12.
[571] Ibid. 12.
[572] Ibid.. 12.

technical and aesthetic challenges for lens designers. As DuBray wrote, "the use of panchromatic film and corresponding use of light filters for the obtention of truer color renditions has proved a crucial test of the chromatic correction of cinematographic objectives of large aperture."[573] The adoption of panchromatic stock did not just create a challenge for lighting systems: it also generated a new set of problems for lens design.

The correction on existing lenses was slightly incompatible with the new studio stock and lighting setups. To correct lenses for distortion, lens designers had historically compromised on lens correction by focusing blue and yellow rays on a common point and getting the other rays, notably red, "as close as possible."[574] In studio standard arc lighting, the primary color was blue, and so lenses used for motion picture production could be designed to focus on the best lighting fit. Lenses could be imperfectly corrected for red light, but prior to incandescent lighting, this was not a significant problem in studio practice. However, since incandescent lights gave off "a preponderance of red and yellow light" and since panchromatic film was also very sensitive to red light, the impending shift to panchromatic stock required lens designers to change the chromatic correction in lenses to correct for the blue and red rays, rather than blue and yellow.[575]

Cooke engineers Taylor and Lee, reflecting on the history of the photographic lens in 1935, would cautiously conclude that "No lens is perfect. When we say that aberrations are corrected we mean not that they are reduced to zero but that they are confined within some postulated circle of confusion, and that itself is imperfectly defined."[576] The adoption of different lights and standard film stock shifted the "imperfectly defined" circle of confusion of what counted as reality in studio production. According to *The International Photographer*, many

573 DuBray, "Large Aperture Lenses in Cinematography," 208.
574 Mitchell, "Historical Background of the Speed Panchro Lens," 27.
575 Mitchell, "Historical Background of the Speed Panchro Lens," 27.
576 Taylor and Lee. "The Development of the Photographic Lens," 518.

cinematographers had to "scrap a lot of their old lenses to use the new type lenses corrected for the combination of panchromatic film and incandescent lighting."[577] The shift from orthochromatic stock to panchromatic stock revealed how situational optical correction was, and cinema lenses were increasingly corrected against these artificial environments as studio lighting departed from natural lighting.

Rather than thinking about the 1920s as motivated by one particular kind of technological shift, the technological environment was characterized by precarity and flux. The change from ortho to panchro stock was the first of a wave of changes to the film industry in the late 1920s. Studio engineers were beginning to look towards sound, color, and wide formats. Experimentations with sound recording techniques "reshuffled production practices several times between 1926 and 1932, as studios and sound experts tested new technologies and filming strategies."[578] Any technological change, in this respect, needed to address both immediate needs and potential future problems.

In a 1928 address to the SMPE, titled "Large Aperture Lenses in Cinematography," Joseph DuBray spoke strongly about how the long-term adoption of panchromatic stock would present new challenges for lens production. DuBray spoke as an editor of *American Cinematographer*, but he was also shortly to be hired as the director of Bell & Howell's motion picture camera division.[579] He began by noting that, between 1926 and 1928, designers and manufacturers of photographic objectives had attempted to address the industry's demand for objectives possessing "the largest possible aperture compatible with the degree of sharpness and

[577] Mitchell, "Historical Background of the Speed Panchro Lens," 16.
[578] Ronny Regev, *Working in Hollywood: How the Studio System Turned Creativity into Labor* (Chapel Hill: University of North Carolina Press, 2018.), 156.
[579] Marzola, *Engineering Hollywood,* 141.

depth of focus which are requisite for the obtention of pleasing photographic results."[580] According to DuBray, cinematographers desired fast glass for two reasons. First, these lenses allowed for the "economic feature" of using "less light energy in photographing interior scenes" and the possibility of working in "adverse outdoor conditions." Second, these lenses offered greater possibilities for "obtaining artistic photographic effects" through control over focus and the lighting of the subject.[581] DuBray suggested that, in the face of the impending shift to panchromatic stock, cinematographers would be faced with additional challenges to maintaining control over the desired focus of their image.

Changes in stock and creative control posed a threat to the predominant aesthetic style of the 1920s: soft-focus cinematography. While soft style had been used in a few films of the 1910s, such as *The Marriage of Molly O* (1916) and *Broken Blossoms* (1919), soft-focus cinematography replaced deep focus as the pre-eminent style of the studio system in the 1920s.[582] Soft style was not just shallow focus, but also low-contrast developing, gauzes, filters, soft-edged vignettes, smoke. Simply put, soft-style was not limited to lenses and was "Anything that could reduce contrast and create diffusion."[583] Because certain lenses were not well-corrected for panchromatic stock, they created an out of focus image. The softness of these images was not, however, intentional. Instead, the mis-match between older lenses and newer stocks had the effect of over-softening the image, and this over-softening ran the risk of diminishing the otherwise controlled use of soft focus cinematography during a period when studios were especially interested in shoring up both creative control and public perceptions of studio quality.

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[580] DuBray, "Large Aperture Lenses in Cinematography," 205.
[581] Ibid. 205.
[582] Bordwell, Staiger, and Thompson, *The Classical Hollywood Cinema,* 288.
[583] Ibid. 287-288.

For most of the silent period, the main cinematographic style emphasized sharp focus and depth of field.[584] The film industry's aesthetic emphasis on clarity and definition largely paralleled the precision optical growth encouraged by the wartime boom. However, in the 1920s, cinematography no longer emphasized sharp focus and depth of field as the criteria of effective practice. As Karl Brown writes in his "Modern Lenses" series, the ideal of perfect definition held force "until it dawned upon the photographic world that art was not necessarily a matter of optical perfect definition…that it might be possible to make a good picture without this cherished precision."[585] The idea that cinematography was more than just an objective process of capturing the world, and could be one of visual management, was the result of a number of different influences – not, as Brown suggests, a dawning epiphany that struck cinematographers with the light of inspiration. As Keating argues in *Cinematography*, three processes helped set the field of cinematography as a professional practice in the 1920s: narrative integration, industrialization, and aestheticization.[586] Through a combination of these processes, the professional role of cinematographer began to become defined as one of artistry rather than as a technical role of the cameraman. The electrification of lighting, in Keating's history, is the most "large-scale technical change impacting silent-period cinematography."[587] The industrialization of motion picture production affected both the responsibilities of the cinematographer, but also the production process in which cinematographers came to participate. An increasingly industrial practice required the technical coordination of camerawork with a number of other technical practices.

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[584] Ibid. 287.
[585] Brown, "The Anastigmat," 4.
[586] Patrick Keating, *Cinematography: A Modern History of Filmmaking* (New Brunswick: Rutgers, 2014), 8.
[587] Ibid. 17-20.

In his 1928 address to the SMPE, DuBray strongly advocated for the centrality of the lens in soft-focus cinematography. While DuBray acknowledged that gauze and diffusing disks could be used to soften an image, since film production took place over an extended period of time, soft-focus lenses were more reliable and would produce a more consistent level of quality across the picture. DuBray suggested that the softness ought to be "*uniformly distributed over the field of the picture* [orig. emphasis]" and that "it should be of such a nature that it would be *felt* more than actually seen [orig. emphasis]."[588] DuBray's advocacy of large aperture lenses was, on the surface, not based on aesthetic considerations. He repeatedly emphasized the importance of efficiency, control, and the consistent value that large aperture lenses provided for studio production over a period of time. However, DuBray's emphasis on the subjective experience – of spectators *feeling* rather than *seeing* the quality of the lens – was a fascinating departure from the technical and scientific language that predominated his address to the SMPE.

"*[F]elt* more than actually seen" was a phrase that prefigured the combination of science and artistry that Cooke used to characterize their creation of the Speed Panchro. According to DuBray, "the exigencies of talking pictures and the definite adoption by the Motion Picture Industry of Panchromatic Films" resulted in Arthur Warmisham, Optical Director of Taylor-Hobson, carrying out an extensive survey of production in Hollywood, New York, and Europe.[589] From this research came the Speed Panchro lenses, which were designed for "photographing with filtered or unfiltered daylight or with arc or incandescent lights as well."[590] The extra light available with these lenses was also useful for sound filmmaking, which required 1) quieter but less powerful incandescent lights and 2) a faster frame rate when rates were

[588] DuBray, "Large Aperture Lenses in Cinematography," 206.
[589] DuBray, "Color Correction in the 'Cooke,' 'Speed Panchro,' and 'Panchro' Lenses," 10.
[590] Ibid. 23.

standardized to twenty-four frames per second for sound recording. As studio production became the dominant system of filmmaking during the 1920s, standardization – the correction of lenses to the artificial, rather than the natural, world – became increasingly central to coordinating the multiple technologies and technical roles involved in industrial film production. Lenses could vary, but they needed to vary in relationship to the central object of the motion-picture industry: celluloid film. This was clear on the November 1930 advertisement for the Speed Panchros, which were advertised for their use on both orthochromatic and panchromatic film.

Bell & Howell's 1930s lens advertisements illustrated that the relationship between craft, mass production, and manufacturing had dramatically changed from the artisan days of lens production. While craft practice connoted intuition and unreliability in the 19th century, the optician-craftsman depicted by Bell & Howell combined scientific precision with the care implied by artisanry. Furthermore, the advertisement of the Speed Panchro's compatibility for both standard and "wide" 65mm and 70mm film indicated that lenses were being considered in relationship to the wide series of industrial changes that were not restricted to film form. Because of changes to stock, sound, and color, Bell & Howell advertised their lenses as being adaptable to a wide range of potential changes in the system.[591] Although wide formats did not become standard in film production until the 1950s, experiments with wide format were increasing throughout the late 1920s until the Great Depression ceased these initiatives. As Brian Winston suggests, all technology often exists for years prior to its 'invention,' which generally marks when a given technology takes shape as a result of its social necessity.[592] Rather than just

[591] An interesting side note: this is also seen in a 1942 BH advertisement for their Cooke lenses, claiming that "This 'Eye' Sees Into the Future." "This 'Eye' Sees Into the Future," *American Cinematographer* (December 1942): 532.
[592] Winston, *Technologies of Seeing*, 4-5.

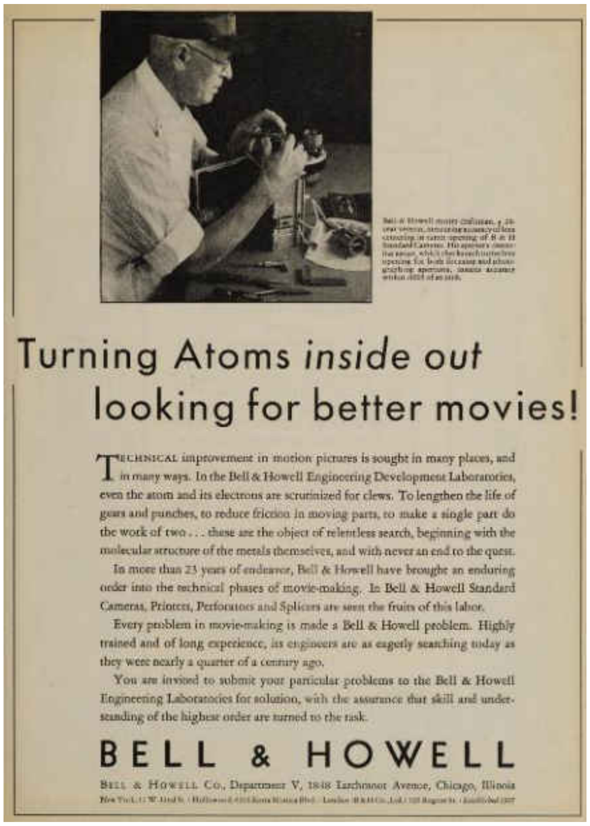

Figure 27 Bell & Howell's advertisements in the October 1930 and November 1930 American Cinematographer emphasized the value that scientifically crafted lenses offered film production.

progressive states of lens invention, the anticipation and uncertainty of what change would take hold strongly influenced what lenses were, in fact, used.

The simultaneous specialization and flexibility of the Speed Panchro was ideally suited to the context of a technologically shifting 1920s Hollywood. Cinematographers and studios investing in equipment, particularly during a period of dramatic technological change, desired lenses that could continue to work effectively with anticipated changes in the system. Lens flexibility was not an explicit scientific criterion, but it was an implicit criterion for Hollywood production. It was largely because of how lenses came to work with the rapidly changing technological environment of the studios that the Speed Panchros came to be so closely associated with the industrial infrastructure of studio production.

Conclusion

In examining how and why Taylor-Hobson became entangled in Hollywood production, we can see that the natural reputation of Cooke's cinema lenses emerged from a constellation of commercial changes that included both a postwar expansion of optical manufacturing and an industrial consolidation of technological control in Hollywood studios. Although the Speed Panchro secured a position as one of the central lenses of Hollywood, as this chapter has suggested, it was the particular commercial endeavor of integrated optical, technical, and commercial industry that shaped the conditions for the Panchro to emerge as such. As studios replaced the natural world with a world built on artificial materials, a lens' capacity to represent natural reality was increasingly based on the embedded commercial relationship, rather than the inherent technological properties, between the cinema lens and its artificial environment.

By examining lens development through its industrial infrastructure, we can see a close entanglement between the development of classical Hollywood and the development of semi-professional and amateur production of the 1920s. By the late 1920s, Bell & Howell had begun to view Hollywood as a "small, ancillary market" rather than as its primary focus. [593] As Marzola writes, while the financial interests of the company lay primarily in the amateur market, Bell & Howell recognized the continued importance of Hollywood to the image of the company.[594] Rather than thinking of Hollywood as antithetical or necessarily distinct from photography or semi-professional motion picture practice, in commercial optics, these communities of practice also constructed Hollywood's commercial and brand identity.

Following the use of Taylor-Hobson's lenses in a range of newly formed technical societies, Bell & Howell, and the Players-Lasky, Cooke lenses became a standard object in the

[593] Marzola, *Engineering Hollywood,* 140-141.
[594] Ibid. 140-141.

studio system. The use of Cooke lenses for the Technicolor three strip process cameras – made by the Mitchell camera company – only further cemented their alignment with Hollywood production. As dramatically and sweepingly narrated by a 1938 Bell & Howell brochure:

> In the United States, Paramount, Metro-Goldwyn-Mayer, and Warner Bros used Cooke Speed Panchros almost exclusively. Fox, R.K.O., United Artists, Columbia, Universal, and other studios were using them increasingly. In England, all film producers, including British Gaumont, British & Dominion, London Films, and British International Pictures, used these lenses. In other countries, Cooke Speed Panchros were used by the Russian motion picture trust, in Australia by Cinesound and Australian Films, and by leading studios in Austria, France, Italy, Germany, India, Japan, and South America.[595]

The extent to which each of these companies did, in fact, use Cooke lenses, should at least remain subject to skepticism. But this corporate mystification was an important part of Cooke's allure: that Cooke's lenses could connect semi-professionals to the quality and precision of a global film industry.

The connection between lenses and the cinema is the same idea that has sustained the recent revival of Cooke lenses. For many years, Cooke lingered as a side division of Taylor-Hobson, which had gone on to focus more broadly on precision instrument design and metrology. Les Zellan purchased the optical division of Taylor-Hobson in 1998, and in the years since, "Cooke Optics Ltd." has aggressively cultivated and commercialized its history in the film industry. The historical revival of Cooke was aided, in no small part, by the Academy of Motion Picture Arts and Sciences, which granted Cooke an Academy Award of Merit in 2013 for lenses that "helped define the look of motion pictures over the last century."[596] At the heart of these accomplishments is the branded promise of the "Cooke Look," a phrase that the Cooke website

595 "History of Cooke Lenses," *ZGC.* https://www.zgc.com/t/techinfo/history-cooke-optics-1930s.html
596 Jon Fauer, "Cooke Optics Academy Award of Merit," *Film and Digital Times* (January 3, 2013). https://www.fdtimes.com/2013/01/03/cooke-academy-award-of-merit/

describes as "a sharp, subtle, smooth rendering that provides dimensionality and high contrast, and pleases the eye."[597]

Formally trademarked in 2008 alongside the company's split from its parent company, Taylor-Hobson, the "Cooke Look" echoes DuBray's 1928 remark about feeling, rather than seeing, lens quality. The Cooke Look is often used in conjunction with the company's newly produced Speed Panchro. Cooke's corporate website uses a number of quotes from directors of photography and cinematographers to describe the Cooke Look. These quotes characterize the aesthetic of the Look as natural, sharp yet soft, full of dimension, roundness, and full of subtlety. For all that the language attempts to define the Cooke Look, the quotes only further mystify the relationship between the lens and the image. The mystification of the Cooke Look and the Speed Panchros draws on the historical aura of Cooke's reputation in the film industry to lend warmth and nature in the face of increasingly cold and sharp digital alternatives. In the context of a pervasive melancholy surrounding the loss of film in cinema, cinema lenses have become a powerful magnet for nostalgia and material fetishization.

[597] "What is the Cooke Look®," *Cooke Optics Ltd*. Accessed 4 January 2019. https://www.cookeoptics.com/t/look.html

Conclusion | The Glass Age

> When future history looks far backward to the middle of the twentieth century, it may well say: "At this period we have come to another border-line. Mankind now having passed through the unquiet turmoil of the Machine Age was entering the Glass Age."
> *5000 Years of Glass (1937)*

In *5000 Years of Glass* (1937), Frances Rogers and Alice Beard tell a sweeping tale of the history, manufacture, and use of glass. The tome covers a long history of glassmakers, bottle making, window panes, mirrors, gas and electric lighting casings, and lenses. From its earliest invention myth to its use in modern safety, the book makes a compelling argument for glass' impact not only on industry, but also on human consciousness. At the close of their work, Rogers and Beard muse on how scientists, engineers, and artists were continuing to find more and more applications for glass in the modern age. They declare: "When future history looks far backward to the middle of the twentieth century, it may well say: 'At this period we have come to another border-line. Mankind now having passed through the unquiet turmoil of the Machine Age was entering the Glass Age.'"[598]

Film history has often thought of cinema as the art of the machine age. Formed at the intersection of industrialization, mass transit, urbanization, and the rise a mass consumer culture, cinema became "the single most expansive discursive horizon in which the effects of modernity were reflected, rejected or denied, transmuted or negotiated."[599] The machine age had a much longer history than the 19th century industrial modernity from which cinema emerged. As Lewis Mumford writes in *Technics and Civilization* (1934), the machine age was defined by more than the factory and the steam engine. Before industrial modernity could take place on a mass scale,

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[598] Frances Rogers and Alice Beard, *5000 Years of Glass* (New York: Frederick Stokes, 1936). 295.
[599] Hansen, "America, Paris, the Alps," 365.

"a reorientation of wishes, habits, ideas, [and] goals was necessary."[600] In order to understand the role that technologies have played in modernity, Mumford writes, "one must explain the culture that was ready to use them and profit by them so extensively."[601] *5000 Years of Glass* ends its foreword with a quote from Mumford; Rogers and Beard were likely familiar with Mumford's understanding of the Machine Age as a longer tradition of ideological and social transformation. In proclaiming the advent of the Glass Age as a way out from the "unquiet turmoil" of the Machine Age, *5000 Years of Glass* foregrounds the material poetics of glass and its potential to bring about utopian change through vision.

The multiple communities of practice that that emerged around lenses in the late 19th and early 20th century – lens culture – believed in the strong utopian promise of lens-based vision. Zeiss' creation of new kinds of optical glass came about because Abbe believed that improvements in the glass-making industry would benefit not only microscopy, but "all sciences and arts that need optical appliances."[602] The promise of lens technology was the promise of seeing and understanding a world that existed beyond human eyes. As Dziga Vertov wrote in his 1926 instructions to the Kino-Eye Groups:

> Our eyes see very little and very badly — so people dreamed up the microscope to let them see invisible phenomena; they invented the telescope…Now they have perfected the cinecamera to penetrate more deeply into the visible world, to explore and record visual phenomena so that what is happening now, which will have to be taken account of in the future, is not forgotten.[603]

At the same time that lenses were being industrially defined as cinema lenses par excellance,

[600] Mumford, *Technics and Civilization*, 3.
[601] Ibid. 4.
[602] Hovestadt *Jena Glass and Its Applications to Science and Art*, 4.
[603] Dziga Vertov, "Provisional Instructions to Kino-Eye Groups," in *Kino-Eye: The Writings of Dziga Vertov,* Dziga Vertov, trans. Kevin O'Brien (Berkeley: University of California Press, 1926 (1985)), 67-69.

lenses were at the heart of a wide range of visual experiments in the 1920s that sought to radically reconfigure the social relationship between vision and technology. As Michel Frizot writes in "The Poetics of Eye and Lens," the notion that the eye's optical role could be transferred to the lens "reappeared in the context of the 1920s avant-garde in a more theoretical and technological form, as an eye-lens analogy and a new eye-photography combination."[604] Collectively, Vertov's *Kino-Glaz* (Cine Eye), the French Avant-Garde, and the *Neues Sehen* (New Vision) photography movements suggested that the "frenzy of the visible" of the mid-19th century had returned with a vengeance.

Among these experiments were a set of short films titled the "Looney Lens" series. Filmed by Fox News and Fox Movietone cameraman Al Brick between 1924 and 1927, the three short films use optical distortions to playfully rearrange the visual forms of people, city streets, and skyscrapers. Echoing the split images of skyscrapers and manic cityscapes that would later appear in Dziga Vertov's *Man With a Movie Camera* (1929), the "Looney Lens" series plays with the lens' ability to disfigure and distort the space of lived experience. These distortions were from more than just the lens, though. A title card for "Split Skyscrapers / Tenth Avenue, NYC" (1924) declares that "New Year Festivities Make New York Dizzy," and "Crazy cameraman, with looney lens, finds the city all in a whirl." While the lens may be looney, what it sees is the whirlwind of modern experience: dizziness, motion, rushing traffic, and an unstable yet exciting experience of vision unmoored from the human eye.

The wide interest in exploring the relationship between technology and vision was aided, in no small part, by the industrialization of lens production described in this project. In

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[604] Michel Frizot, "The Poetics of Eye and Lens," in *Object: Photo. Modern Photographs: The Thomas Walther Collection 1909–1949. An Online Project of The Museum of Modern Art*, ed. Mitra Abbaspour, Lee Ann Daffner and Maria Morris Hambourg (New York: The Museum of Modern Art, 2014), 1.

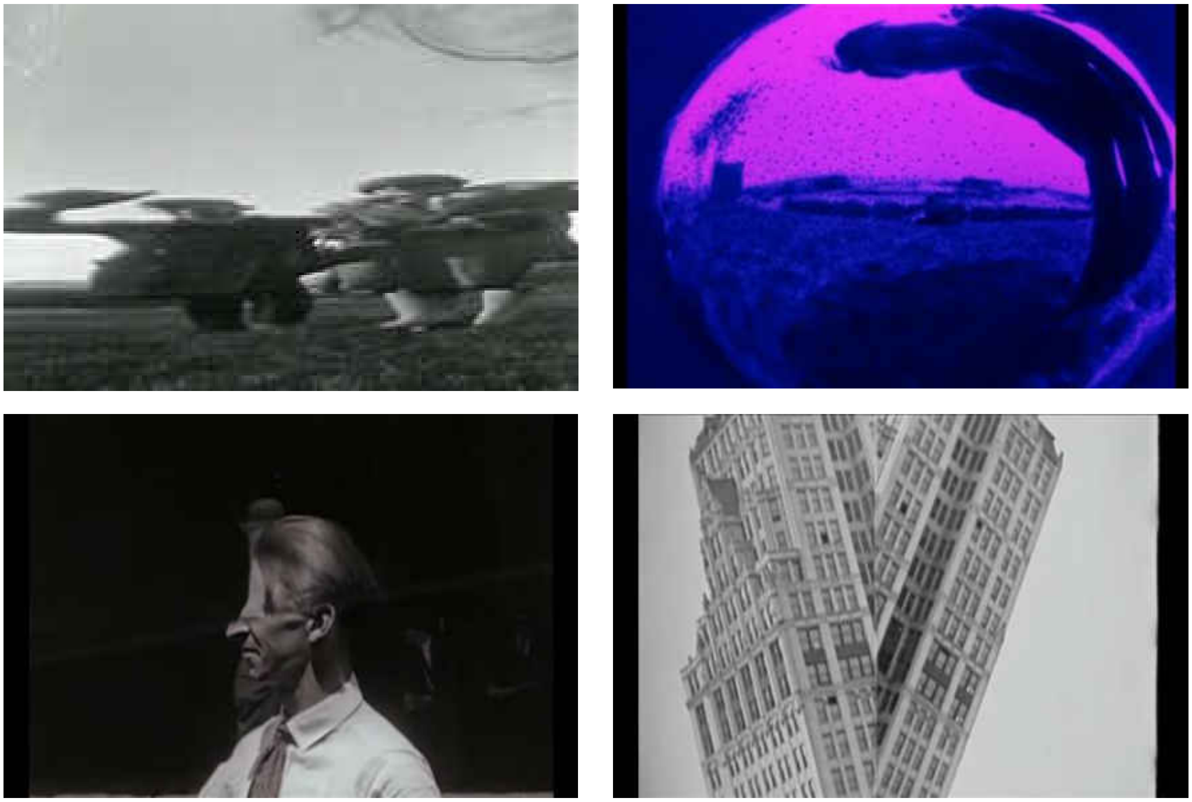

Figure 28 Stills from Anamorphic People (1927), Pas De Deux (1924), and Split Skyscrapers / Tenth Avenue, NYC (1924).

expanding precision lens production to markets outside of professional scientific practice, optical manufacturers brought lenses into intersection with a wider and wider range of commercial, political, and professional communities. The history of the lens is not simply a series of ever-improving technical designs that move towards the complete correction of optical distortion or the perpetual acceleration of functional apertures. Rather, a lens was constituted by a gradual reconfiguration of ideas about the relationship between vision and technology, and what role lenses could play in society more broadly. Lenses were also constituted by national communities who imagined lens production in relationship to national identity and labor, and the production of lenses was influenced by the ways in which industries navigated and constituted their respective national and international identities. Cinema lenses were defined on the basis of specialized studio practice, but they were also defined by instrument sellers who sought to sell lenses to a growing community of semi-professional practitioners. If cinema was an art of the lens as much as it was an art of celluloid film, through the industrialization of lenses, the cinematic character of modernity expanded to places that were less and less restricted by access to lens technology.

The Glass Age never came to pass, but we may nonetheless find ourselves in the Age of Windows. As Anne Friedberg writes in *The Virtual Window*, the architectural function of windows – an opening for light and ventilation – gradually transformed alongside film, television, and computers to function more primarily as a frame for viewing. Glass materialized the exchange between frame and view, and allows spectators to "inhabit, in a virtual sense, two or more spaces at one, and equally, two or more times."[605] While these virtual windows are rarely made of glass, they still retain the same imaginative potential of the lens: to see a world in ways that exceed the limitations of single human perspective. Interspersed between *The Virtual Window*'s primary chapters on the history of the screen are a variety of philosophers and critical theorists whose theories serve as 'lenses' through which Friedberg refracts contemporary terms used to describe technology – window, frame, virtual, screen – through a historical perspective. In Friedberg's book, lenses are a way to adjust contemporary views of media to "vanishing points deeper than the last century."[606] Philosophers become ways of seeing that make visible the ways we think about historical relationships between subjects, environments, and the perception of both.

The phrase "to look through a lens" has become a popular cultural shorthand for perspective. We look through feminist lenses, critical lenses, black lenses, historical lenses, and wide lenses; we zoom in and out, we frame, we change our lenses, we focus. As metaphors, lenses frame the act of perceiving and are useful in negotiating the contractions that emerge

[605] Friedberg, *The Virtual Window*, 122-145.
[606] Ibid. 20.

between individual perception and increasingly multiple views. As objects, lenses shape the way we see and understand the world. Through the industrialization of lens production, lenses circulated more and more widely and became a powerful metaphor for the apprehension of the increasingly heterogeneous visual culture that constituted modernity.

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Curriculum Vitae
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Employment

Graduate Fellow, University of Wisconsin-Milwaukee — 2018-2019
Center for 21st Century Studies
Teaching Assistant, University of Wisconsin-Milwaukee — 2014-2018
English Department
Adjunct Instructor, SUNY Oswego — 2013-2014
Cinema and Screen Studies Department

Education

PhD, University of Wisconsin-Milwaukee — 2014-2019
English (Media, Cinema, and Digital Studies)
Dissertation: Fast Glass: Modernity, Technology, and the Cinematic Lens
Director: Dr. Tami Williams
M.Litt with Distinction, University of St Andrews — 2012-2013
Film Studies
Dual Honors BA, State University of New York at Oswego — 2008-2012
Cinema and Screen Studies, Creative Writing

Peer Reviewed Publications

"'The End of a Foreign Monopoly:' Bausch and Lomb and the Wartime Provenance of Optical Glass." In *Provenance and Early Cinema*. Bloomington: Indiana University Press, 2020. (forthcoming)
"Lens Culture: E. Krauss, Early Cinema, and Parisian Instrument Culture." Special issue, *Cahiers d'histoire du Cnam,* no. 9 (2019). (forthcoming)
"Todd Haynes + Negative Space." *[in]Transition* 5, no. 4 (2018). http://mediacommons.org/intransition/negative-space
"Of Love and Longing." *[in]Transition* 5, no. 2 (2018). http://mediacommons.org/intransition/2018/05/02/love-and-longing
"Not a Betting Man: Stanford, Muybridge, and the Palo-Alto Wager Myth." *Film History* 29, no. 4 (2017): 112-130.
"Of Love and Longing: Queer Nostalgia and *Carol* (2015)." *Queer Studies in Media and Popular Culture* 2, no. 1 (2017): 199-211.
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Additional Publications

"How the 50-mm Lens Became 'Normal.'" *The Atlantic*. May 13, 2018. https://www.theatlantic.com/technology/archive/2018/05/how-the-50-mm-lens-became-normal/560276/
"Texture in Film: Interdisciplinary Symposium Report." *Scope*, 26 (2014).

"In Dublin, Out of Answers: The Question of Irish National Cinema." *Film Matters* 2, no. 2 (2011): 28-29.

Video Work

"New Arctic." *TriQuarterly* 155 (Winter/Spring 2019). http://www.triquarterly.org/issues/issue-155/new-arctic

"Memory Keepers." The Chipstone Foundation, October 2018. https://chipstone.org/module.php/64/329/Memory-Keepers

"Creating the Supper Club: Interpreting Judy Chicago's *The Dinner Party.*" The Chipstone Foundation, May 2017. https://chipstone.org/module.php/64/323/Creating-The-Supper-Club

"Rendering." *TriQuarterly* 151 (Winter/Spring 2017). https://www.triquarterly.org/issues/issue-151/rendering

"Printmaking and London." UWM Digital Humanities Lab, December 2014. www.vimeo.com/113992655

Conference Presentations

"Spectacular Visions: E. Krauss and the Emergence of Cinematic Lenses in Paris." Society for Cinema and Media Studies, March 2019.

"Impact Beyond the Classroom: Creating Teaching and Learning Resources." UWM Teaching & Learning Symposium, January 2019.

"Glass Empires: Nationalism and Lens Production, 1914-1918." Domitor, June 2018.

"Fast Glass: WWI and the Americanization of Early Lens Production." Society for Cinema and Media Studies, March 2018.

"Glass Empires: Cooke Lenses, WWI, and British Nationalism." Film and History, November 2017.

"Writhing World-Flesh: Exhausted Humanity in *Leviathan* (2012)." Visual & Cultural Studies Graduate Conference, University of Rochester, April 2017.

"Of Love and Longing: Color and Queer Nostalgia in *Carol* (2015)." Society for Cinema and Media Studies, March 2017.

"Making the Grade: Shooting Flat and Post-Militant Color Management." Film and History, October 2016.

"Roundtable: Media Ecologies Project." Domitor, June 2016.

"Research on the Paper Print Collection: *Going to the Fire* (1896) and *How Jones Lost His Roll* (1905)." Media with Impact Conference, University Film and Video Association, August 2015.

"Monstrous Time: Vertical Editing and Richard Linklater." Craft, Critique, and Culture Conference, University of Iowa, April 2015.

"Grown Digital: Computer Generated Environments and Subject Determination." University Film and Video Association, August 2014.

"'I Hate Theory': Reframing Perceptions and Applications of Theory & Criticism." University Film and Video Association, August 2014.

"Raspberry Pi Cinema and New Media Education." SUNY Conference on Instruction and Technology, Cornell University, May 2014.

Teaching Experience

Instructor, University of Wisconsin-Milwaukee	2014-2018
History of Film II: 1945 - Present (Spring 2017, Spring 2018)	
Film and Literature (Fall 2017)	
Entertainment Arts: Film, TV, The Net (2015-2016)	
Introduction to College Writing (2014-2015)	
Instructor, International Summer School of Scotland at Yale	2016
Pre-International Baccalaureate (Summer 2016)	
Instructor, SUNY Oswego	2013-2014
Modern Culture and Media (Spring 2014)	
College Writing (Fall 2013, Spring 2014)	
Film Genre (Fall 2013)	
Instructor, International Summer School of Scotland at St Andrews	2013
International Baccalaureate Extended Essay (Summer 2013)	
Teaching Assistant, SUNY Oswego	2010-2011
Film Theory (Fall 2010, Fall 2011)	

Awards and Honors

SCMS Student Writing Award (Second Place)	2019
R1 Distinguished Dissertator Fellowship, University of Wisconsin-Milwaukee	2018-2019
Graduate Workshop Participant, Domitor	2018
Domitor Student Essay Award, Domitor	2016
Graduate Workshop Participant, Domitor	2016
Graduate Student Fellow, University Film and Video Association	2015
AOP Fellowship, University of Wisconsin-Milwaukee	2015-2018
Chancellor's Award, University of Wisconsin-Milwaukee	2014
Faculty Summer Support Award, University of Wisconsin-Milwaukee	2014
Independent Development Award, United University Professionals	2014
Faculty Mini-Grant, SUNY Oswego	2013
Saltire Scholarship, University of St Andrews	2012
Helen Buckley Award, SUNY Oswego	2011
Dean's Writing Award in English, SUNY Oswego	2011
Presidential Scholarship, SUNY Oswego	2008-2012

Professional Service and Activities

Graduate Representative, Silent Cinema Special Interest Group, SCMS	2018-2019
Workshop Coordinator, "Video Essays and Videographic Criticism: What Is It, Why You Should Be Doing It," UWM Digital Humanities Lab	2018
Chair, Midwest Interdisciplinary Graduate Conference	2017-2018
I/O Genre Editor, Cream City Review	2016-2018

Indexer, Elena Gorfinkel, *Sensational Bodies: American Sexploitation Cinema's Scenes of Looking, 1959-1972*. Ann Arbor: University of Minnesota Press, 2017.	2017
Vice Chair, Midwest Interdisciplinary Graduate Conference	2016-2017
Event Coordinator, Midwest Interdisciplinary Graduate Conference	2015-2016
Archivist, SUNY Oswego, Cinema and Screen Studies Digital Archive	2013-2014
Creative Director, 60 Hour Film Blitz Festival	2012-2013
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