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Scanner Epistemologies: Mediations of the Material and Virtual

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by

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ABSTRACT

Scanner Epistemologies: Mediations of the Material and Virtual

by

Lan Xuan Le

Across many everyday contexts and technological devices, we encounter over and over again a mechanical-translation act called *scanning*, performed by flatbed scanners, photocopiers, barcode readers, televisions, x-ray airport security scanners, fax machines, retinal eye scanning, MRI scanning, ultra-sonography, and earth-orbiting satellite imaging. What all of these separate devices have in common is the same core technological mechanism and mode of action—the mapping of differences along a surface to be known by a lensless apparatus that detects via probe-signals. Despite being mobilized to very different uses and within a large diversity of networks and media assemblages, scanners arise from a common genealogical source—the conceptual union of photography to telegraphy. Scanners appear everywhere in our modern infrastructure. It is impossible to avoid these devices, as they mediate even the most basic transactions in everyday life, such as purchasing food at the grocery store or checking out a book at a college library. Yet neither historians of technology nor media scholars have addressed this quotidian device which enables so much of modern bureaucracy in business, government and education to function. While the scanner's absence from the landscape of critical thought precisely marks the problem of the unremarkable in

our scholarship, the metaphor of scanning remains present in both common and scholarly discourse. Scanning may, at various times, stand in for a model of attention, a form of reading, or serve as a simile for searching and/or diagnosing. The imagination of the scan well precedes its appearance as a technology, which further indicates the necessity of understanding this unexamined medium. This dissertation project investigates the object of the scanner as a term for organizing the imagination and materialization of an entire suite of technologies that we encounter daily. Conceived as a social history of technology married to a film and media studies paradigm, this dissertation examines the scanner as a form of machine-perception that, while it extends the dominant conception of the camera-prosthesis, stands as its own unique model of perceptual mediation. The scanner remains unique in media studies because so much of its identity depends upon the place it holds within the historical conditions of the intermedial assemblage in which it has been mobilized. Through a series of case studies in which I loosely divide scanning technologies into genres of perceptual and epistemological function, I triangulate the epistemic role of the scanner in each of its respective media networks.

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Introduction

The earliest known use of the word "scan" in the English language was in 1398: the verb, "to scan," meant "to mark up poetry for recitation."[1] Scanning thus began its conceptual life as a process of ephemeral inscription, of analytical judgment in relation to textual practices. By approximately 1550, the verb would take on a new meaning. It would mean to "criticize; to test or estimate the correctness or value of; to judge by a certain rule or standard." This notion of scanning as an evaluative form would lead into its subsequent meaning, "to examine, consider, or discuss minutely."[2] A scanner became "one who scans or examines critically." This human-centered usage denoted a person who was capable of deciphering the smallest details that escaped others, searching almost in a forensic mode. Over the years, to scan also came to variously mean to perceive, to interpret or assign meaning, or to search or examine in a searching manner with the eyes. These somewhat rare definitions of scanning are no longer in use today, but nonetheless haunt the modern understanding of scanning, especially the notion of perception and the assignation of meaning. Eventually, scanning would come to mean looking over a text quickly with one's eyes. Not until 1927 would the term scanner come to be associated with a scanning machine, "any device for scanning or examining all parts of something."[3] Once scanning became the function of a machine, the changing definition of the verb "to scan" remained concerned with the act of examination, scrutiny and the attendant issues that come with such an endeavor. Although visual practices of scanning preceded the invention of the scanner, the process of scanning remains involved in seeking out differences and making distinctions.

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1 Oxford English Dictionary, 2nd ed., s.v. "Scan."

2Ibid.

3 Ibid

This project studies the unique mediating process of machine scanning and the role it plays in today's media ecology. Serving as a relay point in larger systems of media, scanners act as an interface that transforms material objects into virtual information. The scanner serves various functions, such as visualization, verification, and detection of objects, through the mechanism of measurement and quantification. When understood as its own mediating process, an examination of scanning reveals a buried set of ideological and epistemological functions that serve larger systems of command and control. By examining the process of scanning through a critical media studies paradigm, the following four chapters uncover the ways in which the mediating process of scanning shapes communication and the parameters of what can and cannot be known.

In this project, I define scanning as a process of social and technical measurement that orbits at all times a machine nucleus called the scanner. This machine has taken on many guises over time, and its changes in form, and adaptation to its environment, have in turn shaped the process of scanning in each iteration. For this reason, the machine remains a necessary part of the definition of scanning as the function of scanning has become progressively automated in nature .In a broad sense, the scanner,works as an agent of measuring, which is a sociotechnical task wherein material is made legible in new ways. The scanned material is translated to a system of pulses that can be measured and rendered to generate new epistemologies. The ability to measure serves as the basis for other more specific processes to take place: visualization, detection, and verification.I argue that the process of scanning exists as a unique transformative interface that mediates between the material and informatic and that this mediation allows for unforeseen machine-centered modes of action.

I define the scanner as a *mediating process*. The scanner is a mediating process, rather than a medium, because it does not itself capture and store information in any form. Instead, it transforms different types of materiality into information that may be "caught" and stored through another medium. Sarah Kember and Joanne Zylinska, in their volume *Life After New Media: Mediation as a Vital Process*, disrupt the structuralist definition of media as an interaction between two entities via a third, mediating entity (Kember and Zylinska 2012, 18) Like these scholars, I see mediation as an ongoing "being" or "becoming" which has temporary moments of becoming "fixed" or crystallized into semi-stable institutionalized forms.

This definition of mediation is useful for understanding the scanner. Unlike the camera or the computer, the scanner is not a single technology. Rather the scanner represents a *technological trope*. After its first invention, the scanner independently appeared as a form of mediation in various places. There is no deep genealogy that connects all instances of scanners to one another. The scanner is mediating process because it is an idea that gets taken up technologically wherever it may best serve the interests of the parties involved. To borrow a term from evolutionary biology, scanners are a form of convergent evolution in the history of media technology. Birds and bats both fly despite belonging to two different evolutionary branches. Similarly, the technical operations of different scanners are virtually identical because they draw from the same technological imaginary, despite having very different technological origins. The media ecological niche that the scanner fills is the need for automated measurement. Whenever this gap in the technological landscape appears, a scanner is appropriated or reinvented to fill this purpose. The ongoing "becoming" of the scanner as a mediating process thus becomes temporarily "fixed" into a form in response to a social need.

Lisa Gitelman cautions that technological nuclei themselves do not remain stable through time, but undergo changes and are, at any given time, ill-defined heuristics, or objects in name only (Gitelman 2006, 8). This applies very much to the set of machines, loosely clustered around a material-discursive nexus across time and space, that I have gathered under the lexical stamp of the scanner. By recognizing the scanner as a category of media and understanding its activity, the scanner as a thing becomes constituted as an object of knowledge. Simultaneously, analysis of the scanner leads to the understanding of it as an historically constituted field and not an object in itself.

Scanners represent a profitable site of inquiry for media studies because scanning is a machine-to-machine form of communication. The scanner does not produce an image to be perused by the human eye, but takes a material and transforms it into an intermediary form, be it electrical impulses or numerical values or digital code. This intermediary form of data represents the "pre-image" in its raw and non-optical format. It requires the additional intervention of another machine—or software—to make the intermediary form legible to the human sensorium. Facsimile and copy machines convert images into electrical signals that must then be reinterpreted again by a printer. Flatbed scanners take digital measurements of the image being scanned and then send them to the computer where these numbers are transformed and reworked into a visual format. A scanner is necessarily part of an ensemble. What I mean by this is that scanners act as a relay in a system of media visualization, produce images in concert with a host of other media machines Scanned information is in its very nature a machine-readable form, whose purpose is to feed into other forms of media, like computers and printers and databases. These scanned intermediaries are data that has been generated from scanning that has the potential to be rendered into an image. In that sense, these scanned intermediaries are often in the process of coming into being. Scanners are one of the sites that produce the most varieties and volume of intermediary forms of images and information.

As Trevor Paglen argues, visual culture is increasingly dominated by machine-machine imaging, and the work done by these "invisible" images. These images "have begun to intervene in everyday life, their functions changing from representation and mediation, to activations, operations, and enforcement. Invisible images are actively watching us, poking and prodding, guiding our movements, inflicting pain and inducing pleasure." (Paglen 2016, 1) In his 2016 article in *New Inquiry*, Paglen argues that these "invisible" images (or what I call intermediary images or pre-images) are now moving beyond their function as representational images, instead operating as a form of trigger for further activities within a system of media-machines. Because these intermediary images feed into other non-human media, they are not most profitably understood in terms of human-centric or machine-human interactions. Paglen argues that the human-centered approach has thus far proven insufficient to exposing how these images actually perform operations on our lives.

Trevor Paglen provides an excellent example in the Automatic License Plate Readers (ALPR), a type of scanner, which performs exactly the function stated on the box. Combined with optical character recognition, the license plates scanned by this system are fed into a database available to the police. This database flags any license plates that have a fine associated with them, allowing the police to pull the car over and offer the party two options: pay the fine with a credit card on the spot (with a 25% fee to the manufacturer of the ALPR and its associated database) or be taken to jail. In this scenario, the invisible image of the license plate triggers an operation that serves the interests of both corporations and government at the increasing expense of the citizenry at large. And this operation is performed automatically without the intervention of the police officer (until the very end), which serves as a technological way of re-defining the logic of policing into one of a mobile tax-collector. (Paglen 2016, 1) This leads us to ask, how else have industrial media like this subtly changed the logic of the culture in which we live and work?

The primary purpose of this research is to expose the way that machine-to-machine processes of mediation create very specific visual cultures and epistemologies that support certain structures of knowledge/power. In this approach, I examine the logic of the various scanning machines, and their associated ecology of databases, computational systems, and industrial concerns, to understand the way scanners, as mediating processes, intervene upon and changed the institutional cultures in which they operate. This project will examine some of the social consequences of the use of scanners, and how scanners shape the behavior of users, policies, and institutional practices. Despite the fact that humans have increasingly become secondary actors in the systems that we have created, we are still important actors that simultaneously act and are acted upon in these media systems. These machine systems, while displacing human involvement to some degree, still encode human forms of knowledge and power, and must be examined for the traces of that power in their actions and algorithms.

The scanner represents a suite of technologies that perform many of the types of machine-machine operations under consideration on our daily lives. If we ignore the importance of these invisible communications, we risk missing the deep ideological and epistemological work embedded in these systems. Moreover, scanners represent a mediating process that directly interacts with the material world. The scanner acts on objects and people alike, working as an intermediary between materiality and virtuality. These scanners thus shape our conception of both the material and the virtual and what operations are possible or not possible to perform.

Measurement and Its Consequences

Scanners ought to be regarded and understood and as a distinctive mediating process because their machine-machine communications hide invisible judgments and distinctions that trigger real actions and reactions. To understand the way that scanners do their ideological work, I situate scanning within a critical media studies framework and consider its material design, functions, and outputs within visual culture. We must first comprehend the technical powers and limitations of the scanner in order to dissect how an individual scanner and the intermediary images it produces shapes the way that we conduct everyday life. To understand the scanner as a mediating process, it is first important to understand how the scanner operates as a technical object and then how it functions as a social process of measurement. In the following section, I lay out the general technical definition of scanning and examine the way that measurement can be built upon to perform more complex functions like visualization, verification, and detection.

In their technical mode of action, scanners mediate differently from any other medium that the field has studied before. What all of the separate scanning devices have in common is the same core technological mechanism and mode of action: the mapping of differences along a known surface by an apparatus that detects via probe-signals. Any act of scanning can be divided into three fundamental parts or processes. First, a scanner head must possess a source signal, which is actively or passively deployed towards a surface or object under investigation. Second, that signal bounces off the object and returns to the scanner head, which holds a detection array that registers the return signal. The return signal carries with it information sensed from the interaction of that signal with the surface of the object. Third, the scanner head moves incrementally over the surface of the object being studied and a whole image or map of the of the object is assembled, piece by piece rather than all together at a glance. As this process demonstrates, scanning is a medium of detection rather that visualization. Although deeply complicit in networks of visualization, scanning stands apart from these imaging technologies in that it maps the incremental differences of a surface as mathematical values that are only secondarily translated into a visual form by computer software.

Based on this technical breakdown, scanning can be defined as an automated form of measurement. Scanning, as a form of measurement, is the process of determining the dimension or capacity of an object by subjecting it to a signal of a known magnitude. A scanner measures the difference in magnitude of that return signal once it bounces off the surface of the object and returns to the scanner's sensor. This process requires the signal to mediate a concrete system—the material object—with the aim to render aspects of that concrete system into abstract terms. In this way, the scanner is able to transform different materials into related forms of information: from magnitudes of voltage, to volumes of material, to lengths both great and small. The results of the scanning process exist in an intermediary form as digital bits or amplitudes of some kind. These invisible intermediary images become available for translation into a more recognizable form. The power of the scanner for its human users lies in its ability to accurately and quickly use the measurements acquired and assemble them into the form of a conceptual map or visual image. Scanning can be understood as a form of mapping because it renders objects and surfaces readable, whether that is to another machine or to a human being. As a mediating process, scanning reflects the dominant sensual paradigm of modern knowledge.

Measurement is a powerful tool that gives the scanner a place in the scientifically-driven world of modern technology. The measurement of things takes them from the realm of material or processes and transforms them into useful, quantified representations that do work within systems of science and technology. Without this transformative process, material things cannot participate in the circulation of data and images that forms the core of the modern digital media and cultural system. While science and industry possess many tools that allow them to manually measure objects, the scanner's automation of the process allows unprecedented ease and accuracy in the work of measurement. The scanner's use of signal processing, however, is what makes its ability to measure even more powerful. Take the case of the MRI scanner. The use of magnetic resonance allows the scanner not only to penetrate and peer into the flesh without ruining the organism itself. The alliance with computation opens up the possibility of scanners representing processes as well as objects. Each scan of a brain is a slice in time, but modern computers allow hundreds of these individual temporal slices to be compiled in real time to form a live scan of the brain as it undergoes cognitive processes. In this way, scanners visualize objects and processes across the dimension of time. Thus the use of the signal to sense and evaluate an object produces a situation in which the scanner may access places and processes that remain beyond the reach of other more invasive methods.

Measurement by itself is important, but when we build upon that capacity and its precision, other more complex functions emerge. With the ability to measure volumes and features of objects comes corollary functions. One of the commonsense functions of the scanner is the work of visualization. The unique ability of scanners to map objects in two and three-dimensions allows the scanner to recreate the object under study—in conjunction with an ecology of other media such as computers and 3D printers. This object has a physical form that is scanned into intermediary image data that then rendered into a recognizable visual form, which finally allows it to be studied. The earliest form of scanner, the facsimile, was aimed at transforming images into electrical impulses to be re-interpreted on the other end through a printer. In the case of art preservation, the scanner may be used to create precise models of ancient sculptures to both allow them to be studied more closely without affecting the original copy or to preserve them in a digital archive for the future. This particular form of representation aligns these types of scanners more with traditional visual culture. But these particular scanners still function on the machine-machine level, producing the digital assets that are at their core, still machine-readable first, human-legible second.

Other more complex and machine-oriented uses of measurement exist. The act of measuring can be used as a form of identification and subsequent verification. Take, for example, the case of the barcode scanner, which I address in Chapter 3. The barcode optically represents a unique serial number through a series of white and black lines. The width of these lines corresponds to a number or letter. By measuring the widths of these bars, the scanner and computer combination is able to quickly interpret the serial number of the barcode. Thus the scanner is able to perform the function of identification of visual vocabularies that were designed specifically for this form of work. But scanning never exists on its own. The work of identification goes beyond pre-existing visual vocabularies in barcoding systems. Scanning is always connected to complex algorithmic operations that can record information, trigger an alert in the system, or initiate some sort of process. Within the retail sector, scanning a barcode allows a store to tally up its inventory on a constant basis and, at predetermined times, initiate automated restocking orders using their database systems. This act of verification becomes the first step in a more complicated process that is initiated by the scan.

The last major function of the scanner is as an agent of detection. Detection is defined as the process by which we identify or authenticate the presence of something concealed. By deploying a signal that literally touches the surface of an object under investigation, the scanner is able to gather information and verify the presence of that object. It follows then that scanners function as a means to access and construct the presence of things that cannot be seen by the human eye or accessed easily by other human senses. Marine sonar scanning reveals the presence of objects that are hidden not only by distance but also by the environment. Medical scanners allow the visualization of the interiors of the body without the destruction of that body by invasive surgery. Low-earth orbiting satellites allow the construction of whole earth pictures, which exist at a scale too large for a single photograph to encompass. As a mediating process, the scanner extends human senses through a haptic form of signal modification that allows the cultures of visualization to penetrate into new horizons of both sight and knowledge.

In sum, I define the scanner as a social mediating process that operates via measurement. This process is an ongoing phenomenon that becomes fixed into certain material forms—machines—at particular times in response to specific needs. I define scanning as a process rather than as a medium because the term medium implies that scanning captures information and stores it in some material form. Scanning serves instead as the interface that transforms matter into information so that other media can capture, store, and materialize it. In the following pages, I use this definition of the scanning process to analyze how machine-machine communication embeds particular ideologies and epistemologies in their invisible workings. More specifically, I examine four case studies that explore the thematic problems that arise from the issues of visualization, measurement, and detection. The first case study focuses on the facsimile to reveal the development of the imaginary of scanning over time. The second case study investigates the ways in which the particle accelerator—a special kind of scanner—is deeply entwined in the history of media studies. The third site of inquiry is the case of the barcode scanner, which examines the phenomenon of global surveillance in systems of logistics. The final case study, motion capture technologies, considers the way that language and bodies are extracted and re-constructed.

Sight, Power and Culture

This is the first study to treat the scanner as a process of mediation. A few academic articles and volumes take up local iterations of scanning technology as it has manifested through time, but never as a conceptual category of mediating objects or as an apparatus. There is also no academic literature, besides the work of artist Trevor Paglen, that treats the problem of machine-machine operations that trigger actions independently of the human actors in a media ecological system. Because there is no direct precedent for my approach within the academic critical literature, this literature review constructs a path through related areas of scholarship that inform my thinking about scanning, and frame the way I will approach scanning as a mediating process. Scanning can be broken down into the more specific processes of detection, visualization/optics, and measurement. These processes and their broad concerns can be summed up into broad thematic categories that underlie all three notions. The larger themes and questions of this project revolve around the epistemological consequences of image generation as a form of information in an age where information has largely changed the social and institutional relations of our society. This review of the literature selects the areas of machine-perception (or machine-based sight), epistemology, and the information society, as critical areas to inform the study of the scanner.

The scholarship I have chosen on machine-perception creates a foundation for my thinking about the scanner by examining the notion of sight as historically located and culturally produced. The literature here serves to open up the notion of seeing as a site of power that operates on the objects upon which it is trained, rather than a monolithic idea that operates transhistorically. I extend the arguments made in the literature by examining the ways that scanners, as a form of machine-machine communication, produce new forms of sight and sight-based power which serve to transform our relationship to the idea that sight is knowledge.

As vision is intimately tied to knowledge, I subsequently turn to literature on scientific forms of epistemology to inform my work on how scanners produce new registers of knowledge. Much like sight, epistemological systems are historically embedded and constituted within a network of factors that impact their existence. I look to this work in order to understand the institutional and discursive labor required to transform inscriptions, like scanned images, into facts as the basis of truth claims. Moreover, this work illustrates the process of discursive naturalization that occurs in order for scanned images to possess a transparent meaning. This project builds upon the following scholarship and uses it as foundation for further investigation of the local historical production of knowledge in various cases of scanning. This project will advance our understanding of how new epistemologies emerge and are constructed by new communications configurations lead by machine-machine transactions.

Once its provenance has been naturalized, the information generated by scanning enters into the circuits of the information society. In the final section of this literature review, I look to scholarship regarding the manner in which information has transformed our social and productive relationships through the rise of communication technologies like the scanner. This scholarship considers how information arguably arose as a form of social control over the increasingly dispersed modes of production, a structure in which the scanner actively participates to this day. In this new system wherein information becomes in and of itself a milieu of communication, we are reduced to fundamental problems of signal and noise. These broad studies of information shape this project's understanding of how information reconstitutes the social order into new communicative configurations. My work builds upon these macro level examinations by considering the micro level work of a single technical process that transforms materiality into information. By doing so, this study illuminates the specific ways that information comes into being and grounds it in the material process of scanning.

Machine-Perception

As I argue in my first chapter, the genesis of the scanner begins with the desire to extend the human sensorium into further and further spaces that could not be accessed by the body or current technologies. In the case of vision, the scanner sees on our behalf where the physiology of the eye fails. Its primary work, for a long time, was representational. As such, the scanner functioned in that early phase as another, non-optical extension of sighted knowledge. As the scanner's media environment transitioned to a digital milieu, however, the machine-readable intermediary images began to take on different functions that were increasingly parts of operations of identification and verification. Despite no longer primarily working as a form of representation, the scanner still functions as a form of machine-mediated perception. From reading license plates, to full body scanners at airports, scanners initiate algorithmic operations in response to their ability to sense things that are too fast or too hidden for humans to perceive. This function allows machine-centered relations to enter into and set the parameters for interaction in arenas previously unavailable to us due to social prohibitions, physical inability, or lack of institutional interest. It is important to study the subject of machine-perception with respect to scanning as a site of machine-machine operations because machine-perception is the gateway for many of these vital transactions. They figuratively "open up" the area under question to the colonization of a form of digital procedures. These scanners make the materiality in question operable by digital means.

To understand machine-perception, I look to the work of scholars such as Marshall McLuhan, who argued that media technologies form so-called extensions to the human body. (Mcluhan 1994, 4) These extensions serve as a form of modification of our perception, allowing our senses to be sped up and spatially dispersed. (McLuhan 1994, 90) This enhancement through technological means is not without its social and psychic consequences, as media produce new interpersonal configurations, ways of communicating, and patterns of thinking. I take up this notion of sensory extension as a metaphor for the work of the scanner and use it as a thematic concern throughout my dissertation. This project builds upon and furthers the work of McLuhan by examining the specific ways in which scanning processes produce new epistemological configurations that may remain hidden in by machine-centered operations.

Another modern scholar of machine-perception, Kelly Gates, examines the ways in which sight is itself a deeply cultural process. She analyzes the institutional forces and discursive *topos* that surround the development of what she calls "facial perception technologies," or facial recognition systems (Gates 2011, 3). Facial recognition systems represent an effort to couple visual sensors to computer intelligence in an effort to produce intelligent machines that can simultaneously register and analyze the content of these images. In this configuration of machine perception, we aim to teach machines to see independently of human input. But to see is to see in a culturally specific way, and Gates demonstrates that to see a face, for example, is not a transhistorical phenomenon, but one guided by specific cultural and historical conceptions of what constitutes a face (Gates 2011, 10). I engage with Gates's scholarship to illuminate the deeply cultural foundations of sight and the laborious process involved in producing techno-visual artifacts that can be fully assimilated into the discourse of seeing. This process of mediating an image that is seen to transparently represent something, to stand in as a clear sign for the signified takes enormous work. I use Gates's work as a point of inspiration and departure, taking up where she left off and expanding Gates's arguments into the space of scanning. I build upon her work by examining the way scanners mediate the material into these circuits of visual knowledge, a process that has consequences on the value and cultural circulation of the images produced.

The following scholars explicate the ways in which machine-mediated sight transforms the objects they mediate into sites of ideological work. Lisa Cartwright and Jose van Dijck take the problem of mechanical seeing into the realm of medicine. Cartwright examines the incorporation of the camera into medical practice. The manner in which the camera can constitute and reconstitute bodies becomes part of a larger project through which the social management of human bodies takes on the larger "life-controlling" and "life-generating" ideological agenda of biomedicine. (Cartwright 1995, 16) In a related study, van Dijck deconstructs the notion of the "transparent body" through other visualization technologies in medicine, such as the X-ray scanner. As in Cartwright's work, van Dijck shows how the fantasy of technology that can see inside the body operates as a naturalization of the ongoing discipline of the body, a discipline that constructs the body as a decomposable object that can be perfected and modified. Both these scholars problematize the easy notion that new imaging capacities can lead to more and better knowledge, thus "lifting the veil" from the body and exposing it to perfect surveillance and maintenance (Dijck 2005, 16).

Institutional uses of scanners frequently fall prey to these same forces of surveillance, operating as parts of command and control systems that use this "perfect vision" as a means to create new fields of dominance. What is at stake across the following studies is the relationship between sight/sensing and knowledge/power, in the Foucauldian sense. Kelly Gates, Lisa Cartwright, and Jose van Dijck all dismantle the persistent conflation of seeing with knowing where it continues to operate on the cultural site of bodies as objects of surveillance and medical knowledge production. Moreover, these sites show how the notion of machine-mediated sight renders the body as an operable milieu, where social forces can perform procedures and transactions. This cluster of scholarship illustrates the way in which machine-perception performs ideological functions via technologies of visualization like the scanner. My project takes up these concerns and further investigates how scanning is implicated in various systems of knowledge/power, especially those embedded in the invisible algorithms of machine-centered processes.

Many modes of seeing have shaped the way we observe throughout history, machine aided perception being only one. Art historian Martin Jay argues that sight itself is a culturally-produced concept that changes through time. The act of seeing, as a physiological process, actually functions as part of a larger cultural configuration made up of visual theories of seeing and attendant practices around the physical act that are located in specific historical moments and conditions. Jay borrows the term "scopic regimes" from film scholar Christian Metz to describe these ensembles that shape the act of seeing itself. (Jay 1988, 3) Scopic regimes and the ideologies that inform them exist simultaneously and persistently together, although one dominant regime emerges to characterize modernity. "Cartesian perspectivalism" describes the current visual regime, which establishes sight as the action of an autonomous, rational subject who has the capacity to see the world in its totality from a distance. Jay and other scholars argue that there is no essence or transhistorical meaning to sight, but only historically-located sight. What my dissertation argues, to build upon Jay's thesis, is that invisible or intermediary imaging courtesy of the scanner is decentering the subject from the regime of seeing. No longer is the subject operating as a rational actor, but "sight" itself is a procedure made independent of the subject herself. This project emulates Jay's work to locate scanning as a new form of machine-perception in a particular moment in time and in conjunction with a variety of computational and social practices to model a new relationship between sight and power.

In order to comprehend the magnitude of change that the process of scanning has introduced into the media environment, it behooves us to return to the literature of camera-vision to understand how we critically decipher machine-perception. In the 2008 translation of Italian film theorist Francesco Casetti's book *Eye of the Century*, Casetti uses the figure of the “gaze” to remind us of how integral the apparatus of the cinema was to the last century of modernity (Casetti 2008, 5). While we are still undeniably inside the paradigm of the camera-prosthesis, this framework of seeing is currently undergoing a series of changes in this digital moment. As I argued above, the current moment generates a new kind of intermediary pre-image that exists in a non-optical form that circulates in machine-readable circles of information, prompting actions and operations. As an actor in these networks of operations, the scanner serves as a model for an entirely other kind of “optics,” one that seems to be gaining greater traction in the spaces of everyday infrastructure. Nevertheless, scanning also continues to shore up and occasionally assist the current perceptual framework that it is superseding. If we are facing the destabilizing of an entire apparatus that once framed the experience of modernity, this might be just the opportunity for other buried modes of seeing to become legible (either again or for the first time) in the resultant disorientation.

Epistemology

Related closely to the question of machine-perception are the subsequent epistemological systems that each perceptual mode enables. In particular, the following literature examines the types of knowledge systems that surround and situate machine-machine interactions. Scanning systems articulate the discourse of the scientific and Enlightenment traditions, privileging the construction of a “objective” world in which all things can be known with their ability to see into new spaces through automated measurement, Within the logic of scanning, because all things can be known, all things can also be operated upon with an equal amount of scientific rationality. Through its machine-machine transactions, the scanner serves to automate and extend previous scientific methods to transform unruly material objects into docile, measured scientific objects.

Scanners and other forms of machine-machine procedures operate in the context of so-called objective knowledge. Lorraine Daston and Peter Galison explain the genealogy of the scientific notion of objectivity in the book of the same name. Daston and Galison analyze how objectivity co-evolved with the rise of machine-perception, which depended on an external mediation such as the camera's capacity to register evidence without the intervention of a perceiving subject. Before intervening methods such as the camera, the scientist-artist exemplified the modern schema of natural history, wherein science aimed to create a classification of ideal objects rather than of objects in their infinite variation (Daston and Galison 2007, 26). Daston and Galison link this mode of classification to scientists' tools—printed engravings, for example—and to the philosophical stance of scientific practice at the time. The introduction of the camera and other modes of machine intervention into scientific observation disrupted this model, exposing the supposed fallibility of the observing subject and producing the possibility of a new epistemic virtue— the possibility of mechanical objectivity in science (Daston and Galison 2007, 34). It is into this context of machine intervention that the scanner often figures, serving frequently as a form of verification for "what is out there" in scientific and security fields. Daston and Galison's scholarship shapes this project's understanding of epistemology as deeply historical and situated in very particular times, places, and practices. I use their work as a model for how to approach the scanner's production of new epistemological registers as a historically located phenomenon, influenced always by the latent and emerging systems of knowing around it. We cannot forget that the phenomenon of detection by a scanner must undergo extensive cultural work before it gains legibility and meaning within our current epistemological systems.

The type of cultural work that gives context to and grants meaning to the data of scientific machinery occurs within spaces such as laboratories. The production of knowledge exceeds the medium or the technique of production, because of the fundamental connection between what we know and how our instruments shape that knowing. The instrument of knowledge production works within a system for the social production of knowledge. Bruno Latour, in his early work with Steve Woolgar, studies scientific facticity and how facts and scientific inscription come to have the weight of reality in the circulation of knowledge. Latour and Woolgar write:

> It is not simply that phenomena depend on certain material instrumentation; rather the phenomena are thoroughly constituted by the material setting of the laboratory. The artificial reality, which participants describe in terms of an objective entity, has in fact been constructed by the use of inscription devices. (Latour and Woolgar 1986, 64)

Latour and Woolgar go on to argue that "'reality' cannot be used to explain why a statement becomes a fact, since it is only after it has become a fact that the effect of reality is obtained". (Latour and Woolgar 1986, 180).

An instrument such as the scanner produces data that eventually attain the status of fact, allowing truth claims to be made in an institution such as the laboratory. The laboratory thus shapes and is shaped by its adoption of machine-centered processes. In this way, machine-centered relations go on to construct, to a certain extent, the reality effect itself. This project takes up Latour and Woolgar's points to frame the process undertaken by institutions to naturalize the statements made by scanned images and confer upon them the weight of fact. Building upon their scholarship, this project examines the techno-material work of the scanner and the discursive moves that are necessary to turn a scanned object into a knowable entity.

The historical relation between an epistemology and the medium that shapes it is not always self-evident. Bernike Pasveer demonstrates that, contrary to the claims of some historians of technology, early medical practitioners struggled to interpret the visual correspondence between the x-ray image and the body. Rather than the visual meaning of x-rays being implicitly coded by nature (i.e. x-rays represent a stable referent of the body as it exists "out there"), Pasveer argues that an intensive discursive process took place to reformulate conceptions of the body to bring them into harmony with the x-ray image. Pasveer writes:

> This body had to be crafted carefully out of historically specific other bodies, in order to become a referent for the images. Only through the subtle work of rendering an object that matches and imaging in technology, and vice versa, could and can images be read in terms of that object: as referring to it, as signifying it." (Pasveer 2006, 44)

Media, especially those involved in notions of transparency like the scanner, represent only insofar as the medium and the object historically make one another in a mutually-constructed relationship. Pasveer's work illustrates the point that once an object is scanned, the image produced does not by itself make meaning unless it undergoes a process of discursive framing to make it legible to current systems of epistemology. There is a process of naturalization that causes the meaning of scans to appear matter of fact when they are actually not. Using Pasveer's scholarship as a point of departure, this project considers how scanners relate to their scanned object and the process of discursive manipulation necessary to construct that relationship.

Infrastructure-Informatics

The scanner and other machine-machine functions within our everyday media infrastructure improve medical diagnostics, ease our daily commercial transactions, and mediate material information into virtual data that can be circulated digitally. On a much larger scale, the scanner functions as a machine-machine interface which produces actionable information within computational networks that control everyday transactions. Scanners function as part of an informatic input system that both produces further information and triggers actions within that system. Scanners mediate the everyday world by automating certain interactions between the material and the virtual via the fact and figure of information. In this section, I explore some of the literature on informatics and how the information society has created a situation in which machine-machine interactions are increasingly the norm. This information produced by the scanner plays a critical role in driving these larger systems that come to shape our behavior.

The importance of information as a concept emerges from the ongoing discussion among academics regarding the state of society and its fundamental relationship to capital as it passes out of modernity and into its current configuration wherein information as a commodity and facilitator takes over the primary role vacated by capital. Thinkers like James R. Beniger, Mark Poster and Tiziana Terranova attempt to characterize this new social configuration as "the information society" in opposition to terms like "post-industrial" or "post-modern," which tend to place the current social milieu in relation to the preceding era rather than describe it in its own right. Each of these thinkers attempts to capture some aspect of how an information society operates, the infrastructure and culture that makes these actions possible, and the possibilities for critique and resistance therein.

James R. Beniger approaches the question of the information society as an abstract and largely self-sustained process with a feedback loop, which he compares to circuits. He argues that the origins of the Information Society lie with the need to control and oversee spatially and temporally dispersed production relations that came into being with the Industrial Revolution. With the advent of industrialization, the normal social and market relations of our local economies broke down and were replaced with larger and larger horizons for commercial traffic to expand. This spatially and socially extended mode of production required more and more organization, or control. Control then produces the element of information as a necessary condition of its operation. As Beniger writes:

> Inseparable from the concept of control are the twin activities of information processing and reciprocal communication, complementary factors in any form of control. Information processing is essential to all purposive activity, which is by definition goal directed and must therefore involve the continual comparison of current states to future goals, a basic problem of information processing. (Beniger 1986, 8)

As a consequence, the increasing size and proliferation of industrial society precipitated ever more sophisticated techniques and infrastructure in what Beniger calls the Control Revolution, which was a return to the controlled state of social and productive relations of the past, although now in a new configuration.

The scanner, in its incarnation as infrastructural support, participates as an informational relay in this Control Revolution, most notably as part of automated machine-machine communications. Beniger conceives of information as a control mechanism in modern society, the production and circulation of which is increasingly delegated to machine-machine relations. They have come to initiate and take over social processes in our computationally driven society in ways that exceed the scanner's function as a representational tool and moves it in the realm of operations, triggers, and transactions. The scanner, in its infrastructural form, might be characterized as the embodiment of Beniger's control revolution. Machine-machine information acts as an agent of algorithmic control, taking over the social relations that once enforced the old social and productive configuration. Beniger's scholarship provides a framework for how the scanner fits into the larger function of the information society. Building from Beniger's work, I argue that machine-centered processes might be seen as the natural outcome of this control revolution, arising out of a need to automate certain parts of this circuit of control. Using this notion of control through information, my project builds further upon this idea by considering the very specific ways that machine-machine operations take place and how these new informational relationships encode relations of power and knowledge.

Mark Poster examines the effect of electronic communications on the linguistic constitution of the subject in an information society. Poster takes the information society as a given and, through a play on Marx, names the new linguistic relations "the mode of information." He writes, "By mode of information I similarly suggest that history may be periodized by variations in the structure in this case of symbolic exchange, but also that the current culture gives a certain fetishistic importance to 'information'" (Poster 1990, 6). Moreover, Poster subsumes traditional linguistic signs into the category of information in order to understand language in its new electronically circulating forms and the self-referential genres of language that put classical representation into crisis. As a consequence, the new forms of language that emerge from an information society introduce new manners of constituting subjects that exceed the bounds of the human body and scatter them over time and space.

What becomes of Poster's subject in the world of machine-machine relations? Having been decentered from circuits of modern work, does the subject continue onwards, business as usual? Or does the subject change in becoming part of the new network of machine-human operations? When the very logic that undergirds the institutions in which subjects operate change due to these new machine relationships, the subject too is worked over by these mediating processes. Using Poster's scholarship as a starting point, this project examines the way that machine-machine transactions—as made posisble by the scanner—shape the constitution of the subject even as they delimit the scope of the subject's actions. I argue that these subjects ultimately become an operable part of the whole ensemble of media-machine relations.

Tiziana Terranova, in her book *Network Culture*, approaches information society or culture in a manner much closer to Beniger than Poster. Terranova focuses on the network physics of informational communication, examining the dynamics of information as it moves in culture. She writes, "Information is no longer simply the first level of signification, but the milieu which supports and encloses the production of meaning. There is no meaning, not so much without information, but outside of an information milieu that exceeds and undermines the domain of meaning from all sides" (Terranova 2004, 7). Terranova pushes back on work such as Poster's and asserts that understanding information culture requires that we cease to think in terms of language and representation (i.e. content), but in terms of signals and noise. We can no longer assess cultural politics under the paradigm of earlier approaches, since the very conditions under which we communicate have been "*technically* reduced to its ‘fundamental problem’” (Terranova 2004, 17). The crowded nature of today’s informational milieu forces us to begin first with the question of “Will our message even clear through the noise of other messages and reach our audience?” For Terranova, the dynamics of how we communicate in an electronically mediated information society magnifies Marshall McLuhan’s instruction that the “medium is the message.”

Terranova’s position, to a certain extent, still places the subject at the center of the milieu of information. Machine-machine interactions fit invisibly into this environmental approach to communication, because they are not always rendered for human consumption. This magnifies even further the informational “noise” that Terranova describes in her work. This machine-centered interaction, however, only reaches the human actor after certain algorithmic actions have taken place in regards to the information input. So the amount of informational noise legible of the human subject is much less than what exists in total. My argument in this case deepens Terranova’s conception of the informational environment by expanding the types of communication that circulate to include machine-machine relations as part of an environment or ecology of information.

Across these theorists, I have traced a rough outline of the major indices by which scholars measure the character of the informational society. From the origins of information as a control phenomenon, to its environmental dynamics, to the new constitution of the information subject, to the dizzying experience of information overload, I situate the scanner within the broad triangulation of the information society. Indeed, the scanner serves as a material case study to illustrate exactly how the world becomes mediated into information, and thus brought into the “massless flows” of the informational milieu. Scanners offer an opportunity in media studies to consider the materiality of image-generation in the context of the information society. While these cited works examine information at the broadest level, often disconnected from materiality, this project brings those concerns down to a micro level, focusing on a particular technical process of mediation that concerns the making of information from material objects. I argue that the ways in which matter itself becomes digital information are critical to our larger understanding of how information circulates and flows in the information society.

Technical/Conceptual Assembly

My approach to scanning as a form of machine-machine operations necessitates a mixed methodology comprised of technical archival research, discourse analysis that analyzes how we imagine scanning as a practice, and visual/textual analysis that examines the scans themselves and how they function. I develop a model of inquiry that takes the technical artifact seriously and situates it in the broader cultural context in which discourse and imaginations about scanning processes and scanned images matter. This project engages with the technical artifact in order to ground the investigation in the problem of materiality itself, taking seriously the fact that scanners operate upon material objects and have material consequences.

In this project, I assemble a mixed archive of materials from the literature on early scanners that includes popular printed volumes on scanning for lay audiences, institutional literature produced within corporations that made scanners, scientific academic articles on scanning technology, popular trade magazines, and newspaper and magazine articles. I access this particular technical literature on scanning for two reasons. First, I analyze this archive to illustrate the evolving imaginary of scanning before it coalesced into the distinct notion of scanning we have today. This archive reveals how the inventors and engineers of the time period themselves understood and conceived of the scanner as an intermedial object that engaged the notions of cinema, photography and telegraphy. Second, archival research is necessary for this project to generate a loose genealogy of the scanner, tracing its development as a technology and following the offshoots of the scanning technology that a develop into their own technological branches. Part of my genealogical research took place at the Huntington Library where I accessed the early scanning literature in the Dibner History of Technology archives. Constructing this genealogy reveals the other buried and forgotten types of scanners that fell to the wayside as the process of scanning by machine was developed. This in turn allows this project to constructed multifaceted history of the scanner.

The second component of my research method involves discourse analysis. In this project, I analyze texts that circulate around scanning, such as patents and textbooks as well as social practices of scanning, at the level of the individual and institutional in order to reveal the values and motivations that surround scanning. In addition, I examine the work of the machine-machine transaction in order to reveal the discourses of knowledge and power embedded in their invisible work. The study of discourses surrounding the scanner allows this dissertation to construct an imaginary of the scanner in its social context, especially what we believe that we can know through the scanner. This imaginary shapes both how we interact with the artifact of the scanner, but also the kinds of knowledge that emerge in relation to scanning. Using discourse analysis allows this project to construct a larger understanding of the scanner as process because its work is not just technical, but social as well.

To fully understand the machine-machine model exemplified by scanning, this research must take up discourse analysis to explore how we have come to imagine the very notion of scanning itself. Discourse analysis allows us to piece together the popular imaginary of scanning, which governs how institutions take up and wield a tool like scanning. I take the model of Carolyn Marvin's social history, *When Old Technologies Were New*, as an example of how discursive analysis of historical documents may be pieced together to reveal both the realities and fantasies that erupt during the emergence of new technologies. Part of Marvin's real creativity is that the thinking object at the center of her study is electricity, and the actual objects of study are the discursive trends and social contradictions latent in the professional discourse regarding electricity's place in society. Following her example, I will explore how the popular imaginary of scanning through time taps variously into many different *topos* regarding machine-machine measurement that appears periodically.

The last component of my mixed methodology is visual analysis of scanned images and how they function and circulate. Since scanning participates in a system that produces a dizzying array of visual images, these images remain key components of the larger functioning of scanners rather than merely outputs of the process. By investigating the ways in which these images are mobilized and the rhetorical strategies that arise around them, we can trace the labor that goes into making these images mean. Moreover, images can perform work by triggering operations and transactions when they are scanned, which necessitates an visual analysis of the image in its technical and operative capacities. We must understand also the contextual use of the scanned images as products that operate within a greater milieu composed of discourses, imaginaries of scanning, and technical processes.

My methods are particularly inspired by the work of Lisa Gitelman and her seminal volume *Always Already New: Media History and the Data of Culture*. Gitelman conceives of media as the *result* of both social and economic forces rather than *as themselves* social and economic forces, which lends media an agency that they do not possess (2008, 10). Gitelman is equally averse to the idea of being strictly antideterministic regarding media, as media do in fact shape the conditions of communication. Indeed, what interests me most in Gitelman's argument is the idea that the "matter" of media make a difference and we should mind the local ways in which the very physics of scanning shapes its mediating powers.

In total, I assemble technical archival research, discursive analysis, and visual analysis with the aim to create a mixed method that will adequately treat scanning as a mediating process that still respects the technical artifact of the scanner. This project attempts to define the scanner as a total process, understanding it as a multifaceted blend composed of material machines, discursive practices, and social imaginaries that operate within institutional systems. This mixed method attempts to address such a process by engaging it on the different levels that it operates, from the material to the discursive.

I apply this mixed method to four case studies, which are described in further detail below. The first case is an historical look at the facsimile as an early form of scanning. This particular case study leans the most heavily on archival research and discourse analysis, illuminating the emergence of the scanner as both an imagined mediating process and as a material machine. My second case study concerns the special case of scanning that is the particle accelerator. Through this case study, I examine the contributions of early physics to media history through the figure of the scanner. The third case study considers the barcode scanner, which I chose to illuminate how machine-centered systems of communication create new social and productive configurations. The final case study concerns motion capture performance systems (mocap) used in film making. This case investigates mocap as a scanning system which extracts language from the subject and creates new forms of bodies and performance.

Sites of Scanning

Chapter 1 argues that the history of scanning has always been part of the histories of other technologies, like that of photography and telegraphy. I examine the emergence of scanning by studying the professional literature of electrical engineers and inventors during the period from 1850–1930. At this time, the first attempts to send a photograph across telegraph wires was understood not as a facsimile, but was instead conceived as "tele-vision," or vision-at-a-distance. I break down the "family tree" of scanning technologies from this time period into three loose categories. At its most basic, the act of scanning is not merely a combination of vision (photography) and transmission (radio, telegraph, telephone), but could be said to be fundamentally about signal processing as an analogy for the management of data.

Chapter 2 takes up the particle accelerator as a case study in scanning. Particle accelerators are a special subset of scanners at that take their aim to make visible the invisible parts of matter itself. In this chapter, I examine the history of the particle accelerator to expose the ways in which these accelerators have always already been a part of our media history. From the discovery of the electron to the scientific experiments with radiation in the 19th century, all of the scientific discoveries depend upon the existence of what might be called the first particle accelerator: the film camera. Through all this, I argue that rich new ways of understanding media history can be imagined by eradicating the artificial barriers between science studies and media history. The history of media technology is by its very definition scientific and material in nature, and it behooves us to follow the object of our studies into all the contexts that it demands.

Chapter 3 takes barcodes as its central case study, including a history of barcodes as they developed from a form of automated identification and tally system in the grocery industry through to the present day. Starting as an intermedial invention that combined film technology with telegraphic Morse code, the barcode scanner reinvented the scanner by providing a machine-readable system of annotation. Divorcing the index from any quality of the object itself, the barcode scanner enables new ways of categorization and knowledge. It can be argued that barcode scanners are the material of informatics, as sales data formed the first font of big data. As part of my case study, I specifically look to the online retailer Amazon's giant logistical network, which depends utterly on a command and control system based up on barcoding. Recent developments in business culture shape the way that enterprises such as Amazon and shipping companies ultimately integrate their computer systems to allow the creation of a totalizing system of surveillance over the products that come in and out of the supply chain. What results is a system of scrutinizing of objects that excludes from its purview, but also implicitly controls, the actions of human labor.

Chapter 4 examines motion capture technology in the film industry, with its function of "live scanning." To live scan is to scan a living object, but also to scan a living object in real time. Focusing on several patents, I explicate the work done by three-dimensional optical motion capture system and explore the consequences of mocap systems on the understanding of motion itself. Firstly, the camera is bootstrapped to become a scanner in most motion capture systems, which transforms the camera from the primary instrument of filmmaking into a secondary technology. As the camera becomes less important in the scanning system of mocoap, the discursive insistence that mocap is “just like” traditional film making increases, reifying the traditional filmic ways of seeing. As consequence of the digital nature of mocap systems, enormous amounts of data emerge that need to be be indexed and made searchable. But the nature of motion itself resists being easily searched as it is an experiential and visual form of communication that cannot be easily be described mathematically. Mocap itself begs the question of what is being captured. To that, I answer that motion capture is not merely capturing motion, but it is capturing non-verbal language itself and the system of post-production technology becomes a means of amplifying the signal to noise ratio of mocap as a medium.

Chapter 1 – Television Before TV: Scanner Technologies & the Origins of Images-at-a-Distance

The work of history means always glancing backwards from the present; in doing so, historical writing emerges through the lens of our present understanding of media. From where we now stand, the very word "television" conjures the cultural and technological monolith of American TV with its long broadcast history. Television exists as a *fait accompli* within our technological imaginary. What this chapter does is to re-examine the trope of "tele-vision" as it first manifested, as "sight-at-distance" or "distance vision." Scholars must clear their historical vision in order to appreciate the exciting and nebulous stew of technical and cultural tropes that constituted the imaginary of tele-vision within the technical community before it settled into its present configuration. Indeed, the notion of sight-at-a-distance coalesced not around the invention of TV as we know it, but in the pursuit of the first scanner. Moreover, the scanner itself developed out of a deeply intermedial imagination, one that combined in odd juxtaposition cinema, telegraphy, telephony, radio, and even the long culture of print.

To best grasp the intermediality of scanning, this chapter revisits an historical period from 1850–1935 wherein the engineering community in America pursued the possibility of sending images over great distances. In the technical journals and popular press of this period, I examine the tropes of "seeing" with electrical eyes. In particular, this chapter examines the rich and plentiful media imaginary found in the texts and correspondences of scanning inventors and electrical professionals. This archive is at once more available and more informed than the popular press imagination of scanning. In this case, journalism tended to be more a lagging indicator than a leading one.

Moreover, the material configuration of the technology itself, at this early stage, can illustrate very clearly the inventive imagination of the professional community. Engineering teams do not explicitly state the media from which they draw their technical inspiration, but historical and material interpretation easily unpacks the implied linkages between old and new technologies within the machine itself. Indeed, it is clear to see how the horizon of expectations had engineers recycling mechanical pieces from other technologies in hybrid or mutated form, attempting to imagine how a scan might work (Thorburn and Jenkins 2004, 7–8). The invention of scanning makes clear the professional community was still groping towards how to break down data in such a way that it could be transported across wire or radio. By re-situating ourselves in this period through the figure of the scanner, we can see more clearly the intermedial linkages that may seem less clear from our current vantage point.

Within the family tree of scanning technologies developed between 1850 and 1935, three general trajectories formed around technological approaches to scanning, influenced by an intermedial imaginary of mediated communication. Among the first genealogical branches of scanning was teleautography, or "distance writing." The notion of electrical writing dominated these technologies' material orientation towards communication. If images could be drawn by a human hand, then in the same way, an image could just as easily be drawn by an electrical "hand." This notion of writing organizes the technological configuration of teleautography.

A second line of investigation would lead to a group of optical scanners that currently dominate our understanding of scanning—using light to differentiate between areas of dark and light, translating that to electrical impulses, and decoding those impulses again into a receiving printer. Optical scanners are organized by a fundamental un-bundling of the signal (light/electricity) from the camera lens, forming the most direct use of light and most close coupling to electricity in "seeing" over a distance.

I call the third development within the community of inventors and engineers—the precursor to the progressive scan that would go on to form the fundamental technical component that would enable television—*direct scanning* . The direct scanner, which would later spawn the invention of the beam scanner, works very similarly to the optical scanner. The major difference, however, is the deployment of lenses in the construction of direct scanners. The use of lenses give the direct scanner a material difference that results from influences from film cameras. Moreover, direct scanning, in its earliest attempts, forms an early attempt at what we would today recognize as Skyping, or a form of live, visual telephony. Implicit in the very origins of direct scanning is the trope of multi-media, or combined, simultaneous visual and sound communication. This opposes it to the purely visual optical scanner, whose exemplar was the facsimile machine. These three loosely affiliated types of scanners follow one another generally in chronological order, with the electrical writing instruments arising around the establishment of telegraphy.

Teleautography: Engraving, signature, alphabetic digitization

The scanner family tree, with its loose affiliation of cousins, uncles, and other assorted extended relations tend towards a division by channel of communication. Radio engineers, for example, did not seem to collaborate with telegraphy professionals or telephone companies or even newspapers. The scanners and other electrical visual equipment created by these respective groups tended to be created within professional silos defined by the their communication network, despite the fact that scanner are input and output systems, meaning collaboration and interoperable machines could have been made. But within the professional literature, it becomes clear that each professional group had their respective preferred journals and publications either supported by or associated with that group. Little to no overlap occurred, although I suspect engineers may have read more widely than is evidenced in the archive. As a consequence of these professional silos, the very definition of tele-vision and the scanners that resulted were heavily rooted in specific communications platforms, such as radio, telegraphy, etc.

The Beginnings as Told by the Victors

Few, if any, primary documents from the earliest invention of the scanner exist currently. What remains, however, are histories of technology written between 1890 and 1950 by the professional community that subsequently worked on the scanner, detailing the history of their own profession. It is with a grain of salt and an eye towards historiography that I retell that early history.

According to the oldest book available on the subject, written by Marcus J. Martin in 1891, the very first evidence of a complete scanning system belonged to a British patent submitted by a Scottish inventor named Alexander Bain in 1842 (Martin 1921, 6–7). Bain's system was described as an electrochemical scanner. Also the inventor of the first electrical clock, Bain created a system that worked upon the model of two synchronized pendula (Ranger 1938, 2–3). The pendulum on the sending station was electrified. A sheet of non-conducting material was affixed with metal letters, such as with print type, to form some kind of message and placed beneath the swinging, electrified pendulum. A motor of some type was used to move the message down with each swing of the pendulum so as to, point by point, cover the entirety of the message. As the modified clock pendulum swung back and forth, it came into contact with the metal letters. For that brief second of contact, the system formed a full circuit, sending off an electrical signal to the synchronized pendulum at the receiving station. On the receiving station, another electrified pendulum would spark off an electrical impulse in time with the one on the sending station. On the message bed of the receiving station, however, was a piece of paper made electrically-sensitive by being soaked in potassium iodine. Whenever an electrical current passed through this chemical, it would turn purple, leaving a mark. By this method, Bain was able to perform a scan and "print" a message simultaneously. Richard H. Ranger, an RCA engineer and historian regards Bain's as the basis of all modern scanning, crediting Bain with creating the blueprint for all future electrical picture transmission only shortly after telegraphy itself had come to fruition (Ranger 1938, 2).

Shortly thereafter in 1947, Frederick Bakewell improved upon the model provided by Bain, created the first scanning system that all available engineering and invention writers of the time unanimously regarded as "practical." Bakewell's patent, rather than using two swinging pendula, employs two synchronously rotating drums powered by motors (Martin 1921, 7–9). Affixed to the sending drum was a sheet of thin metal foil with a message or picture painted upon it in insulating ink. The receiving drum was affixed with a sheet of chemically-soaked paper. The system worked exactly like Bain's, only in reverse. As the drum rotated on its axis, a thin electrified needle was held stationary, just touching the drum's surface. Wherever the needle lost contact with the metal, *breaking* its circuit, a signal would be relayed to the receiving drum and a mark made upon the paper. The drum scanner would later come to be the most widely used method of scanning, practical insofar as a picture could be more easily drawn by ink than by assembling metal letters. Giovanni Caselli would eventually take his turn in 1856 to improve upon Bakewell's system, this time combining both Bain's pendulum/clock apparatus (for improved synchronization between the two stations) and Bakewell's insulated-ink-on-tinfoil method. Between these three inventors, the invention of the first scanner can be attributed based upon what evidence remains. Optical scanning methods would directly follow their research in the pursuit of further improvements, but would be nearly thirty years after the discoveries of Bain, Bakewell and Caselli before another inventor could claim success in furthering the art and technology of scanning.

Of particular note in this account laid out by Martin is the manner in which he categorizes these discoveries. There is no indication that either Bain or Bakewell named their apparatuses beyond describing them as devices for the telegraphic transmission of images. In the absence of handy branding, historians would name these inventions after the dominant technical image of the time period. Thus, Martin calls Bain's invention the "chemical telautograph," and Bakewell's system simply the "telautograph" (Martin 1921, 6–7). Caselli, being a savvy scientist who sought out funding and patrons, branded his system the Pantelegraph, indicating that it could send and receive anything (text or images). Later, writers such as Thomas Baker (Baker 1910a, 16–17) would create a distinction between the two, based upon the work of Shelford Bidwell in 1881. The inventions of Bain, Bakewell, and Caselli would be grouped and called "image telegraph" or "copying telegraph." Subsequent systems would be defined against these three and named to emphasize the image-based nature of the technology, "phototelegraphy" and "telephotography" being two common iterations. Many other variations became possible as the emphasis on the channel of communication changed to highlight that an image was being sent: photoradiograms (Ranger

1938), facsimile picture transmission (Zworykin 1938), radiovision (C. F. Jenkins 1929), photophone (Bidwell 1880), wireless pictures (Baker 1927), and even television (Herbert E. Ives 1927). The term "scanner" emerged from the success of later scanners at delivering a fully photographic picture via line scanning, an achievement enabled by the discovery of the selenium cell, which I will describe the following section.

But the relegation of the original scanners to "telautography" is a telling distinction. On the one hand, it is easy to see how later inventors would view the work of Bain, Bakewell, and Caselli. All of the tests conducted tended to emphasize text or hand-drawn illustrations using insulating ink (a form of shellac). These pictures, despite being line scanned like later optical scanners, still had a human hand in their making. The "autograph" not only denoted the written or illustrated nature of the original copies, but also its perceived value merely as an autographing or copying machine. These "autographic" scanners, however, do not fully fall into the truly "written" imagination that would emerge from the work of telegraphic scanning. In principle, Bakewell and Caselli's machines would later form the basis of the first photography based scanning by Arthur Korn.

Truly telautographic models of communication arose simultaneously to the discovery of selenium-based optical systems. In 1888, Western Electrician—one of the major professional publications for telegraphy engineers—published an article on Professor Elisha Gray's telautograph system ("Gray's Telautograph" 1888). In essence, this system was an electro-mechanical set of machines—a transmitter and receiver connected to telegraphy wires—that transmitted hand-written messages. The transmitter consisted of a stylus (ink pen) connected to two electrical rotors, one above the writing area that would translate vertical (y-axis) motion, and one to the right that translated horizontal (x-axis) motion. The act of writing would fire off electrical signals by mechanical means that would replicate the exact mechanical motions made by the stylus wielder. While the inventions of Bain, Bakewell and Caselli made writing hand purely incidental to the act of scanning, Gray's telautograph system electromechanically simulated pure handwriting, truly earning the name "autography."

Key to the telautograph system is the notion of authenticity attributed to of the act of hand writing a message or signature. The act of hand writing text captures the trace of a bodily motion. Because the telautograph captures the displacement of a stylus, it is not simply a machine for textual communication. In contrast to technological interventions on writing such as the typewriter, the telautograph leaves a trace of the bodily performance of a communication in the act of communication itself. The product of the telautograph thus carries a bodily trace linked to the notion of an original, despite being a long-distance reproduction of the originating act of writing. The signature especially stands in the for the presence of a person, serving as a kind of legal and technical "double." This bodily trace explains in some ways the popularity of the telautograph well into the twentieth century as an easy, short form method of communication within buildings such as hotels and banks.

Another relevant example of telautography in image transmission would take the role of language in pre-digital directions. Thomas Thorne Baker's 1910 volume *The Telegraphic Transmission of Photographs* recounts the history of phototelegraphy for popular consumption. In an overview of historical attempts to send pictures over a distance, Baker muses on the theoretical requirements to successfully accomplish such a feat:

> But a picture, just like a written message, can be split up into component parts; the letters forming a word have a distinct meaning when seen assembled together in proper order, while the dots and dashes forming a letter, according to the Morse code, possess similarly an intelligent meaning

> when grouped together in correct order; *by building up a complete picture with dots or small areas of varying depth, size, or density we can produce a picture in a strictly comparable manner* (Baker 1910, 1–2).

Here we see explicit conjecture wherein Baker likens the image to linguistic systems such as Morse code, where proper order allows meaning to be extracted once the signals are reassembled. Baker goes on to cite an interesting, but ultimately untenable example of early digital thinking:

> One ingenious attempt at the solution of photo-telegraphy—as ingenious as it is impracticable—has been to divide up a picture into thousands of small parts, representing each by a certain letter of the alphabet, according to its density; thus a light part might be called C or D, a dark part Y or Z, and so on. The letters are telegraphed to an operator, who forms a fresh picture by building it up with small 'parts' whose densities are in accordance with the respective letters (Baker 1910, 3).

The linkages remain strong in this period between language and scanning. Indeed, most early scanning systems were imagined to transfer not images, but written inscriptions, such as signatures for legal purposes and blueprints, notes, etc., which were less difficult to approximate than the complexity of a photograph. What is of interest in this excerpt is the figure of the "operator," who "forms a fresh picture by building up with small 'parts'." What seems to be telegraphed is a set of instructions through which a trained human might re-draw a picture on the other end. In essence, this is an early from of gridded imagery: paint-by-numbers for the telegraphic age.

The downfall of this alphabetic thinking, of course, lies in its unwieldy process. Here, it is much easier to see the hand of "autography" in the notion of telautography. The human hand and its interpretive artistry play a fundamental part in the rendering of a photograph. Moreover, the material of language itself features heavily in the design of this system (which has no name). The very shades that create the gridded image correspond to alphabetic values.

This adaptation Morse code could be considered a shortcut towards a new aim, but it could just as easily be understood as the heavy influence that textuality continued to play in the pursuit of imaging technology during this time.

A final example of image telegraphy to note would be the telegraphy engraving system of Noah Steiner Amstutz. Amstutz first published his musings regarding a possible system of photograph telegraphy in the *The Photogram*, an engraver's magazine, in 1899. In it, he detailed a telegraphic engraving system, creating metal engravings that could later be used to make multiple printed copies (Gamble 1899). The system rested entirely on the preparation of the photographic film. Using daguerreotype photography as the basis of his work, Amstutz put the silver photographs through a process that would create a textured surface, by washing away some of the silver emulsion after exposure. Afterward, Amstutz was left with a thin photograph that had ridges and valleys corresponding to the density of *light* in the original image (Dougherty 1999, 7). Deep valleys or depressions would represent highly lit areas and shallow hills shadows. Putting this photo under an electrified needle configuration like Bakewell's cylinders allowed these variations of height to translate to the receiver unit. On the reception unit, a sharp V-shaped stylus would mimic the changes in height on the surface of the original photograph (Baker 1910b, 8). This stylus would cut into the soft receiving material, a copper sheet wrapped around the receiver drum, creating a photographic engraving. Where the photograph was lighter, the valleys in the original photo would be deeper. Correspondingly, the engraving would be cut deeper in that area, resulting in less ink being put to paper.

Amstutz's system never saw practical use, because it was impractical to build a transmitter capable of the voltage necessary to cut a copper relief so deeply as to produce a comprehensible image (Isakson 1922, 796).

However, professionals during this period and after hail his achievement as the first attempt to translate photography through telegraphic copy, attempting a method that could reproduce half-tone with fidelity (Isakson 1922, 796). This form of line scanning is also the first on record to scan with the intention of producing what I call *reproducible media,* marking it as a truly unique first case in the scanning family. In no other scanning system until the development of Arthur Korn's "telautograph" (here a misnomer) do we see the production of another intermediate form that might possibly bear further media iterations. While of these three examples, only Amstutz's system represents an attempt to introduce photographic images into telegraphic scanning, and thus is often categorized with the group of latter day telephotography rather than telautography systems. Amstutz's system is, of the three, also the only purely mechanical form of image production over distance. No actual hand produces the image in Amstutz's machine. The presence of a photographically engraved plate, however, ties Amstutz into a system of print and printmaking, which makes it a more transitional system between true telautography and telephotography.

Optical Scanning: Facsimiles and drum scanners and selenium cells, oh my!

This section addresses two major turning points of optical scanning: the discovery of a scanning use for the selenium cell by Shelford Bidwell, and the development of a more responsive selenium coupling by Arthur Korn. These two discoveries would bring the scanner towards the most common configuration of optical scanning. Other scanners would follow in the spirit of this mold, improving upon the speed and quality of the image though not the form of the scanner itself.

The first major turning point in the pursuit of optical scanning occurred in 1881 with the successful use of the selenium cell by Shelford Bidwell, a renowned physicist who studied light and optical phenomena (Baker 1910b, 12–14). In a *Nature* article, Bidwell announced the result of his experiments with selenium, which would come to allow the true photographic transmission sought after by inventors in the wake of Bain, Bakewell, and Caselli. One of selenium's most important properties lies with its reactivity to light. Upon exposure, selenium will change its electrical resistance in proportion to the intensity of light to which it is exposed, making it an excellent intermediary for the scanning system (Baker 1927, 21–30). An early configuration of Bidwell's telephotography machine created a familiar form of scanning by light ("Tele-Photography" 1881). Using a pinhole device, the machine shined a tiny spot of intense light horizontally across a photograph mounted to a turning cylinder drum. As the scanning head of light moved down the cylinder, the turning of the drum would allow the light to draw a continuous spiral of light over the entire picture. Also mounted on the scanning head was a selenium cell. Where the light beam illuminated a dark surface, very little light would reflect between the photographic surface and the cell. The varying resistances that resulted would send electrical signals to a receiving station that would draw a stylus over a synchronized drum covered in chemically-soaked paper. The stylus on the receiver would draw with varying bursts of electricity, producing darker or lighter areas that would better mimic the original photograph. Here we see the first true optical scanner that functioned by signal modulation: the light beam from the pinhole apparatus sent out a light sign and the difference in light reflected back was registered by the photo-sensitive selenium cell, which translated this difference to electrical impulses. With the production of this device, Bidwell may well have invented optical scanning.

The drawback of Bidwell's work was in overcoming the lag in selenium response, as selenium changed resistance more slowly than the drum scanner turned (Baker 1927, 21–28). The lagging speed of selenium was overcome first by Arthur Korn, often called the "father of television" (Korn and Korn 1950). While Korn is often credited with being the first to send images via telegraphic wire, this history shows that many inventions preceded his work. Korn's true accomplishment was in finding a mathematical solution to the selenium lag present in Bidwell's design. Because the method Korn developed is technically complex, and requires some mathematical formulae to be understood, I will not explain it fully here. In essence, Korn's phototelegraphic system improved upon Bidwell's model by mounting a photographic negative to a glass cylinder rather than the photograph itself (Martin 1921, 30–33). In Korn's design, a pinhole light mount shines its beam of light onto a celluloid negative, but because of the transparency of both the celluloid and the glass, the light beam passes through at varying intensities to the other side, and a prism redirects the light beam to a selenium cell. Both Bidwell's original commercially viable scanner and Korn's configuration vastly improved the quality of scanned images, making it possible to truly scan photographs for the first time (Bidwell 1907).

The Korn system has the honor of being the first widely used system in news journalism. The receiving unit would synchronously expose a strip of unexposed film to the same variation of light, in essence, making an electrified copy of a photographic negative at a distance. This scanning system would allow newspapers to make prints in-house and report the news with images beginning at the turn of the century. Photography would come to change the very character of journalism, and it was enabled by the selenium cell modification (*AP Wirephoto: A Miracle of Modern Newsgathering* 1939, 20–21).

Photographic transmission took on a truly massive scale with the inception of the AP

Wirephoto network in 1935, a major organizational invention of the Associated Press in partnership with AT&T (Coopersmith 2000). The Wirephoto, though touted as original and path-breaking, built from the AT&T system, which bears a great deal of resemblance to the Korn system. AP Wirephoto's success in the news market had as much to do with the Associated Press' *de facto* domination of the market as it did with the quality of the photographs available. Moreover, the Associated Press had multiple offices and stations throughout the nation, all of which it coordinated by telephone. When a sending station was ready, all receiving stations would be called on the telephone to help synchronize the process in real time (*AP Wirephoto: A Miracle of Modern Newsgathering* 1939, 20). The signal then could be sent from one station simultaneously to multiple other AP stations in kind of networked hub-and-spoke system not unlike those used by major airlines. From the major Associated Press hubs large enough to have receiving and sending stations, the negatives could be sent out to smaller town presses via railroad or automobile to make deadline (*AP Wirephoto: A Miracle of Modern Newsgathering* 1939, 9). This practice was already in place before Wirephoto, and would only become that much more efficient after.

This group of optical scanners shared one very important feature: the coterminous nature of transmission and reproduction. Before the advent of computing, the ability to "save" one's data onto an intermediary technology was nonexistent. As a consequence, transmission was reproduction. Any scan sent must be immediately received and reproduced as a printout or as a light-imprinted negative. Paper and celluloid might be themselves considered "storage" technologies, but there cannot be a delay between the transmission and the reproduction of a scanned image. These functions are necessarily coupled through the technological parameters and limitations of scanning at this time. The intermediary form, in this case, was a series of electrical impulses sent live over the wire or the radio, which must be decoded and reassembled. There can be no delay in reassembly or else the entire signal will necessarily become scrambled. Thus, scanning was always necessarily performed “live” at this time.

The main historical trajectory of scanning technologies consists of different forms of optical scanning. Because of optical scanning’s concentrated development over a short period of time, the community of engineers pushed this technology forward quickly and with great commercial success. The success of the scanning systems arising out of Bidwell and Korn’s inventions would eventually lead to the steady usage of optical scanners in industry and communications. Eventually, this trajectory of optical scanners would take up the name *facsimile*, a term that would eventually overtake the previous terms by 1929 in the popular press. No longer a product habitually tied to telegraphy, the facsimile would come to be its own technological object. In press such as the *New York Times*, little distinction would be made between the use of the facsimile via radio or via telephone (Guilfoyle 1945). All that mattered was the magic of the fax itself (“Fingerprints Are Now Transmitted by Wire” 1922; Harrison 1950).

Direct Scanning: Cinema and Telephony in the Development of Progressing Beam Scanning

The schematics of the beam scanner illustrate the intermedial approach engineers took to developing scanning technology. Frank Gray and Herbert E. Ives, two inventors from Bell Telephone Laboratories, developed the first beam scanning system in a 1927, publishing their findings in a series of related articles in the Journal of the Optical Society of America (JOSA). In a 1928 article, Gray and Ives produce an illustration of the basic components of what they call their “direct scanning system.” Direct scanning requires four basic elements: an object to be scanned; a lens to “create an image of the object; a disc with a spiral of holes that effectively creates scanned effect (Nipkow disc), and a photoelectric cell.

The process of direct scanning works as follows. A lens concentrates light bouncing off the scanned object (either provided by some source of intense illumination). The lens is necessary in this case to gather light and form a much smaller image of the object. This small image would allow much faster scanning, making it feasible to send a live signal over some distance. The lens projects this tiny image onto the surface of a Nipkow disc. The function of the Nipkow disc is to separate the image into discrete lines that can be registered by the photoelectric cell, one by one (Petersen 2003, 684). Its function is to create the scanning effect by dividing the virtual image into discrete and equal parts. The disc, made of some heavy, light-blocking material like metal, is punctured with small, evenly spaced holes that wind around the edge of the disc in a spiral. Each hole is displaced just enough from the previous one that the whole image would be scanned from top to bottom in one complete revolution of the disc (F. Gray and IVES 1928, 429). The disc is set upon some rod, with a motor attached, which spins the disc in a constant speed. As the disc rotates, the each hole allows a horizontal slice of the image to be registered. The spiral of holes creates the effect of a stack of horizontal scanned lines, creating the first mechanical version of the progressive scan that later defined television.

From a backwards glancing perspective, the Nipkow disc is a form of digitization, the formation of discrete data from a continuous image. It is the original rastering device, and beam scanning (or direct scanning) is the origin of all subsequent raster scanning, which is used in devices as varied as TV and modern laser microscopy. Rastering would later come to revolutionize digital images and the status of the photographic image (Mitchell 1994, 3–4). At the same time, the Nipkow disc evinces some intensely cinematic qualities. The disc functions analogously to a strip of film, which captures a series of images that are recomposed to create the effect of motion. A film strip, however, is not a raster. Each cell of a film strip captures a whole image and is viewed in a series at a speed that the eye perceives as true motion (24 frames per second, for example). A progressive raster like the Nipkow disc takes a single image and divides it into equal parts. These equal parts are also projected in a series, one line at a time in order from top to bottom to form a complete image. In order to achieve the perception of true motion, each complete image must be projected as quickly as a strip of film, requiring the individual lines of each image to projected at a fraction of the speed of film.

Though a raster differs from film in its further decomposition and re-composition of the image into discrete pieces, the Nipkow disc bears remarkable resemblance to many so-called "pre-cinematic" optical machines and toys. The phenakistoscope, for example, creates movement by the action of two spinning discs, one with drawings in decomposed motion behind one with vertical slits that creates the scanning effect (Strauven 2011, 151) . By peering into the space where the slits rotate, the viewer sees the images on the rear disc move. Were the front disc missing, however, the images would effectively blur together. It is the front disc with its slits that creates the scanning effect necessary for the perception of motion. The same principle applies to the Zoetrope, which is built not as a spinning disc, but as a spinning cylinder into which the viewer directs their gaze.

At first glance, the diagram of the direct scanning apparatus recalls a camera: a lens, an intermittent motion device, an aperture (the holes in the Nipkow disc), and a photosensitive material that records or imprints the configuration of light in a serial manner. The cinematic origins of direct scanning connect it directly to modern television. However, the Nipkow disc—the act of rastering—divides cinema and television on a material level. Both the historical fact and the historical figure of the scanner produce the necessary step between persistence-of-vision film and the progressive scan of television.

The lens that so defines cinema is a practical necessity of rastering rather than a defining trait. A truly direct scan could be created that required no lens, but the size of the Nipkow disc would be truly immense if it were made proportional to the size of a human being the scene to be recorded. The concentration of the image via lenses is about a reduction of data for the practical limitations of both space and increased speed of data transfer. Film theorists who find digital precursors in film have a point, in that the reduction and division of data into discrete packages for reassembly is a defining, though not sufficient, characteristic of the digital. In that sense, the cinematic and "pre-cinematic" cannot be truly divided from subsequent technologies such as television through a definition based solely on the reduction and division of data. However, direct scanning does not show the full intermedial imagination of scanning. The transformation of the direct scanner into its next iteration would shift the scanner from its cinematic roots towards what I would call a more *scannerly* configuration, in which light, not the lens, functions as the eye of the scanner. In 1928 March issue of JOSA, Frank Gray published the details of the "beam scanning" system, a system which would depart from scanning's cinematic precursor by transforming the lens from an image producer into a form of laser beam (Frank Gray 1928). Using a beam of light to trace the object, the new beam scanner departs from the virtual image system of the film camera entirely in favor of "seeing" directly with light. The impetus for this change results from the nature of the film camera apparatus. The lens, which functions as the analogous "eye," actually produces a practical limitation within the direct scanning system. In order to scan an image as quickly as television requires, that image must be small, thus necessitating a lens with a small focal length. In order to produce a sufficiently bright image to stimulate the photoelectric cell through such a tiny aperture in the Nipkow disc, the object must be illuminated with extremely intense light at a very close distance (bright spotlights at approximately 4 feet). This level of illumination would prove very uncomfortable for the subject being scanned and ultimately impossible to distribute as a consumer item.

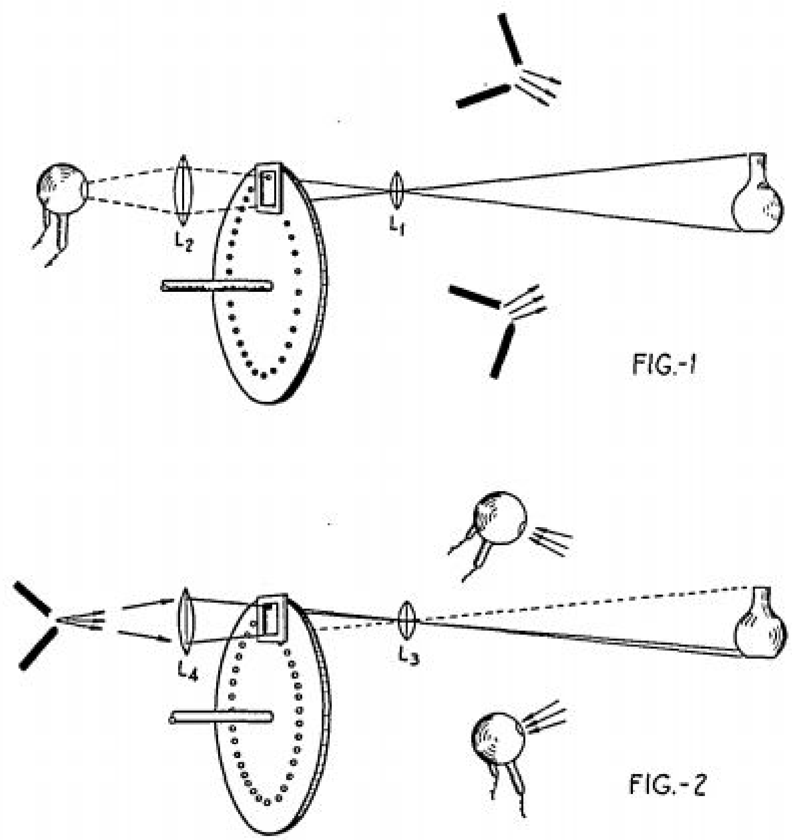

FIG. 1. *The apertures in the disk scan an image of the subject formed by a lens.*

FIG. 2. *The subject is scanned directly by a moving beam of light projection from apertures in the disk*

Figure 1: Contrast between the initial lensed systems of direct scanning.

As a consequence of the limitation created by the film-style lens arrangement, Bell Labs created an alternative form of direct scanning that transforms the lens's function within the whole scanning apparatus. Figure 1 is a reproduction of a diagram from the 1928 article by Frank Gray illustrating the differences between the direct scanning setup and the beam scanning setup. The top figure represents the direct scanning system discussed earlier. The bottom illustration shows the beam scanner. In essence, the limitations and difficulties of direct scanning are evaded by scanning subjects directly with a moving beam of light. The beam scanner entirely eliminates image formation of any kind. The optical system of direct scanning, with its cinematic precursor, is flipped on its axis. Rather than illuminate the subject, the light source lies behind the Nipkow disc, which continues to provide rastering functions. Rather than controlling what can be seen by the photoelectric cell through its aperture, the disc now controls the progress of the beam of light up or down the subject. In this model, the lens acts as a light-concentrating device to create a thin beam of light which traces rapidly overlapping lines of light across the subject's face. The lens functions purely as a mechanical laser of sorts. The lens's status as image-maker disappears, bringing this model of scanning closest to our modern understanding of optical scanning. The light, or signal, sees the subject. Scanning a subject intermittently with a thin beam of light, requires intense light briefly enough to produce little discomfort for the subject. Along with gains in the sensitivity of photoelectric cells, the beam scanner's apparatus can successfully sense and transmit images without difficulty. The beam scanning method also overcomes the limited depth of field of the direct scanner's lens, with its comparatively shallow focal length. With direct scanning, if a subject should accidentally lean forward or backward even a little, the resulting image would be out of focus. With the beam scanner's improved focal length, the problem of focus disappears. The subject need only occupy the beam's region of scanning. However, despite these improvements, these two scanning systems are optically equivalent. Either system produces the exact same image, but the beam scanner works within fewer material and physical limitations.

Beam scanning led the scanner away from its cinematic and pre-cinematic origins toward a technical and material arrangement that was entirely new and unique to the scanning medium. Its elimination of the intermediate image so key to film freed the scanner to sense by direct *signal translation*. The centrality of signal translation to scanning can only be fully appreciated by tracing its material movement away from cinema. Yet intermediality in the scanner's genealogy did not end with the fulfillment of its initial promise of direct sensing. Bell Laboratories was, after all, a telephone company. To Bell, the possibility of sending a live image via telephone merely meant the first step in multiplexing that signal to allow speech with the person watching.

PicturePhone, Skype

In a follow up article to the pair of 1928 articles detailed above, inventor Herbert E. Ives wrote a 1931 addendum that detailed some of the practical concerns that the Bell Lab team had since ironed out (H. E. Ives 1931a). In this article, Ives refers to the beam scanning system as a "two-way television system," a term only used in the original introductory article and nowhere else. Ives states that "it is an inherent feature of the two-way television system that *either* user is continuously scanned as he views the image from the distant station" (H. E. Ives 1931a, 101). This example demonstrates how implicit in the development of scanning was the conception of liveness. The telephone functioned not only as the "channel" of communication via the cables of the national network, but as the basis of the very approach to scanning as tele-vision. These modifications to the beam scanner system allowed both participants to see one another, going so far as to hide a microphone inside the apparatus to allow the speakers to have a “hands-free” experience (as they feared the phone handset would be distracting to users) [See Illustration 5]. If two subjects could only see one another by taking turns, then the television system would be less than useful. This assumption is so implicit and naturalized that it seems to have been left out of the 1929 and 1931 articles I cite above. The intention to allow two subjects to both see and hear one another is only mentioned in a 1927 article printed elsewhere in the proceedings of the American Institute of Electrical Engineers, detailing their original intentions for the system (Herbert E. Ives 1927). Signal multiplexing was being worked out at this time, allowing both sound and other electrical signals to be sent through the same wire (in the case of telephone) or the same radio wave (in the case of radio).

Scanning’s intermedial imagination points to a trope that crops up over and over again in film, television, and novels: the Picturephone (Meacham 1966; Davis 1970; Falk 1973). The seeds of that technological trope seem to originate in Bell Labs’s conception of 2-way television discussed here (Herbert E. Ives, Gray, and Baldwin 1930). Although Bell Labs would not launch their Picturephone system until 1970, the initial seeds of their work were rooted in this pursuit of beam scanning in the late 1920s. Bell even collaborated with AT&T to install and test the first beam scanner apparatus (Herbert E. Ives 1927), a partnership that indicated the telephone sector’s interest in this form of communication and its perceived ability to collapse space further (Lipartito 2003). Although the Picturephone failed to gain an audience, the Picturephone trope would eventually find an consumer audience in webcam communication and Skype. Voice over IP, the method of making telephone calls over Internet Protocol networks, had a market before Skype took it that next step further. The shared notion between the beam scanner, the Picturephone and Skype is visual liveness.

The assumption of liveness has long been a trope of broadcast television and much scholarship has been dedicated to debunking the idea, especially as taped broadcast became the standard model in the United States (Vianello 1985; Feuer 1983; Caldwell 1995). Some arguments for the intrinsic liveness of television lay in its ability to show events in distant places, as an eye displaced across space. Others argue the materiality of television, the beam scanning of images onto a screen, is predicated upon a lack of permanence, therefore a kind of liveness (Vianello 1985). However, I argue that the intermedial model of the beam scanning system was based on a telephonic notion of liveness, rather than the concept of intrinsic televisual liveness that scholars have debated (Mills 1928, 3–5). What if notions of liveness as applied to television arose from the way the scanner was built, without an option to record the signal between two subjects to permanent record? By the 1930s, the social protocols of telephone use were understood to exclude permanent recording, outside of exceptional circumstances of the law that further confirm telephony's apparent immateriality (Marvin 1988a, 63–108). At Bell Laboratories at least, tele-vision by beam scanning was live because telephony was live, and visual scanning was a form of telephony. It was only after further development of the beam scanning system that Bell Labs began considering the transmission of motion picture film via their television system (H. E. Ives 1931b). Even then, Herbert E. Ives laments the loss of the "practical simultaneity of event and viewing, which is the unique offering of television" as he understood that liveness then (H. E. Ives 1931b, 535).

It would not be long after these sets of papers that television as we now know it emerged. Other television systems occurred simultaneously to the Bell Labs beam scanner. I chose this set of writings in particular, as opposed to, for example, the Baird television system, because it more clearly showed the intermedial nature of tele-vision before television (Greenlee 2010). While the Baird television system bears an almost exact resemblance to the Bell Labs system, the Baird system would go on to prominence as one of the discoveries that lead to the invention of television. The Bell Labs system, while similar, worked on a telephonic imaginary, connecting together tropes of telephony and film (Mills 1928, 5). This technological trajectory, as well as the intermedial imaginary it implied, shows the pursuit of the scanner model most clearly as an end in itself, rather than as a byproduct of television. Indeed, this history shows that television came about from the achievement of beam scanning, and in 1909, was originally understood to be a sub-branch of the pursuit of phototelegraphy (Martin 1921, 96).

Reflections: What is/was tele-vision?

Frank Gray, in 1928, observed these basic conditions in defining a television system:

> Television is the electrical transmission of images of a changing scene so that it can be observed at a distant station. In the practical accomplishment of such a result it is desirable to make the transmission over a limited and preferably over a single telephone line or other equivalent channel of communication. Such a channel of communication can at most simply transmit an electrical current that varies with time, the channel is incapable of directly transmitting either light or the complicated spacial distribution of brightness that occurs in even the simplest view. *The problem of television may therefore be broadly outlined as that of converting a spacial distribution of brightness into an electric current that varies with time*, *transmitting the varying current to a distant station, and reconverting the current back into light intensity in such a manner as to reconstruct an image of the distant view* (Frank Gray 1928, 177; emphasis added).

Gray asserts that television was a problem of light and space. At first glance this seems obvious. Television, sight over distance, conquers space by allowing sight to collapse distance. But this definition could as easily describe the scanner. Scanning results from the breakdown to a spatial configuration of light, whether two or three-dimensional, into a data form that can be sent and decoded back into its original form. At its most basic, the act of scanning is not merely a combination of vision (photography) and transmission (radio, telegraph, telephone), but could be said to be fundamentally about signal processing as an analogy for the management of data.

Space implies also a problem of time: in particular, the relation of synchronicity to liveness as a consequence of the spatial management of data in scanning. The motif of time is present even in the work of Bain and Caselli, as seen in the use of the electrified pendulums (cannibalized for clockwork systems), which formed a part of the synchronizing mechanism. The swinging of each pendulum serves to traverse the surface of the scanned item, but also in traveling spatially, the pendulum reads the surface of the item through time. A major failing of many of the scanning systems, from Bain through to Arthur Korn, was the failure to maintain synchronicity between the transmitter and receiver (Isakson 1922, 797). Lag between the units resulted in image disjunction, skipping and mistakes. The selenium cell's inertia and lack of sensitivity also contributed to this asynchronicity problem. Here, synchronicity can be linked to the concept of liveness again, but a form of exact, perfect liveness. As in Claude Shannon's model of information, the technological disruption of the signal distorts the message to the receiver (in scanning, this results in a messed up picture). The need for exact temporal coupling of the sender and receiver puts liveness at the center of many forms of scanning.

In 1950, linguist Falk Johnson countered the Oxford English Dictionary's claim that the earliest known use of the term “television” occurred in 1909 in a British technical publication. Instead, Johnson showed that television existed as a term, and implicitly an imaginary machine, in English language circulation at least two to three years prior. In its earliest use that Johnson could locate, the term television remained closely tied to the idea of vision through telegraphy. It concerned wired forms of visual information transfer, excluding entirely the category of wireless signals, such as radio (Johnson 1950, 157)). Moreover, Johnson interprets the “vision” portion of this “far vision” to “consist either of a ‘moving’ picture, such as that of a person talking into a telephone, or a still picture, such as a drawing or a photograph” (Johnson 1950, 157). The evidence of my research in this chapter linking television, telephony, and scanning bears out both of Johnson’s observations.

First, there existed a substantial division between vision-by-wire and vision-by-wireless in the primary technical literature that continued into the late 1920s. Second, while this distinction between channels of informatic delivery faded away quickly in the popular literature, both popular and technical literature continued to conflate motion and still images in its conception of tele-vision until nearly 1930. The division between the different channels of delivery may have resulted from the understandable division between professionals working on radio and those working on telegraphy/telephony. These respective technologies differed in their operation and required disparate sets of technical knowledge, creating a “natural” division in the professional societies that operated them. This division, however, may have extended beyond their operational differences.

These early divisions of media were rooted in the earliest conception of communication as a form of travel, a view that persists to this day. The early Canadian school of communications theory, led by figures such as Harold Innis, James Carey, and

Marshall McLuhan, explored the connection between "channels" of communication, through which goods and data move, and media theory. For these theorists, the medium shapes, delimits, and enables how the content of communication moves through time and space. The concept of the medium that defines the nature of information is bound up in this theory with the image of distribution over space rather than time, a bias of our modern global imagination. In this discursive context, the first productive examination of the scanner as a medium—as a technological point of interface—did not gain traction until after 1950.

It was the society of radio engineers at the Television Convention in 1952 that first departed from thinking of scanning mediation as a channel or mode of delivery. In the opening of their presentation, titled "The History of Television," the authors—G. R. M. Garratt, M.A. and A. H. Mumford—define "television" in unprecedentedly broad terms, recognizing scanning as a central part of this definition:

> Although the word "television" has come to be associated in the public mind with the broadcasting of entertainment by means of radio, such a limitation seems unacceptable and illogical in dealing with the history of the subject. The authors have therefore interpreted their task as one involving a broad historical review of the various methods whereby *visual phenomena may be reproduced at a distance but without regard to the method of transmission or the time occupied in transmission*. In consequence of this interpretation, the earlier part of the paper deals with a number of proposals which aimed at providing a reproduction on paper of the original image in a form which, to-day, we should associate more with the practice of photo-telegraphy than with modern television. *Since all practical systems of either photo-telegraphy or television involve some form of scanning, it will be realized that both arts have a common ancestry*." (Garratt and Mumford 1952, 25).

Garratt et al, in this opening salvo against the persistent historical framing of media systems as channels, attempt to re-define the categories of media by their resulting product, i.e. images at a distance. This broad definition of television would become the dominant way of thinking about media in our modern age: the dispersion of "television" over any and every screen possible, resulting in the current (or quite possibly ongoing) crisis over what defines television in today's "convergence culture" (H. Jenkins 2006). The most important part of this quotation to my project lies in its last sentence. Here, in 1952, is finally an historical recognition of the common origin of electrically transmitted images-at-a-distance. The authors of this paper construct an historical narrative centralizing scanning, creating a form of technological origin story that dominates the field of history of technology.

From the very earliest technical publications on the scanner in the form of the facsimile, professionals of the telecommunications field have been telling their own history as part of the ongoing formation of a professional culture (Marvin 1988). This historical narrative by Garratt et al, however, represents the first reframing of the narrative of tele-vision away from the mode of distribution to the point of access, or what we would call the interface. This re-framing of the techno-historical definition of tele-vision trails behind the popular press, for whom the technical specificities bear less importance ("Telephoned Pictures in British Press" 1929). Garratt et al. establish a genealogy of technology that places the scanner at the fork in a family tree that will eventually produce the sibling technologies of television and the facsimile. The "origin animal" of this evolutionary trend is the scanner. Whether it is right to accord such a prestigious position as being an origin of the institution of television to the scanner, this historical narrative separates the scanner as an instrumental media technology from its participation in the separate, yet deeply entangled, histories of other more established techno-historical narratives.

Garratt et al. refine their concept of "seeing-at-a-distance" to "seeing by electricity," a phrase in historical circulation that designates the broad umbrella of scanning. Using this term, the authors of this paper trace the genealogy of television not through the usual suspects, but through decidedly marginal figures and more importantly, through several imagined, rather than realized, scanners. The authors give equal weight to the plans, conjectures, and musings of inventors as they do to machines that gained widespread application. These real and imagined machines indicate several things in the broad imaginary of scanning from its first glimmerings in the mid-1850s to the turn of the century.

Though Garratt et al.'s historical narrative recognizes scanning as a medium, their term for this medium—"seeing by electricity"—does not sufficiently express the deep ties of the scanner to the concept of light. In all the post-1950 archival material that I have seen, Alexander Bain's earliest attempts at scanning in 1843 seem to be excluded precisely because they do not fit within the model of electricity as light. As described above, Bain's machine involved a model of touch scanning: the electrified stylus traced over an insulated surface until it hit a conducting metal object; the touch of the stylus completed a circuit, and a charge would be sent to the printer where a blue dot would be "written" onto a chemically-sensitive piece of paper. Bain's model was not practical, since it could not transmit an image such as a photograph and all subsequent attempts at creating a scanner were purely light-based. Scanning began, according to these narratives, when the electrified stylus was replaced by a beam of light. As in modern flatbed scanners or photocopiers, the scanner head would read differences in light and dark in the original document. There is a particular emphasis in this literature on light as the defining property of communication or vision, which in some cases it was (as in the light-based definitions of film, television, and photography). The discourse of scanning at this point was still caught up in the imagery of illumination, which lies in part with the dominance of electrified cities and cinema. Light enabled things to be seen, and electricity is nothing if not the source of light.

Indeed, the image of light in scanning was so powerful that at least three known inventors of light-based optical scanners used the *camera obscura* as the mechanical basis of the scanner interface. Although Alfred N. Goldsmith, a facsimile inventor, calls the scanner light a "light pen" that traces a beam of light across an image (Goldsmith et al. 1938, 1:ix), these early imagined and realized scanners actually used a form of pinhole camera to create this beam of light. The pinhole camera would stay stationary, but the image was slowly moved back and forth before the beam of light, which is a reversal of our current optical mechanism where the scanner head moves over a stationary document. This *camera obscura* apparatus was attached to telegraphic equipment that transformed the light/dark signals into electrical ones. The dominant term used for scanning during this period was "photo-telegraphy." In this way, optical scanning began as a camera jury-rigged to a telegraph. This portmanteau eventually became metaphorical after 1900, but the deep material connection between photography and telegraphy persisted in the imagination of scanning.

The relationship between the scanner and the camera extends not only to photography, but to cinema as well. Indeed, it is cinema that tied the scanner to the concept of modern broadcast television in many imagined ways. In the 1938 introduction to a volume called Radio Facsimile, issued by RCA as a collection of papers reflecting on the 40-year history of its research on facsimile and television, inventor Alfred N. Goldsmith defines the difference between the facsmile and television, both of which employ scanning as a key technological mechanism:"Facsimile" is a system of communication in which images are transmitted for record reception, and in which a record is to be made. In facsmile, there is accordingly used what amounts to an electrically controlled "brush," and this is remotely operated to "paint" the stationary replica of any graphic material, whether type, script, line drawings or half-tone subjects. Again, the record thus produced is, or can be made permanent.

> "Television" is a system of communication in which transient visual images of moving or fixed objects are transmitted for reception by visual observers and in which no record is to be made. In television there are thus employed what are in effect and electric moving-picture camera (the Iconoscope and its lens) and electric moving-picture reproducer (Kinescope) or projector. The reproducer yields a picture in motion, and accordingly the picture is inherently transient in its nature.
>
> *In facsimile and television communication, a process known as "scanning" is used. This is a method of analyzing and re-assembling a picture by a method similar to that used by the human eye in reading. In other words, the eye follows each horizontal line from left to right thus gathering information, and returns to a starting point at the left side of the page and repeats the process many times to reach the bottom of the page*.
>
> At present, facsimile involves a relatively slow-speed scanning process which produces a graphical record of a page in a period of several minutes. Television, however, inherently involves an extremely high-speed scanning system in order to reproduce many complete transient images during as brief a period as one second.
>
> From the foregoing it will be seen that printer telegraphy broadly resembles the art of typewriting; facsimile somewhat resembles the field of the printing press; and *television is closely similar to the motion picture* (Goldsmith et al. 1938, 1:ix–x).

Goldsmith, in an attempt to tie new technologies into the imagination of past media, creates analogies. Telegraphy becomes electrified typewriting. The facsimile becomes an electrified printing press. And television becomes electrified cinema. The power of electricity, in Goldsmith's scheme, becomes a way to renew and implicitly to *transport* old media into new places. Here again is the motif of the channel, but explicitly an electrical one. Moreover, not only are the facsimile and television both born of the same scanning technique, Goldsmith asserts that television attains its special function by being a tremendously sped up form of faxing without the material record: still pictures moving with the speed to match our physiological persistence of vision. He compares television to movies, not in its resulting moving image interface, but through its technological mechanism. Scanning, in Goldsmith's analogy, is the same as cinema, a series of quickly overlapping still photographs. Cinema is the imaginary linkage between facsimile (the progeny of photography) and television.

This same cinematic link appears in multiple places and most explicitly in the work of C. (Charles) Francis Jenkins. The early understanding of images-at-a-distance made little distinction between motion pictures, television, or facsimiles. Simply, images-at-a-distance represented a concept concerned with transmission of information. The key to this broad categorization that modern subjects may find counter-intuitive is that all images, at that time, were considered photographs. All motion pictures were literally photographs set into motion:

> The rapid development of apparatus for the transmission of photographs by wire and by radio may now be confidently expected, because the public is the same empirical process by which motion pictures arrived, *and out of which finally the long film strip was born*. In the motion picture development there appeared the spiral picture disc; the picture 'thumb book'; picture cards radially mounted on drums and bands; and the picture film continuously moved and intermittently illuminated. But finally the development resolved itself into a single, long, transparent picture film, intermittently moved in the exposure aperture of the projecting machine; and upon this has been built one of the large industries of the world. *Doubtless this will be the history of the development of electrically transmitted photographs, and of radio vision, for many schemes have already been tried and more may yet be seen before the final, practical form shall have been evolved, an this new aid to business and to entertainment shall have taken its place in human affairs* (C. F. Jenkins 1929, 5).

Scanning and cinema do not function similarly at all. And yet cinema functions as the *discursive* link between radio, telegraphy, facsimile and television. Historical imaginaries within technological discourse, the tropes of invention that guide and shape the way material invention proceeds, are the most important part of this account. Goldsmith, in the preface this volume, is explicitly writing an historical account of the last 40 years of his professional field. This backwards-looking glance allows at once for revision and trope invocation. This is why I argue for the writing of an intermedial historical account for the origins of the scanner. Cinema's dominant position as the medium of modernity shapes the inventive imagination around the technology of the scanner. The figure of cinema, from the material attempts to attach a pinhole camera to a telegraph to the explanation of television as merely an electrification of cinema as if cinema itself was always a form of high-speed faxing, cannot be underestimated.

Conclusion

I have demonstrated in this chapter that the long history of television in America and Europe began not with the television set as we know it, but with the imagination of the scanner as the starting point for the transmission of images-at-a-distance. In this project, I hope to show that the scanner stands alone as a distinct medium in and of itself, rather than existing, as some people believe, as a variation on the camera apparatus. In identifying the scanner as its own medium, we must realize that the history of the scanner was always already part of various established historical narratives, simply waiting to be recognized. This chapter has concentrated as much on the imaginary of the scanner as on its reality. The history of ideas surrounding the advent of tele-vision serves as a reminder that we must return to points of origin to interrogate the imaginaries of communication forms before they stabilized into the current historical conceptions of the present. By investigating these imaginaries, especially at the beginning of their collective conception, we may reveal the heavily intermedial imagination that undergirds the way we relate media to one another in an effort to understand that which is new and emergent. It is only through the figure of the old that we can find the new.

Moreover, it is important for scholars in the field of film and media studies to attend to the technical aspects of the media they study. To understand a medium requires us to both investigate the social protocols that structure its use, but also to focus on the material limitations and possibilities that form the basis of its operation. If we do not pay mind to the fundamental capacities of the technology itself, we are left only with the image and imaginary of the machine, which is a necessary, but insufficient description of the phenomenon that is a technological medium. Scholars in the humanities may fear the technical, if their backgrounds do not extend to the sciences, but this should not stop the field from tackling the language and concepts of the technical and of the sciences, lest film and media studies abdicate its ability and duty to conduct critique in an increasingly technologically-mediated world. All machines are made within the bounds of language, and thus can be “read” in the same way that one does a text. It merely takes a more schematic imagination to understand the conceptual forms and formula that bind the machine as an imagined and realized object.

Chapter 2 – Material Histories of Visualization: Particle Accelerators and the Epistemologies of Discovery

Chapter 1 has detailed the history of scanning as a new form of mediation, born from the desire to electrically telegraph photographs over long distances. I argue that the history of scanning was always already embedded in the history of electric vision. This buried history, like the recognition of scanning as a medium, necessitates a change in historical perspective. Rather than focusing on scanning as an output, I locate scanning at the interface of material transformation. The field of media studies too often focuses on the social protocols and material traces of a media technology: film texts and their reception, telegraphic messages and their institutional uses, the capacities of the Internet and the social configurations that rise from its exploitation. This approach privileges the most literally and figuratively visible, and less technical, aspects of media. Ultimately, this focus on the visible obscures the transformative act of scanning, which translates one form of media (photography) into another form (telegraphic impulses). Historically, there were no recognized traces of scanning, because the output of this process was so frequently subsumed into the domain of other media. Scanned documents may be understood as telegraphed photographs, divided into the respective domains of telegraphy and photography. A scanned photograph is still a photograph. The process by which scanned media come to be seen has no bearing on their ontological status as images. In order to see the history of scanning, my historical narrative focuses on the material locus of this transformation, the apparatus of scanning. Only by focusing on the material process of transformation does scanning, as a unique patterned and consistent process, emerge from the noise of previous media history. This chapter turns to the theory of scanning, by continuing this focus on scanning's transformative process.

Due to the circumstances of its genesis, scanning's original de facto focus of scanning lay with notions of vision. Scanning was born out of a coupled desire to at once see and transport—extending ambitions of conquest over time and space by eliminating the limitations of the human eye. Scanning's origin point does not, however, determine the totality of its mediating function. The scanner, whether used in the production of a visual product or not, is a *medium of detection*. I differentiate this point from the findings of the previous chapter for two reasons: to move the theory of scanning away from its entanglement in vision, and to emphasize the continuing necessity of focusing on both the material and materializations of scanning as a mediating process. Although scanning continues to participate in larger media networks and infrastructures that go on to produce visual objects and exercise visual discipline, the scanner itself is not a visualizing object. Rather, it is a detection machine, meant to mediate between the discursive unseen and the epistemological systems that require its revelation.

To understand the detecting function of scanning, which is by far its most vital function, it is best to turn away from the light-based visual scanners that produce facsimiles and digital documents. Although these optical scanners were among the first scanner technologies created, their implication in visual networks obscures their true function. In fact, these scanners do not truly visualize. They participate in a multi-media process that requires multiple mediating technologies to produce a single image. Think of the entire multimedia system built around the facsimile in the previous chapter as used by the newspaper industry in the pre-digital era between 1920 and 1990. A photographic negative is first taken with a camera. That negative is then transported by the photographer to the central office of a media company such as the Associated Press Wirephoto service and developed. It is this media artifact that is scanned by a specialized facsimile machine and sent via telephone lines to branch offices across the nation. From telephones, to cars, to photographic negatives, to the newspaper that the images will eventually adorn, the scanner lives in a heavily mediated system as the connection between other media.

The fax machine does not have a data storage function. The digital information of the image is sent as a telephone signal, systematically reduced and disassembled, in the same moment as it is being scanned. This principle of simultaneous disassembly and transportation applies to every scanner ever created. Scanners are neither computers nor repositories of data. The image neither lives nor originates in the scanner. The scanner is a machine of informatic transformation, turning the material trace of the photograph into a linear signal. The scanner's signal is then read and decoded into a recognizable image by a printer, when it reaches the branch offices of AP Wirephoto services, for example. Even a desktop scanner of today disassembles paper documents and transfers this information to a hard disk where a scanning program on a computer interprets the data into a manipulable digital image.

Scanners do not simply reproduce images. While image reproduction was their original intent, the function of scanning is detection by signal translation. Recall the following diagram printed in the introduction to this dissertation.

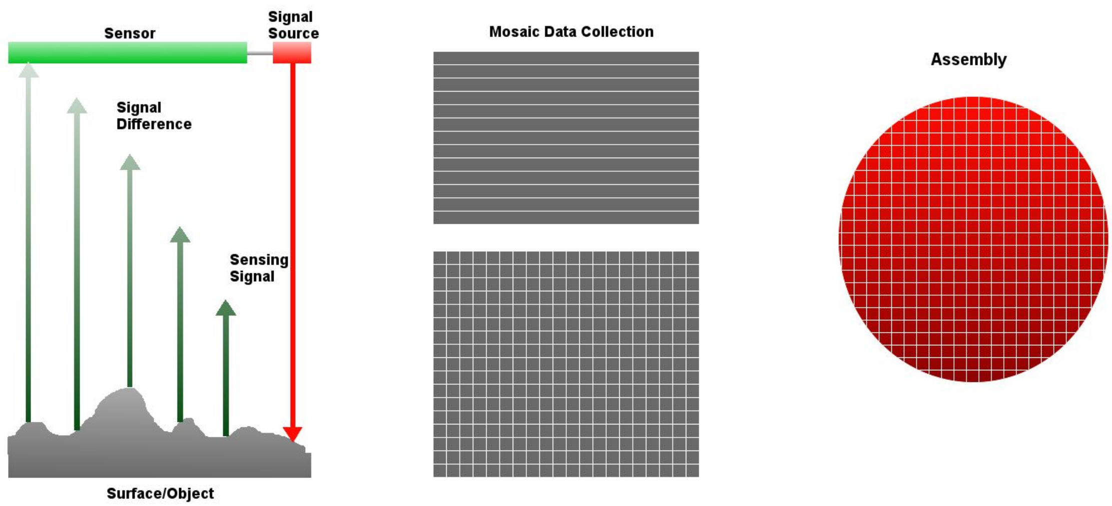

Figure 2: Diagram of the three conceptual parts that constitute the process of scanning. The scanner works by sending forth a light, tactile probe, infrared, sound, or other signal of uniform strength and size with the intention to make direct, physical contact with the surface of an object under scrutiny. The signal collides with this object and bounces directly back to the scanning array, where a detection array captures and records the strength of the return signal. Detection arrays in scanners register the speed and energy of the return signal and compare it to the known constant speed and energy of the original signal. Using basic Physics, the difference in speed or energy of the sent signal and the return signal allows scanning software to calculate the distance from the array to the surface of the object at the place of contact. Velocity = distance/time. The scanner array then moves incrementally across the surface of the object being scanned, recording the signal data at discrete points so that in sum, the machine effectively maps the entire surface of the object in question. This data is then reassembled and interpreted to yield a virtual image of the object. In modern digital scanning, this resultant image requires a great deal of mathematical transformation through software to be rendered as something recognizable to humans as a image. The data

from scanning does not immediately produce an image, but a mathematical Cartesian array of planar information from which the software *illustrates* an image.

Take the example of the National Oceanic and Atmospheric Adminstration's (NOAA) polar orbiting satellites. Imagine that you are trying to take the temperature of huge vertical swaths of air miles above the earth. Do you fly through these air columns with a thermometer? Or do you bounce microwave beams through these swaths of air from a low-earth orbiting satellite instead? NOAA uses microwave sounding units (MSUs) attached to satellites to record the intensity of microwave radiation from earth's atmospheric oxygen. But the vast majority of these measurements do not go through the process to be rendered into an image. These billions of measurements, which take place 24 hours a day, seven days a week, live as digital bits that are beamed down regularly to be backed up to a hard drive. Only some subset of these measurements are pulled to be turned into imaging data, because to see changes in global temperature, only a small sample of data is necessary. The rest are saved for posterity and potential future research. In this case, can we say that an image ontologically exists before it becomes digitally and artistically rendered as an image? The answer does not matter. However, this question of digital image ontology illustrates scanner's function. For my purposes, image production is incidental to scanning. The image comes after the scan.

Confusing scanning with image production is understandable given that we have and continue to live within a regime of sight-based power. Moreover, the products of most scanners become legible only once they are modified and transformed into visual information. So it is understandable that the work of scanners continues to be confused with their end products. Because film and media studies demonstrates a disciplinary bias towards the visible outputs of media systems rather than their less visible processes, the subsuming of the scanner itself into the product of the the scan requires disentanglement. The scanner itself demonstrates a much more important function than image production, a function that is better performed by the camera.

The true function of scanning is to detect. According to the Oxford English Dictionary, "to detect" means to "uncover" or "discover" something hidden, as if to "lay bare" or "display" that which was previously unseen. The scanner embodies and typifies the function of detection in every sense, including the pitfall of attempting to "uncover the truth" or that which we believe to be hidden. Scanning operates on the notion that a truth exists which can still be apprehended with the assistance of prosthetic machines, especially in situations where human faculties fail us. This truth does not confront the possibility that, like the operation of a Foucauldian notion of discipline, a truth can be discursively constructed by the very act of scrutiny. In Michel Foucault's *Discipline and Punish: The Birth of The Prison*, the philosopher demonstrates how eighteenth century thinkers posited that a hidden criminal instinct could somehow be determined from markers exhibited through physiognomy, demeanor, birth, speech, etc. All these social scientists had to do was determine how criminality manifested so that they could cull the undesirable elements from society. Foucault argues that the very notion of criminality was being constructed through these material, embodied investigations and that through their work, social scientists were discursively producing their test subjects into criminal subjects. They were creating rather than discovering the hidden criminal. This same possibility exists in everyday uses of scanning, frequently in similar functions of surveillance and securitization, such as airport full body scanners. The scanner's ability to penetrate layers of clothing that form a social barrier to scrutiny plays into its discursive capacity to ascertain the "inner" nature of those examined. While the scanner merely detects the thickness of materials adorning the human body, with thicker spots indicating a possible hidden object, the whole process of airport scanning becomes discursively identified with the production of "terrorists."

While we must take care not to allow the notions of laying bare or uncovering implied in detection to distort scanning into a discursive monument disconnected from its real material capacity, we must also take seriously the actual possibilities of detection in spaces and places beyond human scale and human reach. The scanner is actually capable of assisting in the detection and discovery of scientific and other phenomena, making visible and constructing spaces, places, and things previously unknown. For this reason, this chapter focuses on the particle accelerator, an iteration of the scanner that has produced major discoveries in the sciences.

So, why accelerators?

Particle accelerators speed up atomic particles and smash them into other atoms at high speeds, employing a very basic scanning mechanism. A particle accelerator only differs from the standard scanning model described in this project in the placement of its detection array. In an accelerator, the particle beam is brought up to a specified velocity using a variety of magnetic fields to add momentum. When released, the particle beam smashes into its target, causing an invisible explosion as the target particle is annihilated. In a standard scanner, something gets reflected back towards the detection array, which is situated next to or very close to the origin of the sensing signal. With a particle accelerator, however, the pieces of the annihilated target explode every which way. This requires a repositioning of the detection array around the site of the target particle so as to capture the different sizes and energies of the resultant pieces after the collision. Still, the particle accelerator embodies the major components of scanning: a signal beam used to make contact with a target, a real energetic difference in the signal after contact, and a detection array that records those differences in order to calculate or map these differences into a meaningful cartography.

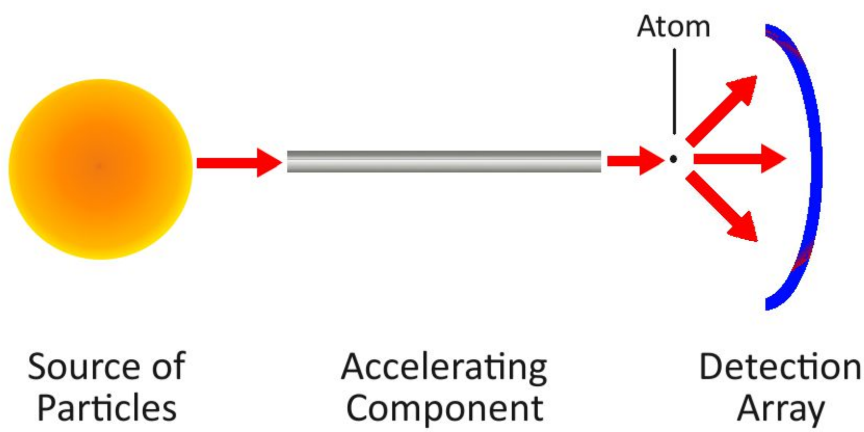

Figure 3: A diagram of the particle accelerator as a special configuration of the scanner apparatus.

This chapter engages in a media archaeology of the particle accelerator. What does the particle accelerator have to do with media history? Everything. First, television broadcasting was long made possible by the cathode ray tube inside television screens, a particle accelerator. The CRT unit beamed particles at a screen, line-by-line, accelerating these particles at the color-sensitive material and lighting it up. This beam scanner is a particle accelerator. By finding within this beam scanner a particle accelerator, we can chart new historical trajectories that intersect with what we think of as proper subjects of media history, such as television. By following the particle accelerator in media history, we can demonstrate the many everyday media in which even seemingly rarified and scientific uses of the scanner have been implicated.

Particle accelerators are used not just in high-energy physics, but in the manufacture of microchips and high-grade plastics. Chip manufacturers use particle accelerators to embed important ions into the chip surface that allow it to function properly. The personal computer interface through which I write this chapter was therefore made possible by the commercial use of particle accelerators. The U.S. Department of Energy has promoted the commercial exploitation of particle accelerators in new areas of industry through an initiative called Accelerators for America's Future (acceleratorsamerica.org). In the promotional materials released at the website's launch, the US Department of Energy (DOE) listed a few of the practical applications of the particle accelerator outside of physics research. Along with the semiconductor industry and its ionized chips, the DOE highlights the use of accelerators in producing radioisotopes used in medical imaging, electron microscopy uses particle beams to scan proteins for further study in pharmaceutics, and even producing the shrink-wrapping on packages found on meat products, DVDs and game packages, and other manufactured and processed products. Proposed uses for the particle accelerator, which are not yet tested, range from using accelerators to clean up polluted water and sewage to potentially producing alternative forms of nuclear energy.

Finding alternate trajectories through the media history we thought we knew by following unexpected objects renews the history we have and allows us to rethink and expand the notions of medium and mediation. Following the trajectory of a unique form of mediation like scanning to the locations of its work allows us to better understand how it functions in a comparative manner to other scanners and other media alike. Most importantly, scanners force us to reconsider the material in a much more obvious and pressing way than almost any other medium. The particle accelerator exists as an imagined machine, part discourse, part culturally and historically specific fantasy, and part metal and electrical impulse. The particle accelerator exists dynamically as something at once material and discursive. While the scanner is a machine, it is also a medium, which necessarily makes it part of a social production of meaning, labor, and power. No scanner exists purely as material, but as part of a symbolic circulatory system of social production. So how do I approach the question of the material in such a conceptual endeavor as thinking through the notion of detection in the investigation of the nature of matter itself?

The particle accelerator serves for me as a metaphor, a case study, and ultimately a provocation. The domain of scanning concerns a category of objects that cannot necessarily be easily seen or touched through human biological faculties. Scanning mediates the very meaning of the material itself. Feminist epistemological arguments struggle to overcome the deeply linguistic rooting of previous approaches that renders matter mute, as if matter itself were merely a canvas upon which discourse takes place rather than an active partner in the shaping of our epistemes (Hekman 2010, 2). Taking inspiration from these writings, I wish to seriously engage the material nature of scanning. I am not attempting to solve the impasse caused by the legacy of a linguistically-focused critical move in the academy that frequently emphasizes the production of meaning at the expense of the material configurations which make the very process of language possible. Critiques of the linguistic turn in continental theory have abounded in the writing of feminist science studies and philosophy. The struggle over how to approach a phenomenon or scholarly object that integrates the materiality of that object with the social, historical and linguistic systems through which it is formed is an ongoing collective effort of thinkers across many humanist disciplines of study, and I cannot answer that question here. Rather, what I will do in this chapter is two-fold. Firstly, I conduct a materialist archaeology of the particle accelerator through the lens of a film and media studies paradigm. What I aim to demonstrate is that following the unexpected trajectories of a technology rather than a literary figure or historical trope can also yield fascinating relationships and uncover the contradictory impulses that form any modern technology as a kind of historical-scientific settlement. By following the history of a technology through its development and proliferation, I challenge the ways in which humanists sometimes discard science and scientific notions, and the labor and discourse of science as somehow suspect. Reintegrating even the barest principles of scientific and engineering labor into film and media studies from the silo of science studies will greatly enrich the theoretical examination of media. Media are not merely machines of meaning-making, stand-ins for the all-encompassing linguistic process. Media machines and their resistant, agentive materiality exist at once as real and imagined machines, function at the nexus of diagrammatic thinking and industrial production.

While I do not try to define a materialist ontology for media studies, my second aim in this chapter is to treat the material seriously in my media analysis. Here, I follow Wolfgang Ernst and Friedrich Kittler's example in isolating and defining the peculiar affordances of the scanner that separates scanning as its own unique form of mediation. To do so requires an engagement with the material process by which scanning operates and a re-focus from the subject-which-is-scanned to the object-of-the-scanner (and the particular ways in which this object-detection medium dyad come into existence together as an historically-situated phenomenon). This is a shift from the products of scanning - images, subject-formation through scanning, social discourses - to the scanner itself at the moment of its work. Too often we have fallen into the trap of extrapolating a medium's function from its products without a solid understanding of how the entire machine system operates to begin with. My approach is to examine the machine first, to give priority to its reality. Only when the principles by which the matter of the scanner becomes legible can we presume to accurately understand the subjects, discourses, and institutions that are formed through and around these media machines.

In studying a machine that verifies "what is out there," I understand how loaded a notion "what is there" can be in the first place for some circles of humanistic and philosophical debate, especially with the ongoing work on new materialisms (Coole and Frost 2010, 5). That objects existing independently "out there" for human senses to discover is not agreed upon, let alone the claim than any biological sense or machine-extension of man's invention can verify the existence of objects in a meaningful way. To even proceed with an analysis, I must side with the camp that takes as its basis that there are objects that exist independently of human sensation and language (Nola and Irzik 2005, 130). Moreover, these objects can be partially, if incompletely, grasped by human sense and thought. This constitutes the core of what Levi Bryant calls science: to encounter objects (and phenomena) that provoke consideration and the journey to produce and diagram the behavior of these objects.

The History of Accelerators

For this project, I investigated several historical accounts and documents concerning the development of the particle accelerator, from internal historical reports written by and for scientists at CERN in preparation for the building and operation of the Large Hadron Collider, to popular media condensations of scientific history by journalists and writers. All these accounts narrate a direct, linear development of the particle accelerator through the lens of particle physics: a story of science and technological development occurring hand-in-hand. This narrative of Western liberal "progress" exhibits all the bad habits of older works in the history of technology. But this story is much more entangled in other media histories than the majority of progress narratives indicate. Part of the problem of the particle accelerator story is how it separates science from all things "non-science." As historical narratives of the particle accelerator rush toward the Large Hadron Collider as a celebratory end point—exhibiting a commitment to the symbolic ideological notion that building larger and larger machines is the natural flow of progress—the story sets aside the truly interesting everyday uses of particle accelerators in our media world.

Histories of the particle accelerator as an isolated scientific object present a unified front that excludes uses of the accelerator in entertainment, industrial production, medical diagnostics, art, environmental remediation, and the isolated, failed attempts to capitalize on and create new markets from existing avenues in research and development. Failures are as much a part of historical writing as perceived successes. Yet many histories frame particle accelerators in the most standard possible way, celebrating unproblematically the virtues of neoliberal gumption and scientific collaboration. In some cases, these histories are written by the professionals in the field of particle physics, scientists working on the history of their own community as a way of distinguishing their sub-field. Others are written to drum up funding or to educate the public on scientific accomplishments. Still others are written as textbooks that range from the undergraduate to the graduate level. These histories provoke interest for media theory and history in how they construct beginnings. Where a writer marks the narrative starting point for their technological genealogy is a choice that inflects the history they tell. Depending on the writer, the particle accelerator may begin with small, early linear accelerators (Baggott 2012, 118-134), or it can begin as far back as the cathode ray tube (CERN documents), an origin that connects the history of particle accelerators to that of television.

The most compelling of the all the histories examined for this project is the work of Raghavan Jayakumar, a physicist and writer. Jayakumar's short volume, *Particle Accelerators, Colliders, and the Story of High Energy Physics*, published in 2012 by Springer-Verlang Press, should be of great interest to scholars of film and media studies. Written in the style of a popular history, Jayakumar's history of particle accelerators is aimed at an undergraduate audience taking introductory courses in electromagnetism. Usually introductory physics courses separate the basic topics of physics into several components: kinematics (laws of macro-motion) and electromagnetism (light, radiation, electricity, magnets, etc.). A particle physicist himself, Jayakumar, surprisingly, locates the origin of accelerators in the film camera. Jayakumar begins the history of all particle physics, not just the accelerator, at the invention of photography.

To understand why Jayakumar chooses this point in time, it is necessary to understand the intellectual milieu of the 1800s. The story of the particle accelerator proceeds to its present development as modern physics through the investigation of electromagnetism, specifically, the topics of natural radiation and electricity. To understand the particle accelerator is to understand that its history is part of the history of electricity. Until the early

1820s, the natural phenomenon of electricity remained a scientific curiosity, a fringe interest that survived in the intellectual community of Europe due to a few periodic experiments that claimed success. From the documentation of static electricity to the discovery of magnets and their basic laws to Benjamin Franklin's lighting experiment, electrical research was sustained only by niche interest until major practical applications of electricity were harnessed. In 1821, when Allesandro Volta invented the first battery using copper and zinc layers that could reliably produce electricity, and Michael Faraday engineered an electrically powered engine that could replace human and animal labor, thus precipitating the possibility of the subsequent Industrial Revolution, electricity finally exploded as an area of research. Over the last century and a half, some of the most important discoveries that changed the way we live proceeded from this electrical research.

What is essential to understand in the history of electromagnetism in general, and the particle accelerator in particular, is that, although the scientific community could make electricity work, they still did not understand exactly how electricity truly operated. A working electrical engine was prototyped in the 1820s, changing the face of modern labor forever, and yet, even by 1950, the collective community of engineers and scientists remained uncertain as to how exactly electricity moved. Missing in their model of electricity was the "carrier particle." Electricity flowed from a positively charged node to a negatively charged node. But how? What passed this energy onward? The scientific community agreed that there must be a medium of sorts, a particle that assisted in transporting the energy of electricity through its course. That search for the carrier particle of electricity is where the story of the particle accelerator begins, and then returns to the camera.

In the 1950s, when scientists were studying electricity in earnest, physicist Heinrich

Geissler used and improved upon a known technological apparatus in his laboratory that would precipitate more future experiments. When a glass tube is evacuated of air (thus removing all the particles that could prove a hindrance to the discovery of very small particles) an arc of electricity could successfully pass from a negatively charged cathode to a positively charged anode. Geissler found that a better vacuum allowed the electrical arc to become more intense and glow brightly. Following this example, inventor William Crookes created an even better vacuum tube in 1879, which we now know as the cathode ray tube. The point of this experiment was not to create television, of course, but to isolate the carrier particle in electricity. Crookes believed the beam in his tube to be a negatively charged "cathode ray" composed of negative particles that were attracted to the anode panel. However, attempts to verify this theory of the negative cathode ray by the famed German physicist Heinrich Rudolph Hertz failed. Hertz had put electrically charged panels in the vacuum tube between the cathode and anode. If the cathode ray were indeed negatively charged—or charged at all—the panel would deflect the arc of electricity and never reach the anode on the other end. This did not occur however, because Hertz's vacuum tube was not totally free of ionizing gasses, which interfered with the electromagnetic field of the charged plates. Repeating Hertz's experiment in 1987 with an even further improved vacuum tube, physicist Joseph John Thomson at the Cavendish laboratory showed that Crookes was correct after all: the cathode ray was indeed a negatively charged particle beam. Through various mathematical methods and other calculations based on known electromagnetic phenomena, Thomson concluded that not only were these "electrons"—so named after the carrier of electricity—tiny and negatively charged, but they also likely made up a component of the previously indivisible unit of the atom. Science had found its first subatomic particle!

American, British, and German physicists had together solved the mystery of the electron! And, in the process, invented one of the fundamental components of television.

Of interest in this particular account is the centrality of technology to scientific discovery and detection. In the case of particle physics, instruments were designed to remove the “noise” of the world. The vacuum tube eliminates all extraneous air and the billions of gases, particles, and ions that compose what we think of as empty air, which is not at all empty. This artificial vacuum allowed physicists and engineers to take better measurements of phenomena that could not be otherwise verified under circumstances of so much natural interference. This example speaks to the relationship between scientific machines and the forces they exert upon the material world. Moreover, it illustrates how much of what we think of as material exists at scales that do not register to our senses. We think of air as composed of nothing, or perhaps oxygen. In reality, our atmosphere is full of material, whether or not we can feel and touch this matter in a culturally meaningful way. It makes for a great rhetorical flourish when we call for a return of agency to the material in critical theory, all the while, grabbing onto a glass of water or a pen or a chair. “We need to study things that we can touch!” But we say this at the risk of reifying the default centrality of the human as the baseline size of the material in the universe. The universe teems with matter that exists at scales unimaginable and untouchable, except through instruments like scanners, the study of which forces us to re-think the definition of matter itself.

For the vacuum tube to provide the proper conditions in which to study particles, two other components remain necessary: a particle detector and an acceleration component. Most historians, if they are willing to begin the story of the particle accelerator before 1900 at all, will place their marker for the first accelerator here, with the events surrounding the cathode ray tube and the discovery of the electron. Jayakumar's book also begins with these events, but he diverges from other accounts of the particle accelerator by covering territory not usually included by other writers, including the tangential scientific discovery of radiation. This tangent through the development of theories of radiation lead to the discovery of materials and mechanisms that would go on to become the basis for the earliest particle detectors. Although Jayakumar does not emphasize this benchmark in the genealogy he draws, it is very obvious that what first appears to be an historical tangent actually constructs the intellectual lineage that produced the necessary partner to Crookes' cathode ray tube: a mechanism by which scientists could detect, measure, and quantify the particles sent through the tube. Frequently, the events surrounding the particle detector's development and its roots in radiation get only a passing mention. This tangent is what leads Jayakumar to conclude that the camera as the first proto-particle accelerator. I will recap and summarize the pertinent parts of this history as part of my analysis.

Jayakumar firstly titles the third chapter in his book on radiation "Nature's Accelerator." Beginning with the discovery of the X-ray in 1895 by physicist Wilhelm Rotgen, Jayakumar continues to follow the story of cathode ray tube experiments after the discovery of the electron. It turns out that when Rotgen left a few tightly rolled sheets of unexposed photographic papers near his cathode ray tube setup, he discovered that they had been exposed, fogged as if they came into contact with light. A sheet of florescent paper that Rotgen kept in the laboratory also glowed when brought next to the cathode ray machine. Clearly there was also an element of invisible light that involved in this phenomenon of electricity. From there, Rotgen went on to discover X-rays and X-ray photography, a Victorian sensation which media history has examined in detail (Lippit 1999, 68).

Jayakumar follows experiments in radioactivity through the accomplishments of various physicists such as Henri Becquerel, who is credited with the actual discovery of radioactivity in 1896 when, like Rotgen, he noticed that uranium salts blackened exposed photo-sensitive paper. Take note of the continued use of photographic equipment. Glossing over his discussion of the Curies and other contemporary work, I pick up Jayakumar's historical narrative again where he re-introduces William Crookes, who in the earlier chapter produced the prototype for the cathode ray tube, called the Crookes Tube at this time.

Crookes, a British chemist and physicist, was the son of a tailor who went on to become a noted scientist for the creativity of his thinking and the precision of his experimental design. Crookes' scientific work, which lasted through his entire life until death, ranged through fields as diverse as meteorology and chemistry to psychiatry, which was of interest to many intellectuals at this time. In 1903, 24 years after inventing the basis for the cathode ray tube and precipitating the discovery of the electron and modern television, Crookes invented the second part of the particle accelerator: the particle detection device. The apocryphal story says that Crookes, while working with a very expensive radioactive element called radium bromide, spilled his radium salts. Jayakumar recounts that Crookes, determined to collect every last piece, used a sheet of paper covered in a thin layer of zinc sulfide, which is known to fluoresce when brought in contact with radioactive metals. According to physicists Claus Grupen and Boris Shwartz, the story goes that Crookes was working in his laboratory in total darkness when he accidentally spilled the radium bromide on the sheet of zinc-sulfide (Grupen and Shwartz 2008, xx). When Crookes looked for his specimens on the sheet with a magnifying glass, he noticed tiny pinpoints of flashing light. Crookes was inspired in this incident to create the first particle detector, a primitive invention called the spinthariscope.

Perhaps I should explain here how radiation works and the links that connect electricity to radiation, making them connected natural phenomena. We are all familiar with the basic structure of an atom. Within this basic unit of matter exists a core nucleus, which is composed of smaller particles called nucleons. Nucleons come in two types: protons (positive charge) and neutrons (no charge). Around the nucleus, in a tiered cloudlike orbit, are the electrons, which exist in some sort of particle/wave state. All the weight and heft of an atom lies in its nucleus, because electrons have virtually no mass. The number of protons, neutrons, and electrons within the nucleus determines the characteristics of matter that make them differ from one another. We have categorized them in the Periodic Table of Elements, which shows how different atomic weights can result in vastly different kinds of matter that conduct, deform and react in a variety of ways.

Matter is not stable; this results in the phenomena of electricity and radiation. The natural energy and motion of even seemingly solid matter causes the change and decay of this material. When matter decays, a phenomenon called particle radiation occurs. Most people are familiar with common radioactive elements such as plutonium and uranium. Particle radiation occurs as a subset of the larger phenomenon of radiation, which is generally understood to be the emission of electromagnetic waves. Sound and light might be thought of as forms of radiation, waves of energy that propagate through a material medium, although scientifically they are not categorized as such. Generally, radiation refers to energies contained in the electromagnetic spectrum, such as ultraviolet, gamma, radio, microwave, etc. When the atom of a material decays, one or more nucleons escape from the energy well of the nucleus. Because nucleons are held together by energetic bonds, as the nucleus gets larger and the nucleons more numerous, the amount of energy that holds the nucleus together gets more and more strained, which results in the increased random chance of one escaping. This is why the heavy elements more commonly emit radiation.

Two common types of particle radiation are alpha and beta radiation. Alpha particles are composed of two protons and two neutrons. Made of 4 nucleon pieces, alpha particles are considered to be heavy and cannot travel as fast or penetrate materials as easily. Alpha particles, because they are capable of interacting strongly with the materials they touch, can do a lot of damage. Since they are relatively slow, however, alpha particles can be stopped by a few inches of air or some other barrier material.

Beta radiation consists of the escape of an electron from the atom. The electron, which weighs almost nothing, can travel much faster and penetrate much further than alpha particles. These will be stopped by a few millimeters of plastic or metal, which explains why in films, you see military or government personnel wearing flimsy-looking biohazard suits. These suits are suitable for the two types of common particle radiation. Beta, or electron, radiation occurs when one of the neutrons in the atomic nucleus decays. The bonds that kept the neutron together as one unit disintegrate into its component parts of a proton and an electron. That electron subsequently escapes the potential energy well of the nucleus and the proton stays.

Detecting the regular emission of these decayed radiant byproducts was incredibly easy for the first particle detector. Crookes affixed a piece of radium bromide inside a brass tube. Into one end, Crookes placed a magnifying glass to better see the radioactive collisions.

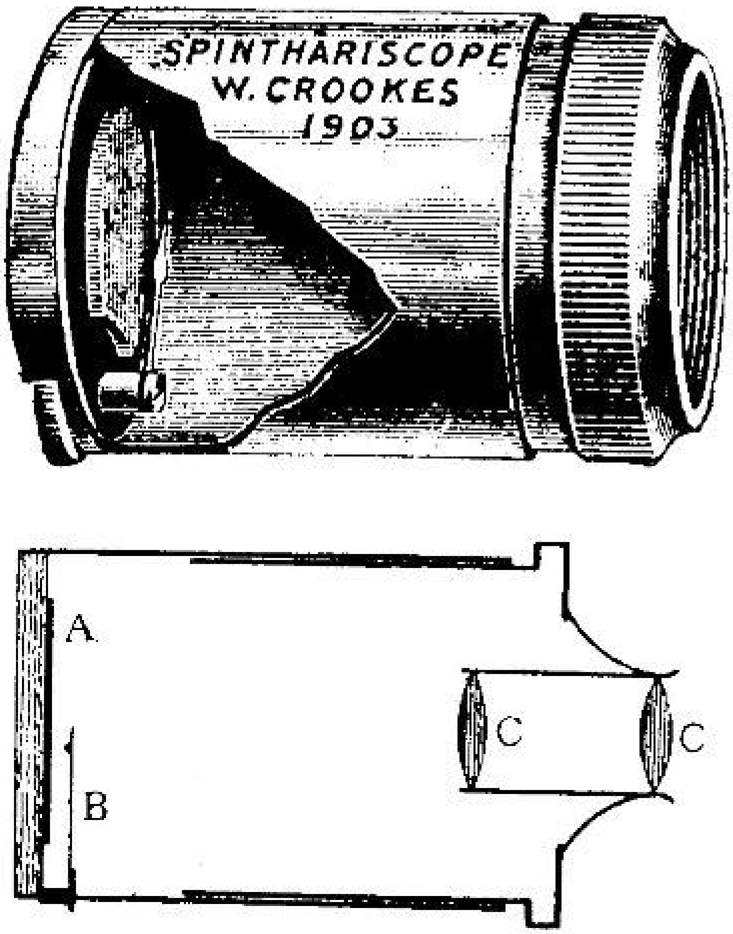

Figure 4: Spinthariscope diagram. Nuffield Foundation.

(http://www.nuffieldfoundation.org/practical-physics/spinthariscope).

The other end was sealed with a small sheet of zinc-sulfide paper glued to the inside the tube. When the observer looked inside brass detection tube, the radioactive alpha particles colliding with the zinc-sulfide paper would briefly glow in a flash of green light. These pinpoint flashes were called “scintillations,” because they occurred frequently enough that the interior of the observation tube seemed to sparkle like stars in a dark field.

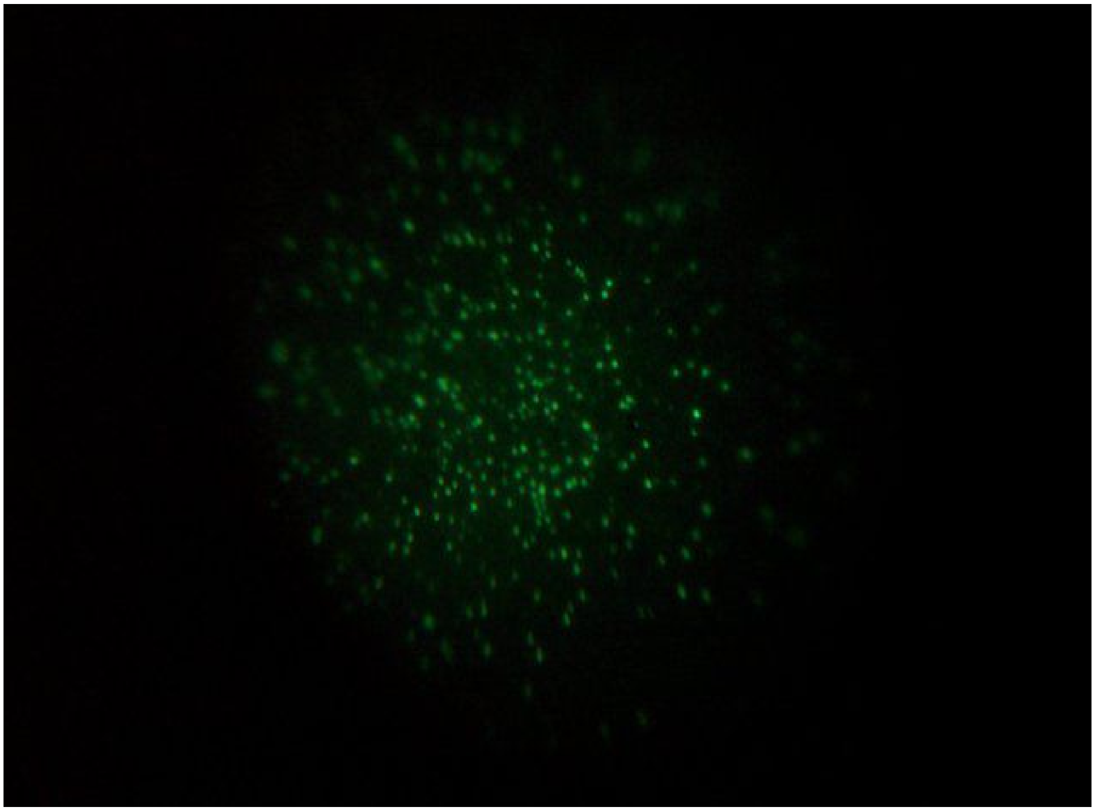

Figure 5: Image of the radioactive "scintillations" that occur as matter decays and emits alpha particles that collide with the zinc-sulfide screen inside the spinthariscope. The Daily Omnivore. (http://thedailyomnivore.net/2011/03/28/spinthariscope/).

In general, these early radiation detectors were sheets of metal covered in some reactive material. Scientists would detect the number of particles colliding with metal sheet by counting "scintillations" and observing the visual density of these together. Scientists never saw the particles that emerged from the broken nucleus in the laboratory. What they observed were trace phenomena of the initial impact with the detector. This is the case with all scanners. The trace, although measurable, merely represents the fact of collision. Any data extracted from the trace goes through a laborious process by which it comes into circulation as scientific knowledge. The theoretical edifice of physics adapts the observation into prevailing scientific discourse. The scanner detects what is there. Scientific labor gives the detected entity identity and value. Today, the name persists, and some particle detection arrays are still called scintillators. The scintillator came into use in the laboratory for a while until it was superseded by more sophisticated detection equipment based on similar principles. Today, particle sensors have become incredibly complex digital apparatuses that constitute their own field of engineering and science.

Before discussing the impact of the scintillator, I wish to demonstrate how entangled the history of science was with media history in this early time period. After creating the scintillator, Sir William Crookes decided to market this remarkable little instrument as an educational parlor toy. These basic scintillators were manufactured under the name of Crookes' spinthariscope, which is based on the Greek word spintharis for "spark." The spinthariscope was a popular Victorian entertainment in the parlor culture of the day, well before the public knew enough to be wary of radiation (Jayakumar 2012, 17). Not that the observers were in much danger. Radium emits alpha particles, which likely could not penetrate the brass observation chamber. This culture of Victorian entertainment recalls the seminal film history work of Tim Gunning and his "cinema of attractions" (Gunning 1990, 56). Coinciding with the early culture of film, the spinthariscope operated in the same cultural milieu where audiences came to watch films for the spectacle itself, rather than for the narratives we expect today. In this time period, the use of technology as spectacle for entertainment extended from film—which showed as many stories as it did scientific footage—to displays of electrified light to objects like the spinthariscope. It is remarkable how the first particle detector became a children's toy. In fact, the spinthariscope became a regular addition to educational toy science kits sold in the 1960s. These old spinthariscopes survive to this day as part of old toy collections and as a nostalgia item.

Figure 6: Gilbert No. U-238 Atomic Energy Lab. Sold from 1950-1951 and included, among other things, a Geiger counter, a cloud chamber and naturally occurring radioactive isotopes. Made by the same company as the popular Erector Set, this kit was designed in collaboration with MIT faculty with the aim to educate and demystify atomic phenomena. Sold for $49.50 in 1950. (http://clockworker.de/cw/2011/07/07/atomlabor-fur-kinder/)

What emerges from this historical narrative is the guiding epistemology of photography in the development of particle detectors. The physicist and sometimes science author Raghavan Jayakumar begins his account of “nature’s accelerators” with the claim that “(t)he detection of [natural] radiation by Victorian scientists was linked to an imaging method that was just becoming popular with the general public: photography” (Jayakumar 2012, 11). Unfortunately, Jayakumar does not pick up this thread of photography later in the chapter nor does he elaborate further on why the camera can be counted as a form of proto-particle accelerator. Jayakumar leaves us to make the connection ourselves.

The first connection between the camera and the particle accelerator lies in the sequence of their discovery. Without the invention of photographic systems and photosensitive paper, the logic that certain types of chemically treated paper could register traces of invisible, radiant energy would not exist. Because of photography, scientists developing the particle accelerator understood that energy could imprint a trace through chemistry, and that photo-florescence existed. Second, once it was understood that light was itself a form of radiant energy, Jayakumar asserts, the community of science became interested in the possibility of other invisible, radiant energy occurring on earth (11–12). Third, due to the rising popularity of photography in both the everyday contexts and in the scientific laboratory, scientists such as Rotgen, Becquerel, and Crookes kept photosensitive paper in the lab as part of their equipment, for purposes of documentation and for the further examination of solar radiation. The incidental exposure of radioactive materials to photographic paper that precipitated the aforementioned discoveries, was possible because of these three factors. Moreover, the particle accelerator, like all scanners, shares a common function with the camera, which is that of detecting a trace presence and transforming that trace into some other indexical form. Thus, the particle detector owes its existence to the very idea of photography and was fundamentally shaped by the logic of the photographic trace.

I would extend Rhagavan Jayakumar's assertion of a primary position for photography in the particle accelerator's lineage to argue that the camera was itself a form of proto-particle accelerator, and that a deep conceptual link exists in the parallel operative logic of the particle accelerator and the camera. A particle accelerator is composed of three units or processes: a source of the particles or radiation, the method by which that particle accelerates and induces speed in the particles, and the detection array that registers the impact of the particles. Compared with this conceptual model, a camera lacks only the accelerating mechanism. Acceleration is not necessary in the camera because the source of light radiation is provided by the natural environment. The camera's detection array here is its light-sensitive film, and the lens functions to focus and funnel the light beams/particles. Because the speed of light is itself the absolute fastest that matter and information can travel under the conditions of special relativity, no accelerative component is required. Light is a form of radiation, like the particle radiation released by the decay of matter is. Indeed, most of the early experiments that produced our basic understanding of the components of an atom as a nucleus made of protons and neutrons surrounded by an electron used particle beams without an accelerative component, relying only on the inherent speed of the particles themselves. Historical accounts of the particle accelerator and particle physics identify the first proposal to add the accelerative component to the particle beam apparatus occurring as late as 1927.

A point remains to be made regarding the particle detector, beyond identifying the particle accelerator's photographic logic. This second insight relates to the scientific and forensic notions framing the idea of detection. The forward of Grupen and Shwartz's graduate-level textbook *Particle Detectors* (2nd edition), grounds the pursuit of ever-better forms of detection in the lack of precision of the human eye. The basic motive which drives the scientist to new discoveries and understanding of nature is curiosity. Progress is achieved by carefully directed questions to nature, by experiments. To be able to analyze these experiments, results must be recorded. The most simple instruments are the human senses, but for modern questions, these natural detection devices are not sufficiently sensitive or they have a range which is too limited. This becomes obvious if one considers the human eye. To have a visual impression of light, the eye requires approximately 20 photons. A photomultiplier, however, is able to "see" single photons. The dynamical range of the human eye comprises half a frequency decade (wavelengths from 400 nm to 800 nm), while the spectrum of electromagnetic waves from domestic current over radio waves, microwaves, infrared radiation, visible light, ultraviolet light, X-rays and gamma rays covers 23 frequency decades! (xvi)

In this quote, Grupen and Shwartz typify several discourses that shape and define the institutional function of particle accelerators. They also pinpoint the relationship between scientists and their instruments. Experimentation became adopted as the paradigm of "objective" experimentation which gave priority to "recording" and "measurement" with devices (Dalston & Galison 2010, 35). To this day, the scientific method remains bounded only to the study of phenomena which can somehow be quantified, which is to say, the phenomena that can be described by the character of discrete units. In this turn to objective truths, Grupen and Shwartz echo the ongoing distrust of the human senses as forensic instruments of primitive and inadequate sensitivity. Here, "sensitivity" stands for the human subjectivity that processes and frames the act of perception itself through culture's discursive definition of reality, and for the rising number of phenomena that exceed our sensorial reality. These modern areas of scientific inquiry concern the invisible, the undetectable, and things that cannot be verified without the introduction of new senses. Grupen and Shwartz use the metaphor of sensorial extension to describe the scientific apparatus that mediates the scope of our reality: "In this way, the human being has sharpened his 'senses' and has developed new ones." (2008, xvi) Mirroring the McLuhan's notions of prosthetic sensory extension, scientific practices have become complex media phenomena wherein producing the social reality of a scientific object necessitates a constellation consisting of the social, discursive, and epistemological framework into which the the object fits, and the material sensory medium that allows a significant and legible form of contact between the subject and object. It is not technologically determinist to say that media technologies are necessary to bring into social reality mediated objects, because at no time can we truly say there is a meaningful unmediated object, or subject, for that matter. The particle detector may therefore represent the most important component of the total material apparatus of the particle accelerator.

Tracing parallels between the history of photography and that of particle physics fundamentally relates our history of experimentation with particles and the radiation of particles to essential parts of modern media history: television, film, and Victorian optical attractions. By tracing technology as emergent epistemological/material configurations that manifest in the body of machines, we can see where previous thinking coalesces to form new media. This particular trajectory through the archive reveals unexpected connections to other media, demonstrating my ongoing argument that scanners, and perhaps all media, are much more intermedial in their operative logics than we think. With the introduction of each new medium, the very ground of social reality changes, and is mediated, by new ways of interfacing with the world. The material, social, and intellectual conditions from which each new medium emerges are made possible by the "terra-forming" of social reality by preceding forms of media.

The final component of the particle accelerator—its accelerative component—is the center of most historical narratives, especially those that pertain to the Large Hadron Collider. In the years leading up to the discovery of the Higgs-Boson, it was necessary to give historical context as to why the Large Hadron Collider was so important to science. However, in my modeling of the particle accelerator as a paradigm for thinking about the scanner, the accelerative component offers the least to media theory.

By the 1920s, the scientific community had learned as much as they could about the particles that made up matter with the precision of the equipment they currently possessed. The community came to a consensus that they needed somehow to break apart the atom into its component pieces in order to detect the fundamental, indivisible particles of matter. To overcome the forces that held a nucleus together, however, required speeds much, much faster than the inherent speed of particles emitted by radiation. What they needed, in other words, was a "particle bullet" to shatter the atom (Jayakumar 32). The language of "seeing" inside the macro-particle of the atom is a motif that repeats in the literature of the time period, despite the fact that these particles are too small to be physically seen. As in Foucault's work on discipline and punishment, sight functions metaphorically and literally as a discursive act of power/knowledge in the history of particle acceleration and detection. The necessary actions of an observing subject become part of the process by which science produces phenomena that can circulate legibly in the public forum. The metaphor of "seeing" may represent more than just a metaphor for physicists, however. In early parts of Grupen and Shwartz's textbook on particle detectors, the authors state that: To peer into the world of the microcosm, one needs microscopes. Structures can only be resolved to the size of the wavelength used to observe them; for visible light this is about 0.5μm. The microscopes of elementary particle physicists are the present day accelerators with their detectors. (xvi)

To understand this statement, it is necessary to understand that "to observe" does not necessarily mean to "see," but to detect—to verify through some kind of informatic or signal contact. With a microscope, we can only see objects the same size or larger than the smallest wavelength of light that is still also visible to the human eye. Keep in mind that visible light is only a tiny section of the electromagnetic spectrum. Therefore, it stands to reason that humans may use even smaller wavelengths of energy to resolve even smaller structures than can be detected by visible light, which is exactly the function modern particle accelerators serve in modern microscopy. A law exists called the de Broglie relation which states that the smaller the wavelength of the electromagnetic signal, the more momentum, or energy, this signal will need to have. This becomes intuitive if one recalls playing with a jump rope, shaking it up and down to make waves. It takes a great deal more effort to produce many small and frequent waves than it does a few long and big waves. What this means is that the smaller the object of study, the faster, more energetic and smaller the wavelength of energy needed to observe it. Thus, physicists can rightly claim that modern particle accelerators—which speed up particles using powerful electromagnets—are actually the modern microscopes. In a literal and figurative sense, they are creating the largest possible microscope at the Large Hadron Collider to observe the smallest possible things. This is why the accelerative component is necessary.

Historical accounts of the emergence of the prototype parts of subsequent particle accelerators provoke a few historiographical questions. In most of the histories in my research, very little is said about the development of the particle detector outside of specific textbooks dedicated entirely to the engineering field of these machines. Rhagavan Jayakumar's account was the only one I found that gave equal weight to both the prototype of the cathode ray tube and the scintillator. Why is the accelerative part, the idea of speed and penetrative power, more important and exciting than the story of the detector? The development of technology that can make detection arrays increasingly sensitive could easily fit into a standard history of technology model that shows increasing progress over time, no matter how misguided that narrative bias might be. Yet, the story of particle accelerators as it is currently written might as well be a caricature of sexist histories of white European and American scientists obsessed with speed and the respective size of their machines. Can we dismiss this as a coincidental outcome of a partnership between technological development and scientific discovery? Or, without making a technologically determinist argument, can we imagine that the very nature of scanning itself, this detection by signal, shapes subsequent notions of the proper way to conduct science? Having already found success in the development of more and more penetrative accelerators, has physics become stuck in a political, economic, and historical landscape that renders particle accelerators "the thing to do?"

Scientific knowledge is a discourse that must be fabricated, creating models that account for the known behavior of natural phenomena. This knowledge is labored upon by an industry of people with a complex history that results not only in a specific culture, but one that has produced a dense episteme that stands in as the truth. Radical constructivists in the study of the sciences would call the Higgs-Boson an epistemological construct, something created discursively by a community through a cultural process (von Glaserfeld 1995, 2). Scanning does not have an ontic existence, but its process is concerned with the ontic existance/traits of objects. Following Karen Barad's reasoning, we could call the entire complex of scientific discourse, the material capacities of the particle accelerator and its computational infrastructure, and the Higgs-Boson a "phenomenon" (2007, 56). The phenomenon then has an ontology that changes over time in such a way that it can account for both the material and the discursive while not being tied to an ontology that is "out of time" and rhetorically transcendant rather than materially immanent.

Perhaps it would be better to call the process of producing the Higgs-Boson a *materialization*. This notion of materialization tries to respect materialism as an approach that emphasizes the corporeal exigencies and agencies of physical phenomena beyond the human and the insights of constructivism. The scanner thus senses and transforms signals in nature into measurements interpreted by humans within an epistemological community, in a material and discursive process. Perhaps we might describe this detection process by scanners as an *epistemological materialization*. The materialization of the Higgs-Boson remains an emergent process, however, until the labor of scientific verification, theorization, and publication settles it into an historically accepted fact, insofar as scientific facts are ever truly settled. Scanning is thus the collision, perhaps better described as the interface between the discursive and the material. I wish to insist that something material exists within this process. It is insufficient to resort to a radical constructivism that merely traces how the discourse of the particle develops. As media theorists, we must look beyond the media event to the event of material mediation, confronting a *media of things*. Detection, as a pursuit of being, seems less concerned with proving the fact of being than in bringing its object into an already realized epistemological structure.

Conclusion

Film studies displayed a puzzled reception to the publication of *The Visible Woman: Imaging Technologies, Gender, and Science* (1998), an edited volume by feminist film theorists Paula A. Treichler, Lisa Cartwright, and Constance Penley. This befuddlement showed, at best, a lack of interest in the subject of medical imaging and, at worst, a lack of understanding regarding the connection of the film image and visual cultures to medical and scientific imaging. However, Jayakumar's historical gesture shows the connection scientists draw between film and scientific images. This connection emerges as much from the conceptual connections between film and science as the parallels in their material modes of action. The difference between how a camera operates and how a particle accelerator operates lies in the addition of a propulsion system to achieve speed, as opposed to taking advantage of the natural speed of light, and in the film camera's need for a lens system to reproduce objects as the human eye sees them. For the scanner, to interpret the resultant form of data into something sensible to human language and vision, the transformation, modulation, and re-imagination of said data require a separate effort that remains less economical and eloquent than a camera lens system, but whose complexity is much more telling of the cultural labor necessary to make imaging technologies legible.

Scanning is, above all, a mechanism of signal manipulation and of the detection and calculation of signal differences. The scanner is a medium that brings into visual circulation traces of objects and phenomena that defeat the limited reach of the human senses. This case study of the particle accelerator serves as a particular subcategory of scanning in general. The example of the particle accelerator, as a massive detection array, merely highlights in its core work the key principles of what scanning does as a medium. In the case of fax machines, the scanner overcomes vast distances to transport images. In the case of the particle accelerator, the scanner overcomes problems of scale. Like other media technologies, such as film, that modulate the trace or evidence of direct contact with objects, the scanner mediates problems of presence, evidence, and truth value. At its most simple, the scanner acts as a point of contact, literal and figurative, between the material and the discursive.

Scanners are also implicated in a new cultural way of looking, a new kind of scrutiny that underlies the broader phenomena of surveillance. Scrutiny is a mode of close and critical investigation, a continuous and sustained effort to monitor and guard. Ultimately, scrutiny is a form of surveillance. More that just a mode of securitization, detection—the fundamental mode through which a scanner functions—enables a new paradigm of investigation and evidence that does not rely on traditional models of vision. In its forensic mode, detection allows the user to mobilize previously unseeable and unknowable horizons into docile quanta. As a piece of our unquenchable thirst for data, the scanner functions to discover and colonize new fields of knowledge, providing new evidence to be worked over and manipulated into assets that feed epistemological systems. The scanner is deeply implicated in facilitating the cultural and institutional mindset of detection, although it would be technologically determinist to argue that scanners have caused this complex institutional orientation. Rather, I argue that the capacities and affordances unique to this suite of technologies—this way of interaction with the world, this mode of mediation—have been mobilized toward unforeseen ends. By thinking the scanner, we can begin deconstructing the new scrutiny that organized part of the biopolitical project of surveillance and securitization. To do so, we must begin by constructing the scholarly object of the scanner, in all its theoretical valences.

Chapter 3 – The Material of Information: An Intermedial History of Barcode Scanning and the Genesis of Automated Identification and Data Collection

Why Barcodes?

The previous two chapters have addressed the history of the scanner, in its material and discursive formulations, and the philosophical-material dimensions of scanning in the special case of the particle accelerator. Throughout, I have explore the intermedial links that connect the scanner to various preceding and subsequent media, such as television, photography, telegraphy and radio. This chapter expands our understanding of media infrastructure by turning to an examination of how everyday scanners enable material and digital transactions, or as Manuel Castells would say, the management and control of material "flows" (Castells 2012, 45-63). The exemplar I have chosen to study is the bar code scanner as it functions within the modern institution of online Internet commerce. In particular, I focus on the role of the barcode scanner as it functions within Internet commerce, through the case study of Amazon warehouses, their supply chains, and the network of data that governs product delivery. This case study illustrates how barcode scanners facilitate the geographical organization of material exchanges from manufacturers to our front door. Through this process, barcode scanning functions as an infrastructural mediator between the material and the digital that eventually comes to inform and organize big data and surveillance.

Of the many iterations of scanning that manifest in material technologies today, the barcode scanner may well represent the most important infrastructure within the American capitalist system. Throughout our daily lives, barcodes not only appear everywhere, but they invisibly facilitate our everyday transactions. At the grocery store, we might purchase a few items for lunch and scan the barcodes ourselves at the increasing number of self-service stations at grocery stores. Indeed, almost every item that we own has possessed a unique barcode at one time or another to identify its make and model, even if we threw away the packaging long ago. As academics, we spend enormous amounts of time in the library, and although some of us still remember the heyday of the card catalog, we now scan our books at checkout. To get on an airplane, the agent at the gate might scan the barcode on our printed plane tickets or our smartphone screens. These are the obvious transactions that the barcode mediates, the ones where we see the scanning directly with our own eyes. Barcodes, however, are employed by any number industries and institutions before consumers even see the end result.

In hospitals and pharmacies across the United States, barcode labels are used to fulfill medication orders and manage the enormous number of requests every day (Poon et al. 2006, 426–27). Indeed, these systems were implemented to increase efficiency and mitigate catastrophic health mistakes for patients due to human error (Altman 1995). Biologists have developed a scanner that scans the natural “barcodes” on zebras, allowing them to uniquely identify individual animals in a herd and track their movements over time (Lahiri et al. 2011, 1–6). Barcodes are even employed to help manage building construction. This form of combined GIS/barcode monitoring allows construction firms to manage delays and the flow of materials in and out of a site and avoid conflicts that can occur when parts of precast building components arrive too early or too late (Cheng and Chen 2002, 23–33). Barcodes were first used in manufacturing to label and organize parts in the automobile industry. Driving our cars every day, we do not realize that every single part of the car in which we travel was at one time barcoded and managed so that the parts arrived to the right place at the right time in the production line (Laosirihongthong, Paul, and Speece 2003, 321–31). Beyond everyday encounters with barcodes exists a largely invisible informatic infrastructure of barcode use in almost every industry on the planet, that structures the movement of matter across space and time. We encounter the results of barcoding all day, every day, whether we realize it or not.

In addition to facilitating everyday labor, barcoding systems also create and collect enormous quantities of data, an archive upon which the entire industry of predictive analytics has taken form. Some work has been written about the use of scanner data in economic analysis, mulling over the attractions and drawbacks of this archive (Basker 2012, 3). What other medium would provide a true census, as opposed to a randomized statistical sampling of data, of a given activity in a continuous and ongoing manner (Feenstra and Shapiro 2007, 2)? Data obtained from barcode scanners are digital, easy to access, and provide the basis of benchmarking analytics for all the institutions that employ them, including pharmacies, airlines, and payroll. No matter how alluring the idea of scanner data, concerns emerge regarding the mismatch between economic definitions of sales as simple, individual transactions, and consumption, a more complex index of behavior. Moreover, the enormous volume of available data is cheap to access, but expensive to analyze. Institutions that seek to make use of their scanner data must contract out their analytics to private, third-party firms, exposing customer data to unreliable “outsiders” (Baron and Lock 1995, 51–53). Even if the data is analyzed, the results may not yield anything useful or actionable. The allure of big data begins here, with barcode data and the insights they provided industrial giants to further refine and exploit the process of production. Data comes from systems of classification and counting, and the barcode (in conjunction with computers) enabled the leap from human collection to automated collection that fundamentally changed society's relationship to the governance of everyday life.

Despite our ignorance of barcoding's place in the facilitation of labor in modern life, the barcode forms an important part of our imagination of modern (and implicitly capitalist) life. The barcode has emerged as an icon of the consumer society and a mnemonic stand-in for the pleasures and dangers of global capitalism. Barcodes have come to be so much a part of our experience of consumption that Japanese graphic artists have exploited the ubiquity of the barcode and its necessary inclusion on packaging. In Figure 7 are two examples of how industrial designers play with the iconography of the barcode by transforming them into illustrated art that supports the branding of the product.

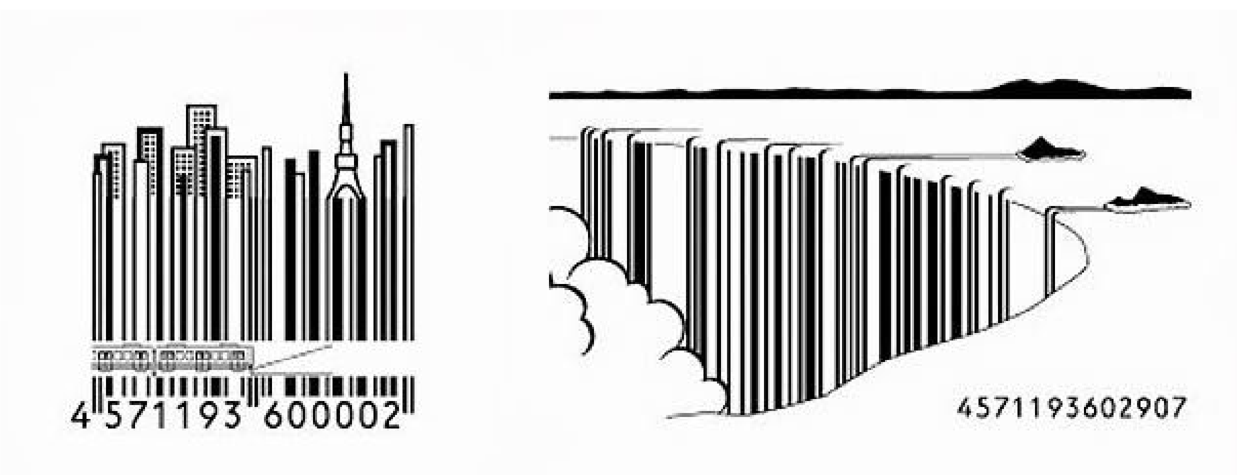

Figure 7: Two examples of creative ways in which Japanese industrial designers have turned barcodes into illustrated art and integrated them into the meaning and branding of the product. From Dark Roasted Blend Blog, by Avi Adams.

Barcodes appear as emblems of commerce used artistically on products themselves, and as a point of reference in architecture. Figure 8 is a photograph of the Barcode Building in St. Petersburg, Russia, which, unsurprisingly, is a shopping mall whose play on the barcode as icon signals its function in its form.

Figure 8: *Shtrikh Kod* (Barcode) Building, St. Petersburg, Russia. Designed by Vitruvius & Sons Studio in 2007. From www.i09.com.

Whether they are deployed in artistic critiques of the anonymity of urban life, or as a celebration of capitalism’s excesses, barcodes figure deeply into the imagination of life and society.

In this chapter, I consider the manner in which barcode infrastructure allows institutions to govern the movement and disposition of matter. Barcodes, and their relationship to space and material, are part of command and control systems that create a global monitoring system to scrutinize the location and status of all items that enter and leave the barcode’s purview. How do digital command systems work? What historical factors contributed to their formation? What is the relationship between the material body and its data body? Is it an index, or is it something more hybrid due to the way we use technology today? This chapter addresses the role that barcodes play in modern life and what characteristics make them so ubiquitous. As in any proper media studies analysis, we must ask what barcoding mediates, and how.

This article concerns, in part, the materiality of information. Bill Brown maps the rise of the "dematerlialization hypothesis," which represents the anxiety that arises around the ever increasing amount of digitization in our every day lives (2010, 51). This position views the very nature of media as fundamentally dematerializing, separating us from access to things themselves. Brown argues that contrary to this dystopian view of our rapidly evaporating material world, scholarship in media studies has engaged quite fruitfully with the embodiment of media themselves, proving that even immaterial things like electronic information have material infrastructures that enable them to manifest (Kirschenbaum, 2008).

The materiality of information can be approached on multiple registers. Paul Dourish and Melissa Maxmanian conceptualize several ways the notion of the materiality of information manifests in scholarship (2011, 100-107). Firstly, there is the material culture of digital goods, which concerns the symbolic value and cultural work performed by objects. Second is what Dourish and Maxmanian call the "transformative materiality of digital networks." In this conceptualization, informational infrastructures organize and give context to space and spatial relationships of human activity. Thirdly, Dourish and Maxmanian conceive of the materiality of information as the relationship between information and its material manifestation and the relations of power that form around them. This category focuses on the actual elements and embodiments that data take, such as server farms, labor, computers, cables, corporate and government partnerships, and telecommunications regulations. Fourth is the manner in which information as an increasingly important category in culture produces new knowledge and subsequently shapes behavior. Certain types of information become more important and others diminish. And lastly, Dourish and Maxmanian recognize the materiality of the representations of information themselves.

Scholars like Lisa Parks strive to rematerialize media by recognizing and theorizing the importance of the equipment, cables, and material embodiments that make up the routes of media. In their edited volume Signal Traffic: Critical Studies in Media Infrastructures, Lisa Parks and Nicole Starosielski define media infrastructures as “situated sociotechnical systems that are designed and configured to support the distribution of audiovisual signal traffic” (2015, 4). At once material constructions and discursive formations, media infrastructures as a materialist endeavor foregrounds the processes of distribution. Taking after the work of Parks and Starosielski, this paper takes seriously the admonishment to attend to the material of information itself as it flows through the distributive networks that enable the flow of objects across the world.

This paper presents the bar code as a new kind of “old media.” To define what makes a medium “old” demands that we understand its opposite – the “new.” The notion of the “new” represents an ever changing category as that which is new lapses into the growing category of the old. New media, however, do have certain features in common and a transformative quality that allows us to identify them as kind of constellation. Lev Manovich in *The Language of New Media* (2001) emphasizes the feature of programmability as what characterizes the newness of new media, asserting that new media is the product of a convergence between computation and forms of media storage, such as film. In *The New Media Reader* (2003), Noah Wardrip-Fruin and Nick Montfort's compilation of readings position new media history as the relationship between computation and art, which culminates in the computer medium's rise as an expressive medium. In a sense, new or digital media focuses on the cultural and social developments that arise from the capacities of today's computational networks. Bar codes then, are not not new media, but perhaps best characterized as new media adjacent. While they themselves are not programmable, bar codes connect to databases and networks of computation which allow their informatic annotation of matter to become mobile and powerful. Set within the genealogy of punch cards and census data, bar codes are old media that have strong linkages to the computational logic of new media.

As opposed to computation and the Internet, this paper delves into an information communication technology that is so prevalent today as to be deeply unremarkable. In reaction, this paper, seeks to make the bar code "new again," as a way to dis-embed this infrastructural media object from its context and renew it as a novel object of study. Geoffrey B. Pingree and Lisa Gitelman, in the introduction to their edited volume New Media, 1740-1915, consider the moments when old media were first new to the scene, when they were emergent within their historical contexts. In doing so, the scholars in this volume discover media in flux, not yet fixed, ritualized and "natural." They discover the moments of crisis when new technologies upset old logics and norms, allowing these scholars to explore the risks and potential of these media before they settled into their current agreed upon configurations. In this article, I historicize the bar code by digging into its context and placing bar codes in the discursive movements that determine its early use in commerce. Rather than simply an unremarked feature of our mediated landscape, this article restores bar codes to their proper place in the history of informatic control and organizational management.

In the move to historicize bar codes as an old medium, this paper borrows methodological elements from media archaeology. "Media archaeology is introduced as a way to investigate the new media cultures through insights from past new media, often with an emphasis on the forgotten, the quirky, the non-obvious apparatuses, practices and inventions." (Parikka 2012, 2). An analytical approach that belongs neither properly to the past nor present, media archaeology begins in the middle where the past and future become entangled. Foucault's archaeological approach to knowledge and culture provided a methodology for excavating what Jussi Parikka characterizes as the "conditions of existence." "Archaeology here means digging into the background reasons why a certain object, statement, discourse, or, for instance in our case, media apparatus or use habit is able to be borne and picked up and sustain itself in a cultural situation." (2012, 6). Media archaeology, on the whole, pays heed to both the material dimensions of media as well as the radically assembly of histories that encompass complex networks of institutions, practices, and technologies. Much of media archaeological research tends towards counter-histories and alternative genealogies of new and traditional media. As a research orientation, media archaeology seeks new ways to understand the current cultural, social, and political configurations of our media environment. As with any kind of history, the goal of any historical excavation is to understand the present through an understanding of the past.

Beginning with a brief history of the bar code scanner, this article delves into the intermedial notions that formed the first bar code scanning apparatus. Following is a discussion of modern logistical systems, focusing on the figure and space of the warehouse. Here, I examine the discursive movements that underpin the mass adoption of bar codes as part of the command and control systems in logistical spaces. After, I feature the example of how a hypothetical item might travel through the bar coding system from manufacturer all the way to the customer's doorway via the logistical and e-commerce giant Amazon.com.

Barcodes: A Brief History

The job of the theorist is to make inscrutable things scrutable, to render them open or transparent to the analytic lens. To that end, analysis of technical systems must first render the technical system. We must draw the system, thickly describe it in the fullness of its function, meaning, and parts. To most non-technical persons, analytic objects such as firmware, computers, and even the Internet as dynamic system of parts remain trapped within a black box. The first step of any analytical endeavor is to un-box the object, not unlike an unboxing video on YouTube that takes out and tests each part of a new product. In this endeavor, we must construct an object in the image of the original, to create a critical description that becomes legible in a system of analytic discourse.

Below, I describe the barcode, how it operates, and the critical avenues through which we can understand this object both as a technology and as a media phenomenon. Following this description, I explain how a barcode is read, the material limitations which cause the barcode symbol to take its form, and cover the underlying principles of barcode symbologies. I end with a brief history of the three major experiments that define how barcodes function and in what contexts and manners they have come to be used.

What is a barcode?

To truly describe a barcode it is necessary to understand the institutional purposes for which it is intended, including how it is used; and the principles by which it functions. Frequently, media studies will favor the former over the latter, which produces a lopsided understanding of an object, resulting in an uneven analysis. I address both these aspects in this section, and break down the significance of the barcode's intervention into the area of automatic identification and the logics of categorization that have come to structure the way in which we think about how both objects and human beings can be aggregated as bodies of data.

Like the engineers and scientists that invented the scanner in chapter one, the professionals in the Automatic Identification and Data Collection (AIDC) industry that produces and sells barcode scanners, printers, and logistical systems write their own histories of the barcode scanner as a way to define their emerging industrial sector and the unique identity of their work. Histories of the barcode appear on many of the company websites of corporations that sell everything from optical scanning systems to companies that specialize in digital monitors and surveillance systems, such as Naples Tech. The Naples Tech website provides a cogent industry definition of both the purpose and the function of the barcode, and implicitly ties the barcode to the notion of surveillance and monitoring:

Barcodes were developed as a method of representing information in a simple, reliable, efficient machine readable, optical format. What does that mean? Simply speaking—barcodes are the representation of information as patterns of marks on surfaces that can be detected by machines using light and optical devices, and that can be efficiently and reliably interpreted by machines. The printed text you are now reading qualifies as a method of optically representing information, and although special OCR machines are available to "read" printed text, they are not very efficient or accurate. Barcodes were designed to be "machine readable", to be easily and reliably detected and interpreted by machines. In sum, a barcode system is an optical symbol format that encodes identification information with the aim of being read easily by a scanner.

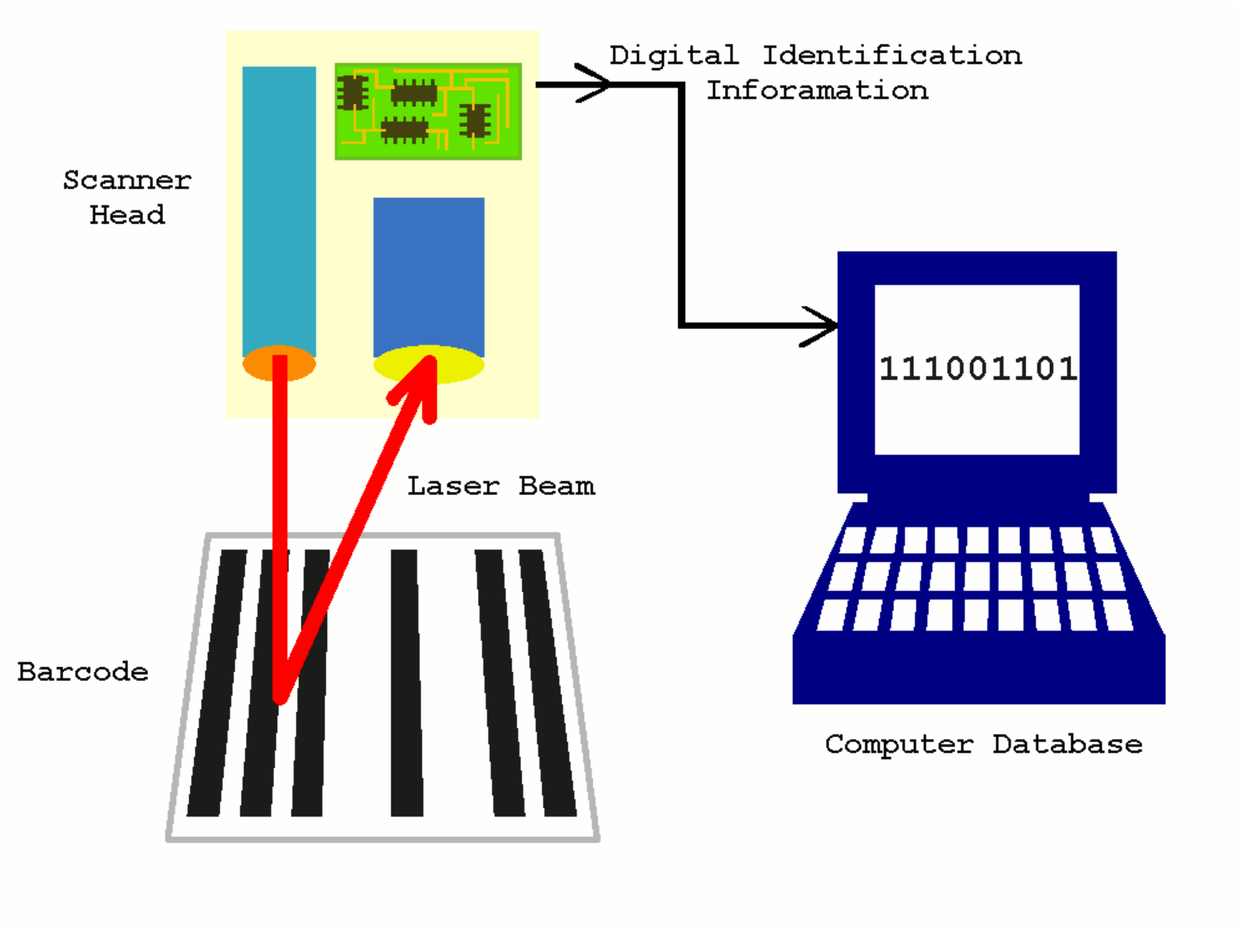

Figure 9: Diagram of how a barcode reader interacts with a printed, black-and-white barcode to retrieve encoded information. From http://www.explainthatstuff.com/barcodescanners.html.

The diagram in Figure 9 depicts the manner in which a barcode scanner retrieves information from a barcode label, which operates in the following manner:

1. Within the "scanner head" of a barcode scanner exist 3 components: a laser or LED light source, which produces the active signal that bounces off the barcode; a light-sensitive photoelectric cell, which detects the laser signal once it bounces back; and a circuit which translates the photo-electric signal into a binary signal and sends it to the computer.

2. The principle of scanning lies in the scanning unit's ability to detect the *difference* between the outgoing signal and the incoming signal. When a laser light is shone on a pattern of black and white areas, the black ink will absorb more of the light, thus reflecting back a weaker laser signal. Conversely, white paper areas will reflect more light back, thus returning a stronger signal. The pattern of stronger and weaker signals encodes the information content of the barcode.
3. The electrical pattern produced by the white and black lines corresponds to an "on-off" pulse pattern. Observing the barcode in Figure 3, humans would read the code as "black-black-black, white, black, white, black-black." The machine, on the other hand, would read the pattern as "off-off-off, ON!, off, ON!, off-off." Barcode scanners do not "read" the pattern of black lines, but the pattern of *white* lines. Remember, the white lines correspond with the "on" signal.
4. The circuit in the scanner head converts this pattern of electrical "on-off" signals into a digital signal—usually a decimal number. The computer connected to the scanner then retrieves the stored information in the database corresponding to the serial number it receives.

These four steps, in essence, constitute the manner in which barcode scanners detect barcode symbologies. Most barcode reading software at checkout points will also include a tallying method that allows the software to produce totals for sale. At grocery stores and other retailers, all the checkout computers are networked to a main server that holds the main store database. The store inventory updates constantly with each sale, allowing a real-time census of all the products on the shelf.

The idea behind the use of a barcode to label and categorize an item can be separated into two separate, but related, issues. The first issue is the need for a fast and accurate way to count inventory in commerce. Before mass barcode use, a grocery store, for example, would have to close once a month and spend the entire day manually counting their inventory and checking that against what they had bought the previous month. Then, once employees had tallied the entire inventory of the store, the manager could proceed with ordering the needed products for the following month. Commercial interests needed a faster way to conduct an inventory, preferably without frequent human error and at a speed that only a machine could achieve. The second issue emerges from the desire to not only count items with a machine, but to identify them. It is not enough to count an item if one cannot tally the items under a particular identity, name, or category. Thus, the barcode represents a scheme of classification and identification as well as summation.

With this basic understanding of the mechanics of barcode scanning, I must address certain peculiarities the Naples Tech's definition of a barcode, which reveals a complex set of reasons why the barcode takes the form that it does. The preceding definition repeatedly emphasizes the "machine readable" representation of language, juxtaposed with the OCR (optical character recognition) of English text. The aim of the barcode is to affix identifying information on to a material object in the form of serial numbers and letters that correspond to data about the object stored elsewhere. The machine-scanning component, in conjunction with some basic computing power, allows for the information to be retrieved faster and with less error than a human being reading a product description of the object. The form of the information can be encoded in any number of different ways, including simple English text. The problem with simply scanning basic text, however, lies in the high rate of error in algorithms that identify letters and words. Degraded, fuzzy letters from dirty printers, weathering, and cheap, inaccurate scanning technology all contribute to the input of text that becomes difficult for the OCR algorithms to parse (Lopresti 2009, 141–42). Moreover, the English language can be expressed in multiple fonts, which change over time and have no industry standardization (Sullivan 2010). Altogether, given the variety of letters that exist, OCR algorithms need to account for a huge number of variables in order to properly identify what has been scanned. This high error rate renders “normal” text a problem for efficient machine retrieval. The commercial industry preference for barcode symbologies, which have many fewer variables in the manner of encoding, forms the basis for the barcode’s overwhelming presence today. The barcode becomes an alternative, machine-oriented ideogram or script system for language. Moreover, this preference is predicated upon the slow speed of a human being’s ability to retrieve information via reading, and the continuing failure of computers to accurately capture text-based language data from the material world.

Benjamin Nelson, a long-time barcode expert who served on many industry boards and headed Nelson Associates, a group devoted to educating the public about the Automatic Identification and Data Capture (AIDC) industry, has written the only comprehensive history of the barcode industry (AIDC100.org). As an insider to the industry, Nelson was able to access many personal papers from friends and colleagues in addition to searching the archives of professional publications in the AIDC industry to pull together his historical narrative of bar coding. In Nelson’s volume *Punched Cards to Barcodes: A 200 Year Journey*, he makes an interesting rhetorical move by locating the barcode’s origin in the epistemological paradigm of math, in particular, the discovery of the number zero and the subsequent development of binary (Nelson 1997, 19–21). From this conceptual birthplace, Nelson’s narrative jumps forward to the year 1801 when Joseph Marie Jacquard perfected a way to automatically weave complex patterns in silk using punched cards (Nelson 1997, 23). Automated by steam power, Jacquard's looms merely needed punched tin cards to serve as instructions to raise and lower specific threads as the automatic shuttle passed through to create a pattern in the fabric. The success of Jacquard's punched-card-controlled loom led to a revolution in the textile weaving industry, and the basis of this technology persists into today's textile mills. Not only are high-end fabrics with woven designs referred to as "Jacquard" designs, but the notion of punched card instructions spread to subsequent media, such as the famous piano roll, used to operate player pianos.

Nelson's choice of rooting the barcode's historical trajectory in the idea of binary makes a kind of sense. Barcodes represent a translation of complex forms of information into simple, mathematical symbols that operate well with machine automation. The punched card takes that notion of a binary and renders it operational upon matter itself. The pattern of holes in a card represents a pattern of on and off, or, in the case of the Jacquard looms, raise or lower each thread in the warp (vertical threads) of a fabric. With only these two combinatorial possibilities, larger, more complex patterns of information can be encoded. In this sense, not only do combinatoric patterns form the logical foundation of barcodes, the punched card figures significantly into the prehistory of the barcode as well. Historians of computing include the punched card as part of the genealogical trajectory towards modern computers (Ceruzzi 2003, 16–46).

Depending on which account you read, the first barcode system is attributed to either Harvard University student Wallace Flint or the Drexel University team of Bernard Silver and Norman J. Woodland. Both teams deserve credit—Flint for forecasting that Amazon would one day become a logistical giant, and Silver and Woodland for envisioning the modern checkout point. Together, these two visions form the basis of modern automated commercial transactions. Each example also implies different sets of concerns and approaches to the same problems of inventory, product logistics, and efficiency.

Wallace Flint, a Master's student at Harvard University's Graduate School of Business Administration, turned in a thesis in 1932 detailing a system of automated checkout and product handling using punched cards (Jones and Chung 2007, 4). Born into a family in the wholesale grocery business, Flint was sensitive to the labor-intensive work of food retail. Bringing this experience to Harvard, Flint's system combined the flow racks of the manufacturing floor with the automated informatic control of the US Government's Census Bureau punched card system. Flint's idea was simple. A customer would enter the store and be given a piece of card stock with columns. Rather than allowing customers to gather their purchases personally, Flint eliminated products from the grocery floor entirely. Instead, consumers would take the cards to stations where they would look up the serial number of each product they wished to purchase from a store catalog and then use a punch machine to record their purchases on the previously provided card. Once finished, the shopper took their item lists to a checkout point where cashiers would run their cards through a machine that tabulated the purchase. While the customer paid for their order with the cashier, a system in the back of the store would automatically assemble the order, package the items, and send the whole lot down a conveyor belt to the front of the store where the waiting customer could pick up their items and leave. "The envisioned market was a giant vending machine" (Cole, Browning, and Schroeder 2003, 37).

According to the *Encyclopedia of Modern Everyday Inventions*, Flint's grocery warehouse turned vending machine did not ultimately succeed for several reasons (Cole, Browning, and Schroeder 2003, 38). The apparatus necessary to run such a huge automated operation was prohibitively expensive. Moreover, the self-service grocery model with which we are all familiar was already popular in the United States. Indeed, for those who still remember the days of punch card computation, card scanning was a cumbersome undertaking. Cards made of cheap paper could be lost, damaged, switched, or stolen. Customers could easily make mistakes when punching their cards, such as misreading a product's serial number or mis-punching the right number, leading to mistakes at checkout. These problems with Flint's model moved the thinking in technology circles toward the idea of affixing a label to the product itself, which would eliminate consumer mistakes and potential mismatch between the serial number and the product.

This early numerical barcode system is interesting to media scholars for its links to the history of computing. This history connects Flint's model of automated grocery distribution to later models of e-fulfillment with companies like Amazon. The Computer History Museum in Mountain View, California hosts an ongoing online exhibition with an entire section devoted to the importance of the punched card to computing (and barcode) history. The very first page of the exhibition claims that "Punched cards, a mainstay of early office automation and computing, helped launch the transition from doing math to processing data." This statement puts the genesis of barcodes into perspective. The barcode, in it shared intermedial history with computing, does not just function as a system of tallying, but as a system of data processing and product census. Moreover, the link between barcodes and punched cards reveals a material linkage between data and data processing in the form of the punched card, which would later be replaced by the barcode label. This intermedial link makes possible Internet commerce, which has come to fulfill Wallace Flint's model of commerce as a giant global vending machine.

The second barcode scanner model originated by Bernard Silver and Norman J. Woodland would later serve as the primary model for all succeeding models of scanners. According to interviews given by Woodland, the pair of Drexel University professors learned of the inventory problem in the grocery industry in 1948 after accidentally overhearing a conversation between a business school dean and a local supermarket executive (Fox 2012, A1). Seeing an opportunity, the pair quit their jobs as lecturers at Drexel University to pursue the invention of the barcode scanner. The resultant model works exactly like the model of scanning in Figure 1, but uses intermedial components from film sound technology and telegraphy.

The problem of barcode scanning can be broken down into two parts: firstly, the invention of a scanning machine capable of detecting a given target and secondly, a target that could be scanned in which a sufficient amount of information could be encoded. The scanning apparatus came first and was actually inspired by a previous invention by Woodland, who coincidentally spent World War II working on the Manhattan Project at Oak Ridge National Laboratory in Tennessee before returning to school earn his bachelor's degree after the end of the war (Fox 2012, A1). It was during this time as an undergraduate student that Woodland innovated a more efficient way to play elevator music. Instead of using cumbersome reel-to-reel tapes or LPs, Woodland expanded on the film soundtrack model. On 35-millimeter film stock, audio tracks were recorded on the edges of the film reel to be played synchronously with the images. Using this preexisting example, Woodland simply got rid of the images in the middle of the film frame and filled it with 15 simultaneous audio tracks instead. These could be played one at a time with the film on a loop. With his experience using projector lights to detect and play visual audio tracks on film, it was a short conceptual step for Woodland to modify this film system to create a scanner. The problem that stymied Woodland was not the scanning machine, but the question of what the scanner would scan.

The answer to that question would involve the medium of telegraphy. In 2004, Woodland recounted the moment in 1949, while sitting on a beach in South Beach, Miami, that he finally settled on Morse code as the model for a visual code:

> "I took a beach chair down to the beach and sat down. And I'm thinking, How the hell am I going to pull this off? I was just thinking to myself, What do I need? Well, the first thing I need is some sort of a code. And the only code I knew of was Morse code. You know, I had to learn that in the Boy Scouts when I was a youngster. And I was thinking"—Woodland starts singing— "'dit-dit-dit, daaah-daaah-daaah, dit-dit-dit.' Remember what that is? That's SOS. Dit-dit-dit was 'S.' I stuck my four fingers down into the sand and for whatever reason I pulled them to myself. And I looked, and I made four furrows. And I said, Wow! I can have encodation in the form of lines! I could have wide lines and narrow lines! Right? And that was the invention of the barcode, right then and there. That was it!" (Varchaver 2004, 145-146).

Again and again, the barcode industry and the inventors of the barcode themselves, refer to the barcode as a "visual" or "optical" version of Morse code. Frequently, the phrase "making the Morse code visible" appears to describe the mediating work of the barcode (Smith 2011). But what does it mean to make "the Morse code visible"? This requires a kind of reverse engineering of the barcode symbology to fit into the way the scanner operates. An optical scanner detects differences in areas of light and dark, turning them into electrical impulses that can then be interpreted in the manner desired, whether as an image or a numerical map. In the case of barcodes, working backwards from the manner in which an optical scanner operates, the design of the symbology becomes clear. A barcode must encode information in the patterned difference between areas of light and dark. Taking a cue from telegraphy's

Morse code, the earliest barcode used the combination of “long dashes” or larger gaps and “short dots” or smaller gaps between black printed lines to create an a symbology that could encode the numbers from 0 to 9.

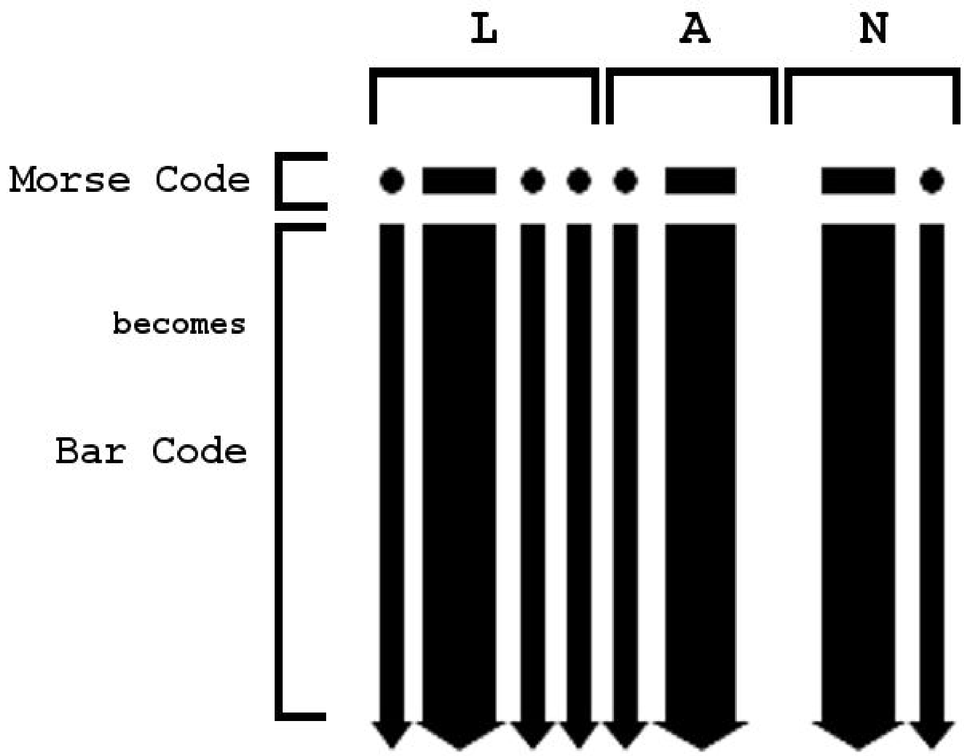

Figure 10: Conceptual Diagram for how a one-dimensional, electrical code that operates through differences in time scale becomes a two-dimensional, optical code that operates over differences in minor distances over a flat plane. The vertically elongated dots and dashes spell out author’s name (Lan) in Morse code.

This form of encodation takes an invisible form of communication and data transfer (electrical impulses) and transforms it into a visual symbology, with the explicit intent of turning it back into an electrical code. Underneath the standard Universal Product Code (UPC), the serial numbers of a product are printed for humans to read when the barcode is too damaged to be read by machine. However, we cannot forget that the barcode was never intended to be read by humans. This , in a way, may be the meaning of the the phrase "“making the Morse code visible."”

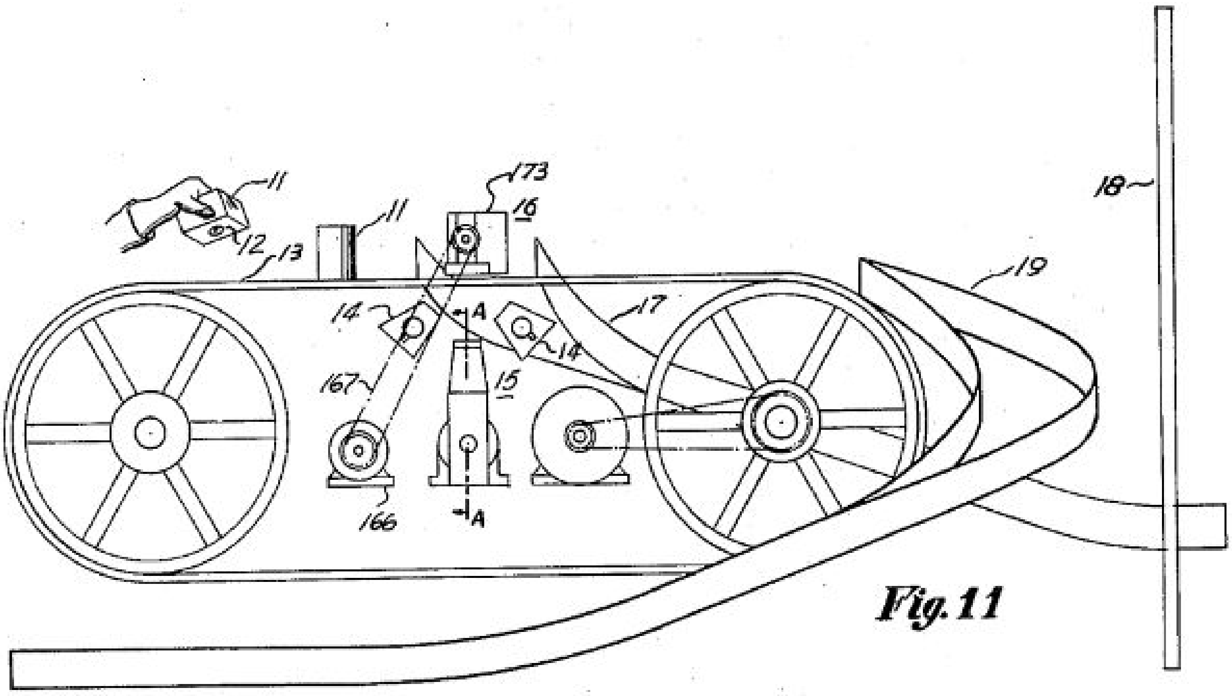

Figure 11: A diagram of the whole bar codebarcode scanning apparatus from Norman ““Joe”” Woodland and Bernard Silver'’s 1952 patent. The object to be purchased is set with the bar codebarcode facing down on the conveyor belt (#11 in the diagram), which passes the item over a glassed square. . Underneath this glass square shines the scanner head (#14 – three components), which detects the bar codebarcode and triggers a reaction. .

Woodland and Silver filed their patent with the United States Patent and Trademark Office in October of 1949. The duo would not receive approval for their barcode system, which they called simply a "“Classifying Apparatus and Method,"” until October of 1952. Reading the precis of the patent, where in which Woodland and Silver list their various claims for the original innovations and purpose of their barcode scanner, includes several issues of interest to media scholars immediately stand out. In the very first line of the patent, Woodland and Silver state:

"“This invention relates to the art of article classification and has particular relation to classification through the medium of identifying patterns."”

It may seem obvious that classification and organization structures the very notion of the object, but it bears emphasizing. The significance of the barcode far exceeds a simple check out tabulator or inventory census machine. The barcode , fundamentally, represents a fundamental a scheme for the organization and assignation of identity to material objects. . Further, the patent claims:

> "It is an object of the invention to provide automatic apparatus for classifying things according to photo-response to lines and/or colors which constitute classification instructions and which have been attached to, imprinted upon or caused to represent the things being classified."

The barcode label consists not merely of an identity assigned to an object, but a set of instructions. Moreover, I must point out that, in Woodland and Silver'’s model, the barcode does not encode the price of the object. The most pertinent information regarding anthe object in a retail store is stored elsewhere. Were the price encoded into the barcode itself, any time the store put the item on sale or enacted a price cut, all items would have to be re-labeled with new barcodes. Employees already had to do this before barcodes, which cost time and labor. By separating the attribute (price) from the classifier (the barcoded serial identification number), barcodes allow flexibility within the organizational system. But this flexibility was not the only innovation of bar coding systems:

> “A further object of the invention is to provide photo-sensitive apparatus which shall classify things without recourse to characteristics of the things themselves for classification instructions."

Here, I call attention to the fact that Identification or recognition of each object does not depend upon any characteristic of the object itself. Think about how most of us approach categorization categorizing of objects and persons people in our everyday lives. We can organize our bookshelves by topic matter, by the author'’s name, or even by the dominant color of the book cover. Netflix filters recommendations by film genres. Retail shops separate clothing by where upon each part of the body the particular article adorns. All of these ways of organizing and categorizing are inextricably linked to characteristics and traits of the objects being divided up. But that is not true of the barcode, which assigns a label that is almost entirely divorced from any feature of the object itself. The serial number encoded in the barcode usually represents the identity of the manufacturer and the model number. A The connection between a serial number and an object is a tenuous connection one that barely, if at all, touches upon the discursive qualities of an object in its lived and consumed relations to the subjects purchasing them. The barcode thus represents a new level of abstraction for the retail sector and for scanning systems in general. Media theorists must question the function of what enacting the transition from telegraphic Morse code to the barcode. does? How does the transformation of this linear, invisible code into a visible sign, in very sense of the word sign, enable it to do a different kind of work? Further more, the barcode-and-scanner complex allows for a kind of "reading at a glance," an interaction that excludes humans from any part of the process except for the physical initiation of the process (and the set up of the master database system). How does this object "agency" figure into academic thinking regarding mediation itself? What occurs when a machine performs acts of "identification?" Might we call this function a form of "recognition?" Can a non-subject truly "recognize" patterns or is does it merely a supply a programmed response to the association between the pattern and its relational data? One issue I do feel certain about is the place of scanners in our media network. In a sense, the barcode-and-scanner complex becomes the *medium which mediates* between material objects and their data representations or their "data bodies".

Woodland and Silver''s barcode scanner was somewhat ahead of its time. The design required technologies not yet available on the open market, such as cheap lasers and accurate printers, to become efficient enough to operate in retail stores. And even when scanners were introduced widely in the 1970s, great resistance existed against adoption. The systems cost money and required a certain threshold of adoption by all stores to work (Gerena 2014, 31). . They were, at first, also unreliable at first, and viewed by business analysts viewed them as a risky investment (Sekeley & Skinner 1972, 44–-47). Indeed, even consumers remained suspicious of barcodes, regarding them as a possible surveillance technology that would rob them of privacy (*The Telegraph* 2011). .

The popularization of the barcode and its spread into commercial practice is due not to the influence of its inventors, but to a man named Alan Haberman, a grocery industry leader (Fox 2011, B19). A grocery industry leader after serving as president of Hills-Korvette Supermarkets and later Finast, a Massachusetts-based grocery chain, Haberman convened the 1973 committee that standardized the use of the barcode. Before this landmark, many barcode symbology systems and hardware existed, creating a confusion of competing systems that kept the grocery industry from fulling fully exploiting the system-wide benefits of standardized bar coding. The committee settled upon a barcode symbology invented by IBM Senior Engineer George J. Laurer, which has since come to be known as the UPC-A code and whose iconicity is now synonymous with all bar coding systems (Smith, *Good Magazine* 2011). Even with the adoption of a standard, the institutionalization of barcodes teetered precariously on the edge of failure despite Haberman's constant campaigning with individual grocers and companies (Fox 2011, B19). In 1976, *Business Week* famously published an article titled "The Supermarket Scanner that Failed." It took until the 1980s for the barcode scanner to truly saturate the commercial landscape after mass merchandisers like

K-Mart finally started using them in stores (Brown 1997). The promise of a technology like barcodes required simultaneous human engineering to create the social systems and protocols to exploit its capacity.

Amazon: A Case Study in Global Monitoring Networks

Amazon's warehousing practices serve as a case study in this chapter for several reasons. Primarily, the Amazon warehouse is an excellent example of how barcoding, or automated identification, is critical to Amazon's ability to serve an instant gratification model of commerce. Moreover, this case study illustrates that scanners serve a fundamental function of organizing the movement of matter in geographical space. By studying Amazon's logistics, we will see how scanning serves an infrastructural mediating role in the larger function of linking material reality to digital identity through the modality of categorization and identification. Finally, not only is Amazon topical in the news today, but it serves as a good example of how online retailing differs from the traditional retailing practices of the grocery store in the previous section. Amazon's warehouses serve both warehousing and retailing functions at once. The "shop front" of this retail space is a web page, leaving most employees to work on the back end and at the warehouse. In Amazon, Wallace Flint's model of commerce has finally come to fruition, in an even more efficient manner than he could have foreseen.

I begin this section of the chapter by exploring the contextual, historical trends that have emerged over the last fifty years within the commerce. New models of business have emerged that re-conceive individual companies as larger symbiotic networks whose capacities for labor are integrated, rather than as isolated entities exchanging items. These key philosophies guide the operation of Amazon, and are fundamental to why barcodes have saturated the invisible portions of the supply chain. In order to illustrate the new infrastructure of the barcode, I examine the journey of a hypothetical item from a manufacturing plant, to an Amazon warehouse, and finally, to a consumer's doorstep. In this process, I note the many barcodes that may appear and discuss their specific functions. It is crucial to understand the context in which a barcode works in order to analyze how a barcode functions within institutions to facilitate and govern nodal transactions in networks of material exchange. Finally, I examine the implications of the emergence of a global monitoring network in commerce and pose questions regarding the place of objects in modern surveillance schemes.

Sea Changes in the Culture of Commerce, 1970–Present

The warehouse may seem an unusual site for media studies. Our discipline usually tends to favor sites of consumption, where labor is increasingly being offloaded onto the consumer, such as self-service supermarket checkouts (Horst 2009). Since the existence of organized civilizations, however, warehouses have been a fundamental part of any city or state's prosperity. The earliest known warehouse was archaeologically uncovered in 1955 in the city of Lothal, which is located in the Indian state of Gujarat (Murray 2007, 23). Lothal was part of the Indus valley civilization, which dates back to 2400 BCE. The site of the warehouse sits in the middle of the supply chain, somewhere between the producers and suppliers, and the retailers and consumers. These architectural and technological units form a crucial command node through which the right product is dispatched to the right shipping company, labeled and charged to the right customer so that it arrives at the right time (Richards 2011, 7–8). Like the network routers upon which Amazon depends, the warehouse routes objects through its premises to their proper destinations in an envisioned flow that sprawls across the entire globe. As a site of constant innovation, study of the warehouse infrastructure allows us a glimpse into the critical role technology plays in the fulfillment of our consumer fantasies.

For those outside the shipping and product management business, the word "warehouse" likely means exactly what it describes—an industrial building that "houses" or stores "wares" for a business or enterprise. These architectural eyesores, frequently located in industrial complexes away from everyday social transactions, have mainly served as stock-holding points where products were left to sit until they were needed to re-stock retail locations in faraway suburban and urban storefronts. For the most part, warehouses used to act as a geographical and temporal buffer in the supply chain that allowed retailers and manufacturers to maintain a steady stream of product matched closely to consumer demand. There is something simultaneously empty and full about the notion of a buffer, of a building whose main importance is regulated as much by its state of vacancy as by its state of occupancy. As a buffer, the warehouse functions, in the traditional manufacturer-to-retailer chain, as a place of overflow, its occupants belonging neither on the floor of the plant, nor on store shelves. Thus, the warehouse has been an important, lively, but largely invisible piece of the supply chain to the consumer. That model of the warehouse has begun to change with the advent of Internet commerce and the rise of e-fulfillment, however.

Firstly, the rise of e-fulfillment as an important component of Internet commerce emerges not simply from the supposed ubiquity of the Internet, but from a confluence of recent economic pressures. The use of warehouses solely for storage purposes was a good option in the last century due to cheap land prices, but rising land, building, labor, energy, upkeep, and transportation costs make this model of the warehouse less and less sensible.

Secondly, e-commerce owes some of its momentum to the recent emergence of business movements and concepts that emphasize consumer-focused service, flexibility, and efficiency, such as Efficient Consumer Response (ECR), Quick Response (QR), and Just-In-Time (JIT) delivery. These particular concepts form the present historical context of e-commerce, and undergird the operational logic of Amazon and other Internet firms. The two business methodologies that most closely structure Amazon's business logic are Efficient Consumer Response and Just-In-Time logistics. These two models also depend heavily on barcodes and associated telecommunications developments to function efficiently, or at all for that matter. These trends date to the eighties and nineties, when the grocery industry perceived that they had fully exploited the easy gains available to them. The use of barcodes not only allowed for more efficient inventory, but made it possible to add even more diversity to their product offerings, which appealed to consumers, and streamlined business operations. Business leaders in grocery supply and retail began formulating strategies to maximize their profit margins point by point, starting with methods that focused on efficiency throughout the supply chain.

The first business development made possible by the barcode is ECR, which grew out of the Quick Response movement. Not so much a philosophy as it is a series of managerial strategies and techniques aiming to minimize costs for all parties in the supply chain and increase value for the consumer, the ECR movement emerged from the grocery chain logics of the eighties and nineties (Finni and Sivonen 2009, 112–14). For the academic audience, ECR principles may be analogized to the aggregated *techné* of power that, in sum, produce a larger effect (O'Farrell 2005, 127). In practice, ECR required extensive collaboration between suppliers and retailers that involves the integration of their two computerized supply systems to allow automation of purchases and delivery of key goods. Traditionally, as sales were processed through a checkout counter, inventory totals would be automatically updated in the store computer. The system would initiate an automatic order for items when inventory ran below some preset level,. This system of integration allowed both parties—suppliers and retailers—to capture and analyze data on consumption patterns, leading to predictive models and constant adjustment of inventory throughout the year. Moreover, ECR proposed the prioritization of customer service and consumer-perceived value, which included better products, greater diversity and assortment of items, increased availability of items, convenience, and, of course, lower prices.

Clearly, ECR principles guide the culture of Amazon. The company's incredible explosion of diverse stock items in recent years, the general perception of good value in price and quality, and, of course, Amazon's logistical system that creates true convenience, all reflect how ECR strategies and techniques have come to quickly suffuse the culture of best business practices here in the United States. ECR practices have filtered out to foreign grocery industries, by the late nineties, the greatest concentration of ECR implementation remains here in the United States (Kurnia, Swatman and Schauder 1998, 5). To be very clear, observing that Amazon practices elements of ECR does not, in fact, mean that I argue that it is an effective best practice. Rather, as a media scholar, I wish to ground the logistical culture of Amazon not in Amazon's particular institutional genius, but in a cultural sea change that occurred at the time when Amazon launched. Moreover, ECR is a very culturally American movement, which drew its inspiration from a variety of places, including from the culture of efficiency in Japanese business (Finni and Sivonen 2009, 119).

The second major logistical model that influenced business practice in the United

States is just-in-time inventory management. JIT seeks to identify and eliminate all waste and inefficiency, on every level. "Wastes in JIT are not limited to tangible items such as excessive inventories and defective items, but also intangible items such as under-utilized manpower and facilities that have better use elsewhere" (Lai and Cheng 2009, 6). Whether it concerns the elimination of delay in customer response or lag time in information flow between suppliers and retailers, JIT attempts to maximize every possible aspect of a supply chain through an obsessive focus on time and timeliness.

The hallmark of just-in-time business philosophies is efficient inventory management: JIT seeks to minimize excess stock kept on hand. Each extra item represents capital locked in material form, unavailable to be reinvested into the business, and therefore unable to work toward greater profit for the retailer. Because each overstocked item represents an inefficiency, the just-in-time model shifted inventory from large lot orders delivered infrequently to much smaller orders delivered frequently. Through data analysis, a retailer should be able to keep incoming inventory perfectly matched to outgoing sales, with orders arriving only "just in time."

These historical paradigm shifts shaped changes occurring not only in the operational culture of the retail sector, but within manufacturing systems and technologies as well. Retailers employing ECR and JIT logistics could not move forward without simultaneous cooperation from their supplier counterparts. Previously, manufacturers planned their business model on long supply runs, meaning that they spent a longer period producing a larger inventory of any given good. By committing to a high inventory of each item, manufacturers lowered costs per unit and increased efficiency (Coyle et al. 2012, n.p.). This approach resulted from the difficulty and time involved in changing features such as type, model, and color during production. Manufacturing equipment was expensive to switch in and out, unlike today's more responsive, quick manufacturing practices (Moon 2013, 47–49). This led to a "push" culture of manufacturing: suppliers attempted to anticipate what consumers would want, produced products, then sold them to retailers. Manufacturing would "push" products to the consumers, concerning themselves with the question of "how much of this product can we convince the customers to buy?" (Cheng and Poldosky 1996, 46–48). The benefits of this model of manufacturing—in particular its great flexibility to create ever more diverse items—caused it to persist for a long time.

However, in the 1970s, Toyota's culture of manufacturing efficiency popularized a JIT approach to manufacturing that focused on flexibility to respond to changing consumer demand, in part, through employing shorter supply runs (Cheng and Poldosky 1996, 2–3). Toyota departed from push manufacturing, designing factories to instead respond to what the company called demand "pull." Essentially, the factories and their employees would make only as much as needed, allowing for idleness and what they called "slack" in the system. This method is very efficient for making repeat orders of a few standard items, and very responsive to consumers; however it having more diverse lines of products difficult (Cheng and Poldosky 1996, 48). Gwynne Richards, supply logistics expert and instructor at Hong Kong Polytechnic University sums up the cultural shift best: "We have gone from a 'push' to a 'pull' supply chain over recent years. In fact, the phrase 'supply chain' can be a bit of a misnomer and maybe it should be called a demand chain, with consumers holding sway" (Richards 2014, 8).

The so-called "short" supply run hearkens back to pre-industrial artisan work. An individual skilled artisan could produce only so many items in a single period, which can be read as an early form of manufacturing "short" supply runs (Goldin and Rockoff 2008, 46). The "long" supply run of early industrialization and the Fordist Era can thus be read as a kind of Gutenberg Parenthesis. The capacity of manufacturers to dictate trends and product availability has given way to quick changes, greater introduction of new products, and a need for faster response to consumer demand. The futurist imaginary surrounding products manufactured by household 3D printers might be regarded as the "ultimate" endpoint of the "short" supply run: an inventory of exactly one.

The challenge of the just-in-time model requires that the entire supply chain—from manufacturing to shipping to warehouse to customer—has had to speed up the throughput of the system and be maximally responsive at all times. Rather than a supply chain that models itself off of a series of exchanges—supplier sells to retailer; retailer sells to consumer—the JIT philosophy envisions the supply chain as a pipeline or thoroughfare through which a continuous flow of material and capital move. Moreover, within the JIT supply chain, related companies no longer buy items from one another, they buy *manufacturing capacity*. The *Tool and Manufacturing Engineers Handbook* states that,

> *Buying supplier capacity in lieu of contracting for actual part numbers and volumes* is a just-in-time objective. It is, therefore, important to reach the point in JIT supplier relationships where *the portion of the supplier's capacity that is attributable to one's products may be regarded as an extension of one's own manufacturing facility*. The objective can be achieved through co-op contracting. (Cubberly and Bakerjian 1989, 7–34, emphasis mine)

What this means is that major suppliers have relationships with other manufacturers that sell them the parts or raw materials necessary to create their own products. An example of this type of network of manufacturing would be the Detroit auto industry. Ford buys many of the parts necessary for a vehicle from other local companies rather than construct them on site. In a JIT relationship, Ford does not order individual shipments from these smaller companies; Ford buys their capacity to produce these shipments as needed. We might think of these satellite corporations that supply parts as being on retainer for the parent corporation. Ford essentially reserves space, time, and labor within the satellite company—indeed, it buys its capacity to produce—contracting out parts of its manufacturing process to other companies. Under this relationship, contracted companies must produce needed parts on demand, or as close to that ideal as possible. This hybridized cooperation no longer allows for truly individual firms, and requires an incredibly intimate level of coordination and information sharing, of which the barcode becomes the facilitating component through networked databases. While this type of relationship can eliminate waste in the system, the close monitoring of the progress of each individual part becomes critical due to the highly dispersed nature of production. A single automobile has hundreds of pieces, with many manufacturers potentially connected to each one. To keep in total control of such a dispersed network requires ever-greater control and scrutiny by corporations over their supply chains.

Commodities are now produced not at singular places but across what Deborah Cowen characterizes as logistics spaces, especially if we think of transportation not merely a link in the system but as part of the whole process of logistics itself. (2014, 2) Because this whole logistical cycle is so delicately balanced, it can be easily interrupted by blockades, construction delays, labor actions, bad weather, piracy, etc. In response, governments and corporations have developed an entire system of supply chain security – of which bar codes are a part – in order to guarantee the continued flow of goods around the globe. Cowen argues that the logic of the supply chain did not emerge from business and commerce, but from the practices of the military (2014, 3).

Today, corporate logistics have become increasingly entangled with military forces, as the military makes way for corporate trade and corporations support military endeavors. Cowen cites the example of Iraq and Afghanistan where military logistics have become the largest privatized part of the campaign. Logistics in warfare is not simply about the delivery things to the correct locations, but about the supply of life itself to battlefield, transforming it from a secondary to a primary concern of strategy. “Logistics is no simple story of securitization or of distribution; it is an industry and assemblage that is at once bio-, necro-, and antipolitical.” (2014, 4) Thus, Cowen argues that these “pipeplines” of flow are not only reorganizing national territoriality and transforming the geography of production and distribution, but also reformulating our political relationship to our world and our very practices of citizenship. “Arguably the most underinvestigated revolution of the twentieth century, the revolution in logistics was not the upheaval of one country or political system but a revolution in the calculation and organization of economic space.” (23) Rather than bounded entities transacting with one another, this revolution creates a whole supply chain whose purview combines both production and distribution into one logical body.

In the transition from a push to pull economy during the 1980s, retailers began to take on more responsibility for the supply chain themselves. Large retailers built more national and regional distribution centers, which were often run or even owned by third parties contracted by the company. Companies abandoned the sunk costs of local warehouses, relying instead on the constant transportation of products from regional centers. This practice has only increased as production is outsourced to India and Asia, requiring retailers to hold all the inventory they buy somewhere in the United States. Shipping a container on a ship from Shanghai to the UK can take up to 31 days, which means a store must order inventory up to five weeks ahead of time to stay on top of the seasonal product cycle. By holding stock in their own distribution centers, retailers could manage transportation demands from off-shoring production. In addition to these factors, changing consumer demand for increased variety resulted in warehouses holding fewer copies of more items. It is into this context that online sales emerged as both an answer and a challenge to the entire global control network.

The whole fragile network described here remains in a delicate balance with telecommunications technology to allow for mass coordination and control. I detail the cultural and historical context of modern global commerce not only to explain the genesis of Amazon as a global logistical powerhouse, but also to emphasize the fundamental role of barcoding and telecommunications in facilitating this global sea change. The new model of material flow would be impossible without the ability to monitor inventory, labor, and the transportation of goods between parts of the supply chain. Informatics, as provided through barcoding, forms a key, structuring foundation of modern notions of efficiency. If institutions cannot benchmark their processes, how would they be able to implement improvements? ECR, JIT, and Toyota-style manufacturing efficiency are all institutions capitalizing on pre-existing technologies like barcodes and computerized databases, transforming individual technologies into a networked system upon which entirely new philosophies toward the disposition of matter itself rest. It is into this context that online sales emerged as both an answer and a challenge to the entire global control network.

Amazon

What follows is a schematic of the journey that a hypothetical item might take from an imagined factory in China all the way to the door of a consumer, in this case the author's place of residence in Goleta, California.. Figure 12 illustrates the process that this item might take and indicates a few of the barcode scans that occur within this process. In the follow section, I describe how barcodes act are used to track the progress of the item through each site on the supply chain as it moves towards the consumer.

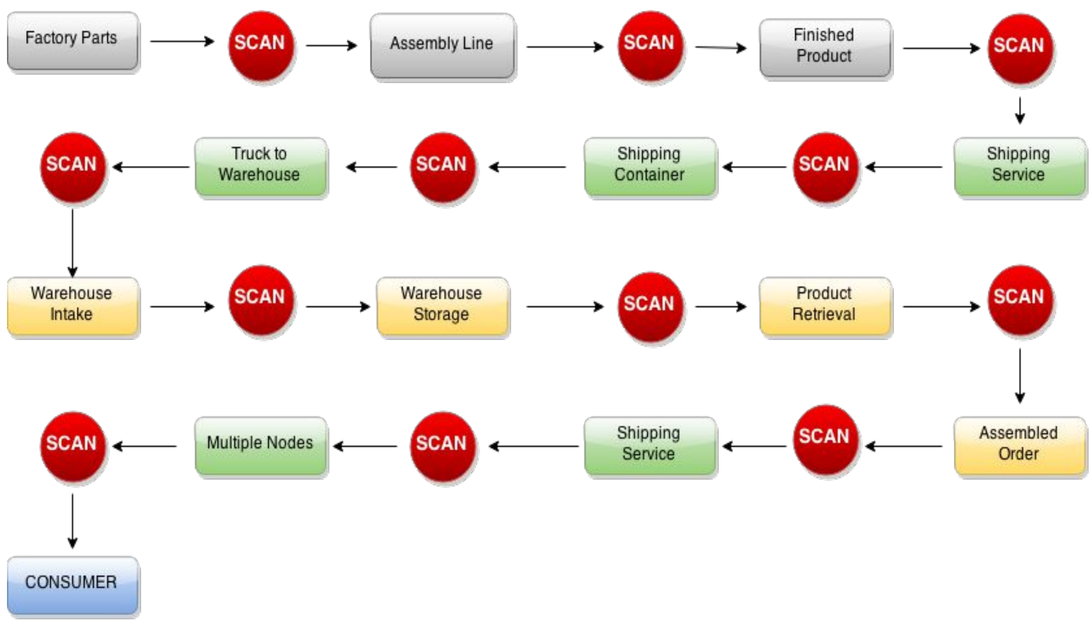

Figure 12: A diagram of the nodes through which an item might travel through the supply chain, from the manufacturer to the consumer. Red circles indicate the major moments when the item is scanned. Factory

The item begins its life as raw materials at a hypothetical factory in China, which are barcoded and stored until needed on the assembly line. Bar coding is a common strategy in manufacturing to monitor in real time how quickly some materials were being used up at each node of the assembly process (Zhou, Xie, and Chen 2011, 330). By scanning when the materials are delivered to the station and as each part is used or applied, the operations management can route parts as needed in a timely manner.

The final product is given a Universal Product Code, which has been registered with a central governing authority. This UPC will appear on the packaging, but it may not be the only barcode assigned once the product is finished. A second barcode may also be applied for internal tracking purposes, such as keeping count of each lot that is made. Thus, a single item may possess multiple "data identities" as it moves through the supply chain, each barcode corresponding to a different internal set of data on the product.

China Post

Once the product is packaged and ready to ship to Amazon, a shipping label with a unique barcode used solely by the shipping company is printed out and applied. Many manufacturers have integrated their computer systems with that of their local delivery company. A service, such as China Post, allows its customers to print out shipping labels compatible its system, and to schedule pick ups as well. This serves both companies well, because China Post offloads labor onto the manufacturing company, while allowing the shipping firm to plan its pickups ahead of time.

When the shipping firm arrives to pick up the order, it will scan the boxes as they are loaded before returning to the main sorting facility. When the shipment arrives, the items are scanned again to indicate intake into the China Post system. Once sorted into the correct outgoing truck, the shipment is scanned one more time at departure to indicate which vehicle has picked up the item.

Shipping Containers

In our hypothetical scenario, the shipment will be taken to the nearest seaport, where the shipping company handling the China Post shipping containers will load items into shipping containers. Each shipping box has a barcode that allows the ship database to know exactly which box sits where on the ship. This will allow the port authorities to streamline the process of unloading hundreds of shipping containers.

Ports and Trucks

The container ship arrives at the port of Los Angeles, where Longshoreman's Union workers use the location data provided by the ship to unload each container box onto the correct truck. Knowing the order of unloading allows the trucks to plan in advance the order they should line up to receive the box. When each box is offloaded, the container is scanned to track that all shipments have been given to the right trucking service.

Warehouses

Amazon does not own a fleet of trucks for the purpose of transport at the moment, and contracts with several firms. The trucking firm contracted by Amazon to pick up its shipment from China Post arrives at one of Amazon's West Coast warehouses, for example, the Inland Empire warehouse in San Bernadino, CA.

The truck's contents are unloaded into the warehouse proper by employees. Each box is scanned again as it enters to confirm receipt with China Post and to check that the manifest list is accurate.

Intake and Chaotic Storage

When products arrive at the warehouse, they must be put away until they need to be retrieved. Amazon uses a random storage system, also known as "chaotic" storage, loading items into the first available spot on a shelf (Sterling 2013). So long as the item fits into the space, there it goes. This approach eliminates any internal categorization system, such as grouping goods by type or by manufacturer, as seen in a grocery stores for example. In order to locate an item in this system, you must have a barcode and database system in place, or else the warehouse would descend into chaos.

As soon as the item is unpacked from the delivery crates, a worker assigns a barcode number to the item and applies the label. This barcode number is then scanned using a handheld scanner to register that this item is now in the system. The intake worker then takes the item to the nearest open spot on what Amazon calls a "bookshelf." This shelf will also have a unique barcode number, describing its exact location on the rack, and where that rack is located on the warehouse floor. The employee then scans the item barcode and, immediately after, scans the shelf barcode. Now the two pieces of information are linked in the database. The computer now holds the exact location of the item in the warehouse for when the item is ordered. This system of storage allows for flexibility and responsiveness, which benefits Amazon due to the vast and ever-changing diversity of products it offers either through its own inventory or through third-party sellers.

Order Fulfillment

When a customer places an order, the main computer will create a list of items in that order and their locations. Previously, each Amazon employee assigned to assemble a purchase would have to walk from one shelf to another to gather all the items into a single bin, which represented the order. Each employee carried a handheld scanner connected to the main operations computer. This computer, which tracked the location of the employee within the warehouse, would assemble the list of items in the order that they should be retrieved based upon algorithms to cut down time and increase efficiency. Then the handheld scanner would issue directions to guide the employee to the right shelf on the right rack. The employee would take the item from its shelf, scan it to confirm that it is the correct item, and finish by scanning the shelf space to indicate that the space was once again empty. This process was repeated until the order was filled, at which point the order bin was deposited at a station where another worker would package the order.

In the new system, Amazon warehouses have implemented a robotic fetching system to eliminate the strain of employees walking up to ten miles per day (Bernton & Kelleher 2012). Now, Kiva robots fetch the items and bring them to the packaging stations around the periphery of the warehouse. Kiva robots are round, wheeled platforms that sit underneath a whole rack. Instead of grabbing an item off the shelf and carrying it to the packaging station, a Kiva robot simply picks up the bookshelf. The robot, controlled by algorithms and GPS tracking in the main operations computer, takes the bookshelf to the correct packaging station. If there is a line, the robot waits. When the packaging worker is ready, the robot moves forward into place and the worker removes the item from the correct shelf. The worker then scans the item and scans the shelf to indicate that the correct item was selected and that the space is now free. With that scan, the main operations computer sends a signal command for the Kiva robot to return the bookshelf to the warehouse floor. Following the logic of chaotic storage, it does not return the shelf to its former spot, but to the nearest open space. Once finished, the robot receives its next order.

Packaging

At the packaging station, workers scan each item as it arrives, packaging orders in appropriately-sized boxes. They apply a shipping label that was generated when the order was submitted to Amazon's system. This label, which prints at the packaging station, determines which carrier will take the shipment. A worker scans the box to indicate that it is ready and places it onto a nearby conveyor belt to be taken down to the shipping dock.

Shipping

Once our hypothetical package arrives at the warehouse's outgoing shipment area, workers scan the box and divert it to the trucks of the correct shipping company. The shipping company loads the truck, scanning each item to indicate successful pick up, and takes the orders to the nearest central sorting warehouse. For items coming from the San Bernadino warehouse, the nearest United States Post Office sorting facility lies in West Covina.

At this sorting facility, the Amazon order is scanned upon arrival and sorted into the correct truck. As it is loaded, the package is scanned again, and taken to the correct local post office, in Santa Barbara, California. The packages are scanned again at the local post office in Goleta, where they are sorted according to each mail carrier's route. Once loaded onto the mail carrier's truck, the items are scanned to indicate that they are now out for delivery. When the mail carrier finally arrives at the author's door, he scans the package one more time to indicate delivery and leaves it for the author to find. If the consumer should need to return the item to Amazon for some reason, Amazon would generate yet another barcode to initiate the acceptance of the item back into the system, providing an additional unique shipping label to be affixed to the package for pickup.

As items move through the supply chain, they acquire multiple data identities at each node of the system. At the manufacturer, there is one internal barcode system to track the item. The shipping agency uses a different internal barcode system, which again differs from the barcode system used by Amazon itself, and so on. At any given time, an object will have passed through multiple networked systems that assign and discard data on the item. Each of these internal systems exist primarily to track the geographical disposition of the object, allowing a tightly refined control of the movement of each item as it moves through their institution. As demonstrated in this hypothetical example, it takes an enormous surveillance effort to track and manage the flow of materials that travel across the globe.

Martin Dodge and Rob Kitchin argue that the recent trends in the increasing use of identification codes on everything is driving us towards what they call a machine-readable world. (2005, 852) Bar codes represent the physical manifestation of what Martin Dodge and Rob Kitchin (2005) call identification codes, which are unique keys that allow like things to be separated and pinpointed from within group. Identification codes can be attached to people, places, things, or even processes, such as transaction numbers in banking, passports, bank account numbers, zipcodes, or computer passwords. Achieved through physical tokens like the bar code or credit card, identification codes allow not only for the individual item or person to be disaggregated from the whole, but it the information they generation allows the subsequent reaggregation of that of these individuals into new groupings and axes. The power of these identification codes allows entities and organizations to represent, sort, collate, monitor, profile and generally manage the items to which which these codes are attached. Invoking Michel Foucault, Dodge and Kitchin argue that the with movement into modern society, populations needed to be managed on a mass scale through the quantification of society itself. This required an "objective" and accurate means of identifying and measuring the components of this system, which identification codes provided the operational means of doing.

This move to bring order to the world accompanied a shift from local, subject forms of knowing to more centralized and objective orders of knowledge. In order to know a population in detail, governmental organizations not only articulated a language to describe these objects of governance, but also invented devices like identification codes to inscribe these objects, rendering both processes and people as “calculable” in the scheme of governmentality. Through techniques such as health records, social security numbers, criminal records, tax records, registrations of birth and death and marriage, etc. these identification technologies created overlapping systems of surveillance that in total, especially with today's increasing ability to collect data, have created a panoptic assemblage, of which the bar code system is merely one component. The language of business logistics and the automation enabled by control technologies like the bar code tap into a powerful discourse of risk management that suffuses the idea of governmentality, spurring a transformation of the supply chain from a series of transactions into a unified logistical space. These discourses of productivity, reliability and flexibility have been powerful drivers in the adoption of this form of scientific quantification and control. Thus, bar codes can be identified as being part of a larger trend of governmentality and biopolitics, sharing a common logic of quantification, management and surveillance.

As items move through the supply chain, they acquire multiple “data identities” as they pass through each node of the system. At the manufacturer, there is one internal barcode system to track the item. The shipping agency uses a different internal barcode system, which again differs from the barcode system used by Amazon itself, and so on. At any given time, an object will have passed through multiple networked systems that assign and discard data on the item. Each of these internal systems exist primarily to track the geographical disposition of the object, allowing a tightly refined control of the movement of each item as it moves through their institution. As demonstrated in this hypothetical example, it takes an enormous surveillance effort to track and manage the flow of materials that travel across the globe.

What I describe here represents a totalizing control system that stretches across international borders. Barcodes act as the nodes of the network that allow the global monitoring of objects, and indirectly, of people. In each step of this process, not only are objects governed in their material disposition, but people are as well. An employee initiates each scan that occurs, the only aspect of labor that is visible to the computational control system and yet is fundamental to the operation of the entire chain. Despite the system's direct surveillance of the object, it implicitly disciplines the body of the laborer. The ability to monitor the flows of purchases through the surveillance scheme also allows the indirect measure of the productivity of the laborer. The barcode system works as a duel system of productive surveillance, which stimulates the “docile bodies” of the laborer to work even harder. Thus, human subjects are reduced to merely data appendages of the objects that exist as the primary focus of these commercial endeavors.

The rise of discrete and individual surveillance systems coming together to create a larger “surveillant assemblage” that abstracts individual bodies into a flow of information that is later reassembled into a “data double” (Haggerty and Ericson 2000, 606). These data doubles allow the processes to be scrutinized and targeted for intervention. The convergence of these systems into a larger surveillant assemblange begins to draw in more and more previously exempt groups of people into regimes of routine surveillance. Much of surveillance focuses on the human body, which is first broken down and abstracted from this context. This body is then reassembled in a different context as a flow of data. What results is a monitored body that is decorporealized, a “data double” of that is purely virtual, but simultaneously tied in a cyborg fashion to its corporeal reflection (Haggerty and Ericson 2000, 611).

These hybrid objects under our surveillance then are hybrids because their bodies are tagged physically with a bar code, allowing the movements to be recorded as they travel through space. This allows a reconstruction of that journey in total from the trails of information that appear through out this bar coding system. Haggerty and Ericson call these surveillant assemblages a “visualizing device that brings into the visual register a host of heretofore opaque flows” of information, behavior, and processes (2000, 613). Like scanning itself, these surveillant assemblanges are characterized by the ability to bring into visibility things and processes which exist beyond the human sensorium. “Likewise, the surveillant assemblage is concerned first with rendering and transforming the body into pure information soch that it can become mobile and comparable. (2000, 611). These data flows are then centralized into a data center that takes these flows of the surveillant assemblage and scrutinize them to develop strategies of governance, commerce and control.

According to scholar David Lyon, the globalization of of surveillance is characterized the performance of transactions at a distance. No longer are exchanges like commerce done in person, but now operate at a distance and often anonymously with people geographically apart from us. Lyon argues that while social relations are stretched out of shape by the abstracting logic of new communications technologies, the trust that once existed in face-to-face transactions are now restored through the use of tokens, like password, Ids, PINS, telephone numbers, and drivers' licenses. (2004, 139) Although technological developments like the bar code are central to the ability of this system to communicate and control the

movement of objects, technology is not the cause of surveillance. Rather, technologies like bar codes serve as enablers to the ongoing quest to increase mobility and speed.
Barcodes become in this instance an annotation of matter that allows for the control of that matter through time and space. The barcodes serve to attach a variety of data to the object, linking it to its "database double". Perhaps, more accurately, the barcode system might be described as an index of sorts. Dictionary definitions of computer idices describe the function of the index as the creation of a value (or in this a marker) that identifies an object and is used to locate a particular element within a data array or table. Thus, barcodes function as physical indexical markers that allow a computational logic to be applied to the organization of matter itself.

Barcodes represent objects within the command and control system, allowing for both system-wide snapshots and individual scrutiny of objects. This global monitoring system goes beyond just the disposition of objects through time and space. Barcodes allow for the monitoring not only of things, but of *processes*. Commercial endeavors, like academics, are turning to the study and evaluation of their work as a process, rather than the production merely of things. This makes the ability of the bar code to provide a live census of items, and implicitly a the flow of processes, the most powerful form of surveillance possible with this type of technology. This is a world envisioned as nodes and the transactions of matter as a flow. Commerce is not about items, but about labor capacity, and the complete control thereof. We've already arrived in the brave new world. The wizard is not the man behind the curtain, but the illusion of instant gratification that is produced through a complex infrastructure of technologized labor.

Chapter 4 – Archiving the Gesture: Motion Capture and Scanning at the Limits

The previous chapter on barcode scanning dealt thematically with a form of liveness, which I call the *live census*. This chapter continues the theme of liveness, examining the role of live scanning in motion capture technology. The act of scanning barcodes provides a continuous series of snapshots of all the elements in play in a system at the same time. This form of live census data focuses entirely on flow and productivity. At any given moment, these barcode snapshots of the system allow systems engineers to see backups or slowdowns in the constant flow of a system. With motion capture, scanners move from constant snapshots to a truer form of liveness. Motion capture allows scanning technology to record the actual motion of a subject over time and play it back. The key to liveness in this case of scanning hinges on the power of computation. Computers can be networked in such a way as to allow the motion just captured by camera-scanners to be nearly instantaneously rendered on a computer screen. Thus, we approach the realness of real-time in motion capture technology.

The types of scanning discussed in previous chapters largely dealt with and produced two-dimensional images: fax machines, barcode labels, and television screens, for example. While scanned data is often represented in two-dimensions plus time, we must not forget that some of the most important scanners in our daily lives actually operate in three dimensions plus time. Airport security scanners use low sound frequencies to canvas 360 degrees of the body to search for areas of unusual density under a passenger’s clothing that might correspond to hidden items (Mitchener-Nissen 2012, 229). Medical scanners such as dental imaging technology allow for the rapid examination of a patient’s teeth in the office (Birnbaum and Aaronsen 2008, 494). These medical scanners also eliminate the limited hazards and discomfort of previous X-ray photography. Archaeologists employ three-dimensional laser scanners to recreate and study in detail cultural heritage items too delicate to undergo the traditional plaster casting process so that replicas can be constructed for further examination (Levoy et al 2000). In this case, 3D data of an object such as Michelangelo's David or the Pieta of Florence can be fed into increasingly affordable 3D printers, which have allowed art historians to map individual chisel marks made by long-dead artists (Scopigno et al. 2004). Finally, three-dimensional scanning remains a critical part of quality assurance processes in manufacturing. When manufacturing parts which require precision, such as for automobile components, three-dimensional scanners are used to measure and double-check the dimensions to ensure proper fit and function, even on mass-produced items (Computer Journal 2007, 14). Three-dimensional scanning is a study of the biomechanics of motion through space.

For this chapter, I will examine motion capture scanning, a particular sub-category of three-dimensional scanners. Beyond the obvious deployment of motion capture technology in film making today, 3-dimensional scanners allow scientists and corporations to study and break down and examine the biomechanical distribution of force during motion. Athletic apparel companies, such as the shoemaker Asics, might record the physical motion of running in order to study an individual's gait when running (Riley et. al. 2008). Because the of the variability of human bodies and physical habits, a runner's foot might strike the ground with different parts of the foot (heel-strike, mid-foot, or toe). Three-dimensional scanning of a runner allows research and development teams to slow down the motion and detect the mechanical force exerted upon the human body depending on the running posture. This in turn leads to further development of running shoes that compensate for and cushion the impact of a runner's gait. The complexity of a mechanical motion such as running encompasses a variety of factors beyond the position of the foot as it strikes the ground (Kerrigan et al 2009, 1059). An individual might suffer from excessively high or low arches, which lead to uneven distribution of weight on the foot. They might have a slight rotation of the foot, causing increased chances of sprains. Given the variety in human morphology, something as seemingly simple as the act of walking, which is actually a very complex physical motion, cannot easily be understood by simple ocular observation. The minute contribution of each muscle and ligament in orchestrating a single step can only be visualized literally and conceptually by using a non-invasive technology that can scrutinize the motion in a more detailed and careful manner.

Scanning answers the need to study motion as a whole without destroying an object in the process. By capturing motion, which is an elusive object because it is enacted in time and space, three-dimensional scanning allows for detailed analysis later. Motion is, in essence, change, and can only be quantified in its difference from one position to another. While tied to bodies and objects, motion has no substance except that it must be enacted through some kind of substance or medium. Motion is at once visible and invisible. It takes up space and is made manifest through bodies and objects, and yet is itself incapable of taking form independently from matter. As such, complex motion is both difficult to examine and break down into its component parts. The ability to study things in their wholeness is a hallmark of scanning technologies. Scanning also reveals, or visualizes, motions and mechanics too small for the human eye to detect. For example, the varying degree of height of the arch of the human foot has major consequences in how weight is distributed when standing. Undetectable degrees of difference can result in major pain. Without the ability to scan, these minor differences might not be revealed.

Many different applications of motion capture technology exist in areas such as sports, psychology, medicine, and engineering. For this chapter, I will focus on the use of motion capture technologies in cinema. Filmic motion capture is the most well-known type of motion capture. In recent years, filmmakers have increasingly publicized motion capture technology, promoting their movies and the technology itself. From behind-the-scenes featurettes to promotional materials, to interviews, the paratextual discourse surrounding uses of motion capture in movies has increased exponentially. By promoting motion capture technology, filmmakers have introduced popular fantasies regarding what the technology enables the performer to do. Motion capture technology in film, more than any other use of motion capture technology, is discursively positioned as producing the ultimate freedom of performance for actors, allowing them to shuck off the limitations of their physical form and inhabit characters that would have proved beyond their means before the technology appeared. Like early discourses regarding the freedom of the Internet to create and inhabit new identities unlimited by a person's physical gender, race, and sexuality, motion capture plays into fantasies digital, cyborg-like freedom. Motion capture is used with increasing frequency today in films, games, and other visual media. Recent improvements in motion capture toward real-time capture and the visualization of motion have made motion capture —already a more affordable option than traditional cel animation—an increasingly common choice for producers of media.

Cinema studies scholars have written on the subject of motion capture in a variety of rich and fascinating ways. Scholars like J.P. Telotte (2010) and Yacov Freedman (2012) examine the production contexts around the process of animation and motion capture. Joanna Bouldin (2004) and Tom Gunning (2006) have placed motion capture in the historical genealogy of animation techniques, while Lisa Bode has linked motion capture to the history of prosthetic makeup practices. Other scholars like Jessica Aldred (2011) and Barry King

(2011) have studied the enframing discourses that surround how we receive and understand a technology like motion capture, whereas Dan North deals with how spectators engage with motion capture visuals (2008). Stacey Abbott (2006) and Scot Balcerzak (2009) are concerned with the relationship between the body of the actor and their digital avatar.

In contrast to these varied approaches to motion capture technology in cinema, I focus on the nature of the technology itself. In this chapter, I take a Marshall McLuhan-esque approach and ask how the medium defines and shapes the message. Missing in the literature on motion capture technology is a deep technical understanding this technology. Most articles gloss over how exactly the technology functions, painting a simple, conceptual picture, or using analogy to describe motion capture technology, focusing instead on their particular arguments. I add to this literature by delving into the intricacies of motion capture's operation, and how this technology has changed over time. By examining the technology in depth, I am able to specify exactly what it is capable of doing, as opposed to imagining the possibilities of this technology. By using technical specification, this chapter uncovers the surprising ways in which motion capture technology does its work.

A Short History

The history of motion capture can be told in a number of different ways. In most accounts, mocap is often related as just another recent development in the separate teleologies of cinema, animation, or computer imaging respectively. Rather than placing the history of mocap in relation to any of these areas, I wish to draw a different genealogy for motion capture, one which places it in the photographic history of labor and laboring bodies.

Academics generally place the first origin point of motion capture technology with Eadweard Muybridge's landmark photograph of a horse running in 1872. Often cited as the earliest predecessor of film and animation, the artist Eadweard Muybridge was commissioned by the industrialist and former governor of California Leland Stanford to conduct a photographic experiment. Stanford wished to settle the matter of whether, at any time, all four of a horse's hooves leave the ground when running at a full canter. Because the motion of the horse's legs is too quick for the naked eye to see, the intervention of photography was necessary. Setting up a series of cameras at even intervals, Muybridge attached tripwires to each so that an image could be captured as the horse passed by. As we know, Muybridge's experiment was a success. The successive photographs do show all the horse's hooves completely leaving the ground. This would be the first successful decomposition of motion. In later years, as Muybridge continued his work, he would place the photographic plates of his running horse into a spinning device that would project the motion at speeds that would mimic real motion. This would be one of the first successful attempts to recompose the decomposed motion. Over the course of his subsequent life, Muybridge photographed a variety of human figures in his motion studies, a subject on which he lectured and published until his death in 1904.

While Muybridge might rightly be called the first person to decompose motion by photographic means, Étienne Jules Marey should be credited with the first recognizable foray into what we today might call motion capture technology. Marey, a French physiologist, was interested in making the invisible motions of the body visible, whether they were hidden inside the body, like the heartbeat, or hidden because they were too fast for the unaided eye to see, like the flutter of a moth's wings. Marey saw his work as a science of motion and his aim was to find some way to translate that motion into visual terms (Braun 1992, xvii). He needed a way to decompose human motion, whether running, jumping, or walking, in such a way that Marey could depict the relationship between different parts of the body in time and space. The solution came in the form of photography. In 1872, inspired by the work of Eadweard Muybridge, Marey turned to the camera to produce his scientific motion studies. Rather than decompose a single action into multiple images like Muybridge, Marey instead photographed his subjects so that the entire action was captured on a single glass negative. The idea behind the single motion image was to somehow combine the power of the photographic image's ability to capture what it saw with the power of the graph, which could express the aspect of time. Together, Marey married these two scientific instruments together to create the a chronophotograph, that could take multiple images on a single plate from a single position, allowing him to record ongoing, overlapping motion. In order to better visualize the ephemeral motions of human mechanics, Marey had his subjects wear dark-colored suits with bright white lines along the arms and legs. When photographed against a black background, these suits would render the subject invisible, with only the white skeleton visible as a trace of their motion over time. In this way, Marey invented the first motion capture apparatus in the 1880s, long before digital filmmaking was able to make the enterprise a live-capture event.

Marey's work was part of a larger intellectual and cultural movement influenced heavily by the new scientific realities of thermodynamics. This scientific movement in social and economic spheres centered on the notion of the "human motor" (Rabinbach, 1990, 1–7). This notion saw the human body as a field of intersecting forces wherein the conversion of energy into labor power took place. If the body served as the locus of work, then it was up to science to study the mechanical properties of the body in order to maximize the capacity for work through the means of efficiency. If one could decompose motion into its constituent phases, then any motion could be studied in depth and extraneous movement removed. It was to this end that Marey developed his motion studies, and his work would go on to influence the likes of Frederick Winslow Taylor, the founder of the American-based scientific management movement, and his followers Frank Bunker Gilbreth and Lillian Moller Gilbreth.

Scientific management, in its narrowest sense, was the pursuit of ergonomic efficiencies in industrial production. Taylorism, the movement named after founder Frederick Winslow Taylor, sought to bring scientific rationality to the shop floor. Instead of allowing workers to be in charge of how they produced goods, management engineers sought to study the tasks performed and break them into basic, repetitive parts. These tasks would be examined with motion studies analyzing the repetitive tasks of industrial work and seeking to optimize the motions of this task so as to eliminate any wasted movement and decrease the time each repetition would take. This study led to the standardization of work movements, a disciplining of the body. This manner of working, replicated all over the shop floor, allowed employers to tie workers' compensation to their output. Critics accused the Taylorist method of fragmenting labor and turning workers into automatons, but this attitude of scientific rationality would come to dominate much of the discourse of management for the following few decades.

Frank Bunker Gilbreth and Lillian Moller Gilbreth, a husband and wife team, followed and eventually broke away from the main body of Taylorist scientific management to pioneer their own method of motion and time studies. Motion studies generally just observed the motions of a work using a stopwatch to time which disposition of the body produced the most efficient results. Inspired by the work of Marey, the Gilbreths sought to take the motion study further and make it more objective with the use of photographic and scientific equipment. To this end, they would film workers in a dark room with lights attached to the their bodies, most notably to their hands. Over a long exposure, the Gilbreths would photograph the worker performing several iterations of a task. The lights on their hands would trace motion trails on the dark photograph, allowing the Gilbreths to observe how consistently the worker was able to perform the movements of their work. Because the only part of the worker that was lit was their hands, the rest of the worker's body disappeared in the dark photograph, leaving only a record of their movement in space. The end result of these studies was a symbolic effacement of the worker, and the estrangement of the body from its labor. These motion studies attempted to isolate motion from the body, the medium of that motion. The photography of these light trails in a darkened room became a record of movement abstracted from the context that gave it meaning.

Continuing with the use of film, motion capture technology is also frequently linked to the practice of "rotoscoping" motion in animation. Invented by Max Fleischer and his brothers in 1915, the popular creator of Betty Boop (1930) and Popeye (1933), the rotoscoping machine was essentially a film projector used for tracing. The rotoscope would take traditional film reels and project them frame-by-frame onto the rear of a clear panel. By placing a piece of paper on this panel, the artist could then trace the outlines of people and objects onto the paper. By tracing each subsequent frame, the animators could use filmed human motion to create cartoon character animations. This apparatus exploited the medium of film as a motion study device in order to create animated pictures. Disney famously put rotoscoping to commercial use in feature-length animated film classics such as *Snow White and the Seven Dwarfs* (dir. David Hand, 1937) and *Bambi* (dir. David Hand, 1942).

Motion studies, in this case, can be set against the history of labor and the ways that the representation and capture of labor disciplines the bodies of those involved. Motion capture's historical roots lie in the double effacement of the body of the worker. First, at the level of the equipment, motion capture obscures and estranges the bodies of the experimental subjects from their performance of the motion. Then, at that the level of discourse, motion capture erases the role and personhood of laborers in the application of scientific management methods. To this day, manufacturers continue to use modern motion capture technology to perform motion studies of this kind as a means of improving the performance of laborers in factories (Sato & Murata 2008,1480). In this historical trajectory, motion functions as a stand-in for the process of capital extraction of labor from the laboring body. Motion is the measurable component of the notion of labor itself, a scientific object that serves as an icon of the body's capacity to work.

The Technology Itself

To understand the manner in which scanning operates in motion capture technology, this section investigates three patents. The first belongs to Qualisys AB, a three-dimensional motion capture company specializing in sports and engineering uses of mocap, which submitted a 2002 patent under the name of their head designer, Thorleif Josefsson. This patent represents the typical, most pared-down design of motion capture, as we know it in popular culture. When we recall images of mocap in action, we likely are either envisioning systems produced by Qualisys, or ones provided by the following patent. This second patent, submitted by Motion Reality Inc. in 2008, represents the breakthrough in motion capture technology whose major principles underlie all modern mocap systems today. The primary inventor, Nels H. Madsen, eventually won an Oscar for technical achievement for the adaptation of his motion capture system in films such as the *Lord of the Rings* trilogy (dir. Peter Jackson, 2001–2003), *The Polar Express* (dir. Robert Zemeckis, 2004), and James Cameron's *Avatar* (2009). The third patent I will discuss builds upon Madsen's model and introduces, in my opinion, the next major step forward in motion capture wherein we observe the total elimination of the camera altogether. This system, as submitted by inventor John M. Griffith in collaboration with Twentieth Century Fox Studios, takes film towards video games in a new and unprecedented fashion that hinges entirely upon the liveness made possible by scanners and modern computational power.

So, what exactly is motion capture? On a basic level, it is the recording in digital form of the movement of an object or subject through space. For motion and performance capture artists, "motion capture is the process of recording a live event and translating it into usable mathematical terms by tracking a number of key points in space over time and combining them to obtain a single three-dimensional (3D) representation of the performance" (Menache 2011, 2). By definition, motion capture need not be a purely digital endeavor as we observe it today. Indeed, in the history of imaging, we might trace motion capture's impulse back to the history of art, in examples such as Marcel Duchamp's Nude Descending a Staircase, No. 2 (1912) or Disney animators' use of rotoscoping human motion in *Snow White and the Seven Dwarfs*. To translate a live movement into a digital one, the performance artist or subject in the real world must first be broken down into key points that define their motion. For any subject, be they human, animal, mechanical, the important points on a body are pivot points (joints) and connections between rigid parts of the body. These points, or markers, represent the data collected by motion capture specialists, be they animators or advanced digital technicians. These data are then rendered and recreated in either analog or digital form into a new, animated performance.

Alberto Menache, author of the popular textbook *Understanding Motion Capture for Computer Animation* (2011) cautions that motion capture—the act of recording movement—should not be confused with "performance animation"—the rendering of that motion into animated form as a new, collaborative performance between performers and the rendering artists. He writes:

> Whereas motion capture pertains to the technology used to collect the motion, performance animation refers to the actual performance that is used to bring a character to life, regardless of the technology used. To obtain it, one must go through the whole process of motion capture and then map the resulting data onto a 3D character. In short, motion capture is the collection of the data that represents motion, whereas performance animation is the final product of a character driven by a performer. (2)

This chapter devotes itself to better understanding the complexity of the motion capture technology rather than to an analysis of the nuances of performance animation, and the process of rendering after capture. It is the process of capture, especially the scanners used therein, that will reveal to us the truly transformative nature of motion capture technology to our theoretical understanding of film itself.

The key to understanding how motion capture works is to understand how a scanner operates. As discussed above, a scanner deploys an active signal that bounces off an object and back to a sensor, which is usually right next to the detecting signal source. The signal that returns has a lot of information in it, most importantly, how far away the object is from the detecting signal, whose position is known. Using this information, the computer can map where the scanned object is in the real world. By deploying the detecting signal many times across the surface of this object, we can map the exact contours of this object as well as its location. A motion capture system works in exactly this same way. A motion capture system, according to the Thorleif Josefsson in his 2002 patent for a Method and Arrangement for Determining the Position of an Object (US 6,415,043 B1), is composed of a contained motion capture environment (the "volume"), subjects wearing markers on their bodies, a set of high speed cameras connected to a network of computers to receive and process the information captured, and an a set of infrared spotlights to illuminate the markers and capture volume.

In this system, the detecting signals are infrared lights that are arranged in pre-determined intervals around the space to be captured. This space is called the capture volume. The volume is the new virtual stage. This denotes the area within which digital signals will be captured by the scanning system. The staging area is called a volume because the sensor system captures location in three dimensions that can used to calculate the volume of a 3D object: length, width, and height. The entire enterprise is not unlike a return to the theater, but this time in three dimensions, like a theater in the round. Only things within the boundaries of this three-dimensional environment will register on the scanners, because they all point inward to map the interior of the volume.

Infrared or near-infrared lights are used as the detecting signal in motion capture because invisible light will not overwhelm and overheat the performers. Moreover, the glare of visible light in the intensity necessary to register the markers on the performer's body would interfere with the performance. The objects being mapped are the markers on the body of the performer, distributed to create a skeletal outline of the body. These markers—small plastic balls—must be of a known size to help the computers calculate how close the markers are positioned to each camera sensor. Traditional object scanning in three dimensions attempts to map the surface of an object with as many points or markers as possible in order to recreate the likeness of the object as a digital asset. Unlike these forms of 3D scanning, motion capture technology captures the gesture, rather than the full likeness of the performer, and thus needs far fewer markers. Since the performer will be replaced with an animated character, the essence of the performer's movements becomes more important than their body. The markers that adorn the performer are made of highly reflective material that will bounce the infrared light back to the sensors.

Positioned next to these detecting infrared lights are the sensors. In this case, the sensors are charge coupled device (CCD) cameras, which are especially sensitive to infrared light. These cameras record the infrared-illuminated volume and feed the images back to the bank of computers that are integrating similar information from a number of other camera and infrared light setups around the perimeter of the room. The software on these computers then integrates and calculates the information being fed from all the cameras in the room in order to create a live, three-dimensional model of the performer based on the markers that he or she is wearing. This model, being three-dimensional, allows the viewers to examine the performance from all angles and decide exactly how they will position the virtual frame of the shot. Once this is decided, a rough model of the performance can then be sent to animators who will watch the performance as recorded and then use the 3D model produced as a digital foundation for further modification.

This general arrangement of features—markers, lights, sensors, and computers—constitutes the basic setup of most motion capture systems (Qualisys 2002). The particulars of this system deserve closer examination, however, for they have a huge bearing on both the effectiveness of the system and on how we think about the nature of the camera. The Qualisys 2002 patent in particular uses language that may illuminate the manner in which modern cameras function. Moreover, it helps us to understand why a scanning system operates through a series of cameras, as opposed to using scanner parts exclusively. The patent reads:

> Presently, cameras equipped with so-called CCD plates are used. CCD plate, which is a light sensor, is generally arranged in communication with necessary optical elements. A CCD plate, consisting of lines of charged coupled sensors arranged as a matrix, i.e. arranged in an X and Y coordinate system, for one or several colours, converts the light (from the optical element) projected on it, by electronically

> scanning in Y direction each line of X sensors and producing a television (video) signal. Then, the signals may be analyzed in different ways to detect the position of the markers attached to the object. (2002, 4)

To understand the significance of this description of the CCD digital image sensor, we must first understand how a modern digital sensor compares to the previous celluloid system of the movie camera. The silver halide of traditional film stock serves simultaneously as its conversion system and data storage system (Nakamura 2005, 2). This silver halide is the sensor that reacts to the presence of light, darkening in proportion to the intensity of illumination. Unlike a digital sensor, the silver halide of film reacts permanently to this change, rather than changing back to be used again and again. While an integral part of celluloid filmmaking, silver halide is not a permanent component of the film camera. Secondly, silver halide also acts as the storage device for the images committed to film, recording the light on the celluloid containment strip and thereby storing the image and allowing it to be replayed over time. In digital photography, however, these two functions of conversion and storage are separate. The digital sensor is a different technology from the storage, which, in part, allows digital camera sensors to be hijacked and hacked to function as scanning sensors in addition to capturing photographs to storage for their users.

A camera sensor is made up of thousands of photosites or light-sensitive pixels. A two megapixel camera sensor contains two million individual photosites, each capable of capturing an independent amount of light to form a pixel in the final image. Two sensor devices exist on the market today: charged coupled device and complementary metal-oxide semiconductor (CMOS). CMOS now dominate the market, but previously, high-end cameras all used CCD sensors, which are slightly more sensitive to the near-infrared light used commonly in motion capture technology. Invented by Bell Labs in 1969, the duo of Willard Boyle and George E. Smith conceived of the CCD during their search for improved forms of computer memory (Janesick 2001). At the same time, Bell Labs was also working on their videophone, which was featured in the first chapter. In this environment, the two different projects—videophone and computer memory—collaborated to create the CCD sensor for video imaging.

The CCD sensor contains a grid of photosites arranged in rows and columns. Each point in this grid contains one photosite, which includes the light sensitive component of the sensor, called the photodiode, and an electron charge container. When light hits the photodiode, the diode reacts by converting the intensity of light into a comparable electrical charge, which is held in the electron charge container. This charge or voltage is read, pixel by pixel, line by line, by the onboard computer chip until the primitive computer extracts all the information from the sensor. An image is then produced from this information.The CCD sensor operates in a scannerly manner. Not only is image information sensed through a series of grid-like pixels, but the information is recorded in a pixel-by-pixel, line-based format reminiscent of other scanning technologies. In the end, the information must be reassembled after the fact in a similar, line-by-line fashion. In the Qualysis patent itself, the authors describe the line-by-line reading of information as a television signal, rather than a photographic one. In this sense, I argue that the digital video camera is the turning point of the parent-child technological dynamic. In Chapter 1, I showed how the scanner emerged as the conceptual progeny of the photographic camera and the telegraph. Now, with digitization, we see the camera essentially being hollowed out, its silver halide technology replaced with what amounts to a very small photosensitive scanner mechanism. This means we now use scanners to replicate the function of photography. The parent has been subsumed by the child. This technological reversal hinges entirely upon the invention of the CCD sensor, which was itself a conceptual child of the videophone (television + telephone) and computer memory. Thus, the television scanner begets the digital camera's scanner.

Moving on to the second patent submitted under Motion Reality Incorporated, I direct your attention to the particular improvements that Nels Madsen and his team wrought upon Qualisys's basic system. Madsen and his colleagues at MRI were able to eliminate the large, bulky markers from the motion capture system, citing that:

> One disadvantage of the type of systems (using markers) is that the limitation on the position and number of the markers leads to accuracy problems. Another disadvantage is that the markers can interfere with the subject's motion. (2008, 1)

Accurate characterization of movement represents the highest priority of any motion capture system. In place of these big markers, which are shaped like small plastic balls of reflective material, Madsen's advancements used small reflective stickers. Madsen's software is an admirable step forward in the comfort and flexibility of the motion capture system. The way it bootstraps the camera sensor to capture motion data also reflects a profound change in the way a camera works. In the previous patent from Qualisys AB, we observed a fundamental change in the internal organs of a camera that turns it into a camera-scanner. Now, Madsen's software transforms this camera-scanner dyad into a scanner conveniently housed in a camera body.

Madsen's system is based upon calibrating a careful comparison between an empty volume, called the *threshold image*, and a volume with a performer wearing reflective tape, called the *captured image*. The computer, during this comparison, searches for any "hot" pixels, pixels that are of a greater brightness or intensity in the captured image than their counterparts in the original threshold image. The program makes this comparison pixel-by-pixel on each frame of the captured footage. Once it locates hot pixels, the program must decide whether or not the pixels are part of a reflective tape marker, or if they are a fluke. In order to determine this, the computer counts how many other hot pixels are clustered nearby. Only clusters of a certain size and shape are accepted by the program as representing real markers. Once the software is satisfied that a bunch of hot pixels represent a marker, the program marks these pixels and follows them from frame to frame. By comparing the threshold image and the captured image, the software program learns what a bright marker looks like and is able to follow the track of a marker over the time of the shot. This software maps each one of the markers in three dimensions simultaneously to create the final model of movement.

The function of the camera in this form of motion capture is not simply to capture an image, but to capture and, with subsequent software processing, compare the relative brightness of its pixels to one another. In this way, the motion capture software is using the camera as a scanner. As a scanner, the digital camera's function is to record relative brightness or luminance for computational comparison. In contrast, a digital camera taking photographic images desires the impression of light in each pixel in total rather than in particular. Because the camera in this case, is scanning for bright spots to schematize a performer's movement, rather than filming the performance for future reference, this example of contemporary motion capture completely shreds the traditional notion of camera imaging.

Also of note in this computer software is its frame-by-frame analysis. When looking at video footage filmed by a camera, we do not observe it frame by frame, but play it back as a whole. Motion capture software treats each frame like a single scan that is subsequently compiled together in order to track each marker's three-dimensional movement over time. This model of digital photography as scanning reflects an animation-oriented manner of thinking. For this program, the camera is not producing a length of footage, but a stack of scanned images in chronological order. It is a very fast, very convenient stop-motion flipbook, which completely reverses the logic of the normal film camera.

Even more telling is the language used to describe the three-dimensional location of each marker. Once a marker is located a “set of 3 D rays (Rc) is constructed from each set of markers” (Motion Reality Inc. 2008, 6). The ray is an imagined line of sight from each camera in the volume to each marker, which allows the program to locate the markers In space. Using the term “ray” treats the camera even more as an active scanner, as if the camera emits a form of energy that it uses to ping or locate the marker. With this virtual ray, the program tracks the markers from frame-to-frame, creating a track, or a visualized trace of the motion of a marker through the volume. Through tracks, these rays literally illustrate the trace of a movement through space. As conceptualized by Madsen and his colleagues at Motion Reality Incorporated, the camera-scanner dyad becomes a scanner only, ignoring entirely the photographic functions of the camera.

Patent #3

Publication number WO2013096403 A1
System, Method and Apparatus for Rapid Film Pre-Visualization

Inventor: John M. Griffith, Los Angeles, CA

Applicant: Twentieth Century Fox Film Corporation

Despite its innovativeness, the camera-scanner dyad continues to be used for the most part for photography and videography. Motion sensing is the only area where the scanner function overtakes imaging and representation. It is exactly this scannerly manner of the camera, however, that allows for the eventual disappearance of the camera. In this next and final patent that I examine, the camera withdraws from material existence and becomes virtual. We might think of this virtual camera as an aesthetic trope or a legacy of the material practices of filmmaking and photography.

The premise of the third patent, invented by John M. Griffith on behalf of the Twentieth Century Fox Film Corporation, is that storyboarding by hand is a difficult and ultimately inadequate process for conveying the vision of the director. Instead, what if a director could use motion capture technology and the assistance of a few performance artists to near-instantaneously render his or her vision a reality? This is the purpose behind what Griffith calls real-time "pre-visualization" of films. The language of the patent puts this form of motion capture pre-visualization in a so-called evolution from artist storyboards and frame sketches to a system that puts the ability to express the director's vision directly into his or her hands.

Griffith's system works very much like the previous examples. It contains a smaller volume the size of a room, as opposed to the size of a warehouse like that used by James Cameron's LightStorm production company. Within this volume, the same system of high definition and infrared cameras encircle the room, providing live scanning information that is sent to a large bank of computers for live rendering into a graphics engine. The performance artists still wear body suits, albeit less bulky ones without the need for tethers to power them. The real difference is in how the director interfaces with the motion capture performance.

In the previous system by Nels Madsen of Motion Reality Inc., the director interacts with the captured footage using a 35-pound over-the-shoulder camera unit. This is a hybrid camera unit with a computer screen where the eyepiece would be. Through wireless connectivity, the director can use this unit like he or she would a real camera in a real filming situation. Instead of the camera interacting with real-time filmed performances, the director instead sees the recently captured and computer rendered performance displayed on the camera screen. This allows the director to move in and around the virtual performance to “film” the camera angles and framing of the action that he or she desires. Gathering footage of motion-captured performances has always been a two step process. First, the performance is captured and then that performance is framed by the director or cinematographer. These steps can be combined into one step, although the nature of motion capture information, which is three-dimensional, easily allows the director to go back and try new camera angles without having to move a camera setup, or having the artist repeat their performance. The director simply picks up the mo-cap camera unit and tries something new.

The Twentieth Century Fox system does away with this camera unit altogether. In the patent for this system, Griffith cites several drawbacks to the physical camera unit for interfacing with the captured performance. Firstly, the physical limitations of a camera also present artistic limitations. In Madsen’s system, the camera unit functions like a real camera. As the cinematographer pans, the camera mimics a pan. As the cinematographer zooms in, the footage also zooms. All the physical limitations of a real camera, the mocap camera possesses as well. If the motion capture shot calls for a crane shot, a real crane would be needed to film the capture performance. The footage secured is limited to both the traditional lens view and the walking distance of the camera operator. The Twentieth Century Fox system is strictly a pre-visualization system. It allows the director to test out and play with the footage to his or her satisfaction before actual filming takes place, because this small, fast, light system costs less than the high quality mocap system of Nels Madsen. As a pre-visualization system, the director does not need to keep the actors and stars on call during the process. A few motion capture artists hired for the short term would cut down costs during the pre-production process. This less expensive process then encourages directors to explore the limits of what a motion capture film experience can do. The Twentieth Century Fox system overcomes the limitations of Madsen’s system by eliminating the camera unit altogether. In Fox's model the camera, already working partly in the virtual realm, disappears completely into the virtual. What remains in its place, for the director to control the visualization of the film, is a game controller. Griffith's design has the director sitting on the edge of the volume area on a couch, observing the motion capture rendered in real time on several large screens. In his or her hands is a tablet screen with two game controllers built into the sides. One joystick will allow the director to control how closely the virtual camera will zoom into the action and the other allows the director to pan 360-degrees around it. Because the camera now works on the virtual plane only, the director can design camera shots and frames that run the gamut of his or her imagination.

This technology is made possible by the use of game graphics engines. A game engine works as a sort of pre-made virtual world, into which anything can be populated. It already comes complete with everything a company might need to create the next new blockbuster game: fast, beautiful graphics; the game world's physics, including for example, how rain reflects light on different surfaces, how objects fall through space, etc.; the building blocks of buildings and people; and most importantly for motion capture, the camera controls over player point of view. These engines come pre-assembled at a price, and frequently game manufacturers make more money leasing out their game engines than from the sales of their games. Twentieth Century Fox pre-visualization motion capture system depends upon these powerful game engines, such as CRYENGINE 3, for rapid, near real-time rendering of action.

With this mixture of live scanning, game graphics and control technology, and a hefty dose of computing power, what results is a new hybrid form of filmmaking that renders the camera's point of view as an aesthetic trope rather than a function of the material properties of the camera. The panning, zooming, and other forms of camera movement in a game engine are there to mimic a real camera's visual capacity. This does not include first-person shooter camera points of view, because those are made to simulate human limitations as much as possible rather than camera limitations. The game camera movements to which I refer are third-person games in which the player can see his or her avatar on screen and can control the camera from a third point of view, rather than strictly the character's point of view. Because we conflate our own vision so much with the camera's visual field, we tend to forget how many visual conventions dominate the way we watch films and the way that we see and remember the world around us. With the disappearance of the camera from this system, we still have a camera. We are still defined by a cinematic way of viewing within the game engine, despite the possibilities of other ways of viewing. The camera might not continue to exert its physical limits upon us in this system, but its cultural and aesthetic ones remain.

Filmmaking has gone not only completely digital, but completely scannerly. The scanner acts as the interface between the material and the digital in the performance and the gamic acts as the interface in the control and visualization. Where we commonly perceive mediation between the material and the digital as a single process, often this process is actually a series of technologies, including the scanner, that function in tandem to produce one great effect. It is critical to understand what each component contributes to the larger mediation, because each individual component is frequently acting as its own medium.

Cinema scholar Dudley Andrew, in his volume *What Cinema Is!*, asks the question of whether having a camera is even essential to making a film. Even if we bracket animation films, Andrew cites several experimental filmmakers such as Man Ray who created films by directly manipulating and printing the celluloid film (2010, 1–2). Today, many films are more computer-generated than they are filmed in the traditional sense of light creating an indexical trace on photosensitive material. While technology has changed and our notions of what cinema can and ought to be have shifted, cinema still remains recognizable as a form and practice.

The Consequences of Scanning

One consequence of automated motion capture is the resulting profusion of data. For each take in filming a performance, a standard system can take between 120 to 140 frames per second. Multiply the number of frames tracked by the number of markers on a performer's motion capture suit and it becomes clear how much data is generated for each segment of motion tracking. Once generated, this data becomes a new resource for public or commercial use. Take, for example, free motion libraries such as the Carnegie Mellon University Graphics Lab motion capture library or Mocapdata.com. These resources allow the public to download generic, pre-recorded motion in a variety of file formats for personal and non-commercial use. These free files often serve as a basis to manipulate and practice creating post-capture animation on real mocap data. Paid motion capture resources also exist for professional use in video games and other forms of animation. After a performance is captured, the data it generates can be used again and again. It is a renewable resource, in a manner of speaking, and it continues to produce capital for the duration of its existence. As opposed to the singular nature of an actor's regular performance, captured in the final edit of a film, raw takes motion capture performance can used over and over for any number of subsequent new performances using the exact same base.

Just as the body and labor of the actor become overwhelmed by the digital nature of the motion capture system, the sheer amount of data becomes a problem to the companies that produce and store it. Due to the wide popularity of motion capture data across movies, games, animation, and other virtual environments, it is difficult to quickly and efficiently navigate the sheer amount of data produced across all this media. A single movie or video game can produce massive amounts of motion data, which need to be organized in order to be used. For such masses of information to be searchable, workers must label it with descriptors, such as “walking” or “fighting.” Within these linguistic labels, there could be a huge amount of variation. Walking could include different speeds of walking that describe very different gaits. Data labeled “fighting” could describe any number of actions, such “punching,” “counter attack,” “lunging and tackling,” and “grappling on the ground.” To search through all of the data produced by any large mocap production company would be at once tedious and expensive. For this reason, new search epistemologies are being developed to automatically index and describe motion capture data for easy search and retrieval.

In everyday life, we identify the character of a motion through a combination of discursive knowledge and visual identification. When a person walks, we identify this motion by visually matching it to an approximation of walking from personal experience, which allows for all the variances in walking gait, body size, and speed from our previous experiences. In essence, we have a mental database of motions that allows us to query a mental match when we see something happening in real life. Motion capture data lives in binary files that mathematically describe motion. We cannot visually inspect the motion in order to identify it without opening each file and looking at each one. Such a manner of searching would be inefficient. So search algorithms for motion data must identify the motion in its mathematical form rather than in a visual form. This is a fundamentally different way of knowing the body and its motion.

For a computer, numerically matching up similar motion files is easy. But the difficulty of motion lies in the individuality of bodies and the attendant kinds of motion they produce. Take, for example, a tall person walking and a short person walking. They are visually similar to one another. But they are not numerically similar at all. The markers that are attached to the joints of the tall person are in very different places than the markers attached to the joints of a small person. They are visually and conceptually similar without being defined by the same numerical points in space. This variance in categorizing visual data in numerical form requires more sophisticated approaches, such as analyzing similar spatial arrangements of points, rather than simple numerical correlation (Lin 2006). While capable of capturing the general similarity of a motion, motion matching may still fail to capture other aspects of the motion such as the kind of emotion encoded into the motion by the performance. Other search paradigms have allowed the user to use the mouse to draw human a pose into the query box. This pose is then mathematically matched to the poses in the motion data. As effective as this search method can be, it still does not describe the motion itself, because it is a static, not dynamic, way of searching for a multi-dimensional action over time.

Search engines must learn to describe spatial relationships between parts of the body with respect to each other rather than simply matching up similar mathematical sets. With mocap data, we must give up our understanding of motion as a visually experienced form of data and think of it as a mathematically-described form of data.

Not only does motion data need to be indexed for searching, but the data must be compressed without any loss of information (Wang et al. 2011). Each new technology produces new capital resources. With the loss of the performer's body comes the advent of the performer's data and all the attendant complications of its categorization and archiving. The challenge with indexing motion data is how to describe the data in a useful way, such that similar types of motion will show up together in the search results. The new search epistemologies that need to be adapted specifically for motion capture data are, like any other form of search epistemology, searching for an essential description of the body in motion. For something as experiential as moving through the world, the level of abstraction necessary to describe it mathematically becomes extreme. The motion is preserved despite the complete loss of the body.

Motion capture search algorithms are groping for a description of the body in motion. What makes a motion a motion? How is it possible to describe motion using mathematical forms that do not rely on visual inspection and cultural forms of knowledge to retrieve? Making motion knowable as data is to attempt to close the gap between culture and math, a form of linguistic representation that explicitly rejects the broader conceptual and cultural capacities of language. This process becomes an exercise of interpretation, for the transformation of motion to data has already occurred during the process of scanning. Interpreting motion data through search algorithms is a way of disciplining motion knowledge, an attempt to take a mass of data and give it form. But the very form of mathematical description itself excludes the knowable parameters of emotion and mood. The cultural knowledge in which motion exists resists the process of interpretation.

The End Result of Capture

What exactly is captured by motion capture technology? A glib answer might be simply be that it captures motion, the change in spatial position of a given object over time. Beyond recording a change in spatial position, motion capture encodes a great deal of information. Take for example the shape and body size of the person performing. This morphology of the performer's body is encoded into the capture as well. A production cannot cast a motion capture performer whose size and shape do not match the size and shape of the character that they intend to portray. In Dawn of the Planet of the Apes, actors playing the apes were forced to wear prosthetics on their arms in certain scenes to extend the length of their arms to match the length of an ape's arms. In some scenes, actors were forced to wear prosthetic teeth in order to achieve facial features more closely resembling that an ape's jawline. In motion capture, body morphology makes a great deal of difference even once the actors' bodies are replaced with that of their digital avatars, because body morphology can restrict or express very different kinds of motions. More important than the simple capture of morphology and motion, however, is capturing of the element of performance. For media theorists, the question for performance capture is, what is being preserved and taken from the performance to the final product? How does this system of performance capture mediate the performance itself?

Andy Serkis, actor and evangelist of motion capture performance, speaks frequently to the press about the "transparency" and "fidelity" of the technology with regard to an actor's performance (Clark 2012, 1). He asserts:

> For me, I've never drawn a distinction between live-action acting and performance-capture acting. It is purely a technology. It's a bunch of cameras that can record the actor's performance in a different way. In terms of animation, animators are actors as well. They are fantastic actors. They have to draw from how they feel emotionally about the beat of a scene that they're working on. They work collaboratively. They all have to understand the psyche of the role that they're developing. And that will never change. It's an art form . . . Without taking away any of the visual effects work that animators and visual effects artists and programmers and technicians in the visual effects world, in my mind, it is a form of digital makeup (Clark 2012, 1).

Serkis minimizes the role of motion capture technology in his performance by calling it "purely a technology" and arguing that motion capture, as far as the performance is concerned, nothing more than a "bunch of cameras." Serkis's argument diminishes the role of the technology in his work, as if to argue that this process, no matter how strange, is still just another form of filmmaking. The notion of "digital makeup" is often deployed not to minimize the role of post-production animators, but to emphasize the fidelity and transparency of the medium of motion capture. These statements regarding digital makeup are often supported by the images chosen to represent motion capture in the press. Promotional materials frequently show an actor's face set alongside their avatar's face to show how faithful the process of motion capture is to the actor's original performance. This is a move to establish the veracity of the technology despite any evidence to the contrary. In the same interview, Serkis goes on to talk about the imagined freedom he has as an actor to inhabit any kind of skin with this digital makeup:

> [Performance capture is] such a liberating tool. I am quite evangelical about it to other actors because I think it's such a wonderful—it's a magic suit you put on that allows you to play anything regardless of your size, your sex, your color, whatever you are. As long as you have the acting chops and the desire to get inside a character, you can play anything. so I long for it to be accepted by the acting profession so that it can proliferate.

We know this imagined freedom is not true. Just as a short person cannot play the role of a tall person, the technology of motion capture cannot fully free the actor of the constraints of their own flesh. What is striking is the discursive fantasy of the technology to overcome the bounded nature of our own bodies. The digital makeup of motion capture exceeds the bounds of traditional prosthetics and takes on a radical form of human transformation. This transformative fantasy hearkens back to fantasies of total freedom allowed by the anonymity and immaterial nature of the Internet. Lisa Nakamura writes about the way early Internet users attempted to pass as other races online as a method of identity tourism (2002, 31–34). In doing so, Nakamura argues that users merely reinscribe the stereotyped markers of difference that allow whiteness to pass as unmarked. With the discourse of digital makeup, motion capture falls into the same trap, failing to recognize that performance and gesture, especially the emphasis on behavioral marks of difference, can still reinforce and reassert stereotyped notions of race and gender.

In another 2014 interview, Andy Serkis continues his argument regarding the increasing "transparency" of the technology (Woener, 2014):

> The technology has evolved in the sense that it's become more transparent. You don't really realize that it's there at all anymore. And even more importantly, the perception has changed—the use of the authored performance is much more respected . . . The technology is one thing, but basically one has to remember that it is only technology. Performance capture is another bunch of cameras. It's 360 degree cameras filming an actor, and I think it's the understanding of that has changed, and that's happened because we've gone from a single character like Gollum to multiple characters in films like *Avatar*.

Serkis makes a number of assertions in this particular quote. Firstly, when Serkis invokes the "transparency" of the medium of motion capture, he is saying that the technology is capable of transmitting all aspects of the performance without any noise or disruption. He compares the act of performing in motion capture to performing under traditional camera-mediated conditions. The use of a real performer simulating a character's movement is simply a new formulation of the old trust in the camera. The camera is seen as somehow special because its light actually touches the object in front of it, giving the observed object and the camera a special relationships. With the absence of what the camera used to represent in motion capture, the argument of presence transfers to the general motion capture technology itself, as if the technology were capable of the same fidelity to an actor's performance as the camera before it. Serkis links the ability of the camera to faithfully capture reality with that of the motion capture apparatus by referring to this assemblage as just "another bunch of cameras," which they clearly are not. As I argue in an earlier section of this chapter, these cameras no longer even function as cameras in the traditional sense. Yet the authority of the camera remains as a specter in the discourse of motion capture. Serkis continues:

> But also the way that Weta digital, whom I've worked with on all of those projects, that they have now schooled their animators to honor the

> performances that are given by the actors on set. And the teams of people who understand that way of working now are established. And that's something that has really changed. It's a given that they absolutely copy [the performance] to the letter, to the point in effect what they are doing is painting digital makeup onto actors' performances. It's that understanding which has changed as much as anything.

Here, Serkis brings up the contradictory point of post-production animation. After the initial performance is captured by the mocap system, the movement information is imported into another program where the digitally animated avatar is attached to the movement. It is, in a way, a reverse of puppetry. The movement is made first and the puppet is then made to perform the motion, creating a total performance. At first glance, this process may seem as "transparent" as Serkis asserts, but upon closer examination, there is a great deal more work done on the mocap performance to achieve that vaunted fidelity to the performance than we realize.

First of all, the facial performance cannot be scanned in with great fidelity during a mocap performance. The technology that allows for the mobility of the actor in the scanning volume sacrifices detailed scanning of the face. In order to achieve any fidelity with a facial performance, the actor must sit very still in front of a much larger and heavier piece of scanning equipment. One much choose either one or the other: scan the whole body performance, or scan just the facial performance. What happens to facial performances when scanning the full body performance of the actor? In most motion capture circumstances, a small camera is attached to a skullcap worn by the actor. This camera is pointed directly in front of the face of the actor to record the nuances of their facial performance. This video footage is later used by the post-production team to animate characters with as much fidelity as possible to actors' facial performances in the scene. So much of the seemingly transparent performance of the actor actually takes place through the interpretive work of animators.

In response to this contradiction, Serkis tries to at once defend the authorship of his performance and recognize the extended amount of work done by the post-production art team (Hiscock, 2014): Two things have to be understood: the authorship of a performance happens on set with a director and other actors in a very conventional live action sense. The animation process is what happens afterwards, and the skill and artistry and the brilliant work the animators do in interpolating that performance and manifesting it on screen is an art form which is unparalleled. Then, almost defiantly, he adds:

> Acting is acting and visual effects are visual effects and it's a marriage, but the authorship of performance—everything you watch on screen that you feel and think about a character—comes from the actor.

Matt Reeves, director of *Rise of the Planet of the Apes* (2011), defends Serkis' minimization of the work of post-production animators. In an interview with the blog *Slash Film*, Reeves, asserts that rather than think of the process of motion capture as one unitary performance, we must think of it as being composed of two parts (Skiretta 2014). The first part is the actor's motion capture performance and the second part is the post-production animator's translation or interpretation of that performance. Serkis' performance forms the core component of the final rendered product, but the artists at Weta Studios must also interpret his performance through the body of the ape character, Caesar, that Serkis portrays. Since Serkis is not an ape and has a mouth instead of a muzzle, the artists must imagine and adapt the motion capture data so that it expresses what Serkis expresses in his performance. In that sense, the artists at Weta do hew very closely to the actor's performance, but to do so requires massive amounts of artistic interpretation on their part to obtain that fidelity. Both aspects of this process are equally necessary and equally constitute the process of motion capture performance. If we think back to Claude Shannon's notion of communication, we might liken the work of the post-production team to a form of amplification or clarification of the performer's "signal" from the potential "noise" that the technology introduces

(Shannon 1948, 381).

We must remember that the body is itself a medium of symbolic communication. Beyond speaking, language encompasses the gestural signs of the body as well. Markus Hallensleben writes:

In other words: not only do gestures embody language, and thus they are language and have a textual structure built into them. They communicate language, and they communicate by moving the body in space. Thus the body, and how it moves in space, would be nothing other than the embodiment of language, and thus communicability would be nothing other than an incorporation of language into the human body." (2010, 19). This being true, motion capture becomes the extraction of language from the body that gives it form. Language-as-body—the body is eliminated such that only the gesture remains. This gesture, now liberated from the medium of its origin, can be digitally applied to a new body-medium. This process, then, becomes the isolation or extraction of language.

The body in motion capture becomes a multiple body. Firstly, there is the body of the artist, erased except for what can be inferred from the motion track, such as height, approximate body size, emotion and expressiveness. Second is the mathematical body of the actor rendered into digital programs. The final body seen on screen is a CGI body sculpted within 3D modeling programs like Maya. This body becomes a multiplexed body, much like the way signals can be multiplexed, combined and bundled to be sent over a single transmission line. Much like the actors, the animators can contribute to the shaping and refining of a performance. In the aftermath, the animators can be asked by the director to make changes to the original mocap performance, exaggerating the action in certain places or minimizing an over-acted performance in others. The singular performance seen in a film using mocap is itself a hybrid, a product of intense collaboration between animators and the authorship of the performer.

There is a conflict between the urge to understand a real trace or authentic body underneath motion capture, and the knowledge that this trace is heavily modified after the fact. Perhaps knowing, despite how modified that trace becomes, that it is still the distillation of a gesture, of a linguistic concept, might bridge the dissonance between the desire for a real trace and its eventual modification. No matter how we render language in text, no matter how we dress up the font or arrange the words to be pleasing, the words and their ability to communicate remain the same. In performance theory, the classical body is thought of as an enclosed and unitary object. In contrast, the grotesque body is open and porous, leaking fluids continuous with the world around it (Spackman 2000, 14). The motion capture body, while not grotesque, is also an open body, one made violable to animators. It is an incomplete body whose purpose is to be made whole once more on the big screen. In this way, mocap changes the notion of performance before the camera from unitary to multiple. A performance for mocap can no longer be defined by the definite boundaries of the body of the actor. The ontology of the performance, according to Peggy Phelan, must be its liveness (1993, 29). To film a performance is to mediate a performance, and thus it is no longer a performance, but merely the filming of a performance. To motion capture the performance is different mediation that makes porous the idea of mediating the performance ever further. In the case of motion capture, the true performance lies not with the "authored" performance of the actor, but is located downstream somewhere, as a composite of multiple inputs. Does motion capture, then, change the ontology of the performance if the performance is dispersed across an entire human-machine complex?

What are the consequences of this type of scanning technology on acting? Acting itself does not change, and actor compensation has not yet caught up with the times. For example, actors do not get paid for each time their character's motion file is downloaded and used. Their performance can be spread across the landscape of film, television, and games without them even knowing that it was their performance that served as the basis of various new animated performances. The use of this digital file anonymizes the actor whose bodily labor produced it.

Film scholar Tanine Allison argues that motion capture creates a form of "digital indexicality," which combines together both input from the real world and computer-generated imagery to create something that resembles the traditional indexicality of film (2011, 326). Allison asserts that a photograph, for example, is linked to the original object through being touched by the same rays of light and also the final product bearing the outward appearance of the original object. A photograph thus becomes both an index and an icon of the object simultaneously. Motion capture, however, differs in its loss of the iconic aspect of photographic indexicality. Indeed, the resulting representation bears very little resemblance to the pro-filmic event. Allison invokes Charles S. Peirce's definition of an index, which is something that "corresponds point by point to nature" (2011, 335). Citing Philip Rosen, Tanine Allison reminds us that the signifier need not bear a likeness to the referent for it to function as an index. When wind blows a weather vane in a particular direction, the vane becomes the visual signifier of the motion of air passing through the atmosphere. But does a weather vane resemble the wind? In this same manner, Allison argues that motion capture offers a form of indexicality that creates a strand of continuity with our older understanding of the film index.

We continue to be fascinated by the perceived reality of the motion capture, its material there-ness, or the idea that there is really something behind the camera. We are still caught up in the cinematic discourse of trace and deferral, that there was something there that the camera nominally touched with its light. This commitment to the material trace is an inheritance of the camera, an old protocol that still has power in the new context of the digital age. In part, our interest in the workings of motion capture may be a struggle over the veracity in the performance mediated by a new technology. The object of fascination is the gesture, the ineffable unit of human communication reduced to the most material and simultaneously symbolic of our language, the moment of speaking in silence. What do we preserve in this obsessive archiving of the gesture? Do we attain that which we desire? Or do animators do the real work of restoring meaning to something that we have so lovingly and carefully stripped of flesh and embodied communication? Perhaps what fascinates us with this method of representation is motion capture's imagined ability to preserve the essence or trace of an action and allow that performance to live in another skin, figuratively. Maybe our fascination with mocap is less about the motion of a performance than about the skin of that performance.

Conclusion

This project has examined the object of the scanner as a unique and novel mediating process among the constellation of technology in today's media ecology. Acting as an interface between the material and virtual, the scanner serves to transform material objects into new registers of virtual information. The scanner performs this function via measurement, a process wherein the machine evaluates, according to preset parameters, the shape and depth of an object. Measurement serves as the basis of other more complex functions enabled by the scanner's close partnership with computation. The scanner is able to build upon these basic measurement operations and further transform them into more complex transactions, such as verification and identification or representation.

Using signals like sound or light or magnetism, the scanner is able to direct its sensing apparatus into areas previously denied to regular human senses. These signals can often bypass the materiality that obscures what we could not previously “see,” revealing—or constructing—new horizons of knowledge. The extension of the human sensorium allows the colonization of these new arenas by the apparatus of power, producing them as both literal and figurative insight. This new insight is nothing less than the work of ideology, the production of new arenas where power refigures the work of sight into new operations.

The extension of the sense of sight is itself an extension of ways of knowing the world. For the most part, scanners do the work of extending current paradigms of sighted ideology, primarily that of the camera. To see is, therefore, to know. Sight constructs certain ways of knowing that are historically-situated and culturally-produced. The camera's seeming transparency as a medium lies in part with the trust we place in it as an mechanically objective machine that excludes the shortcomings of subjectivity. This faith in the camera's transparency allows us to ignore the process wherein it actively transforms the object being photographed into an image of that object. Moreover, we have learned to construct a direct relation between the object photographed and the photograph, as if we can easily read the latter as a clear manifestation of the former. The scanner enters the historical scene in the aftermath of this mechanical objectivity and acquires the same sense of transparency as a mediating process. Since the scanner first reproduced and transmitted photographic images, it became implicated in the same discourses of sight as the camera. It acted as a channel for the camera. When the scanner came into its own as an independent visualizing force, it echoed and adopted the same discourses as the camera. To scan, therefore, became to scan transparently and without intervention on the image produced. To scan, however, is not limited simply to visualization. Scanning takes up forms of machine-machine communication that exceed the process of representation.

Automation of Vision

Scanning is a machine-machine form of communication that triggers a cascade of programmed actions and operations, a process which figures heavily as a theme in this dissertation. Rather than represent images and information, the act of scanning participates in a relay of communications that result in a series of actions taking place. Scanners represent the shift from human vision to machine forms of vision, which are largely invisible to the human subject. In our previous paradigms of sight, the human is central to the process of seeing, acting as the primary spectator to the image. That paradigm, however, is being undermined as new machine forms of vision produce increasing numbers of images not intended for human consumption. These images serve as communications between machines rather than between humans and machines. Invisible images are recruited into systems of algorithmic operations that trigger further analysis, actions, and provocations. These invisible images come to shape the way we act and what we know about the world without our direct participation. Scanners are among the family of technologies that provide these invisible images, mediating between materiality and virtuality to shape the way human subjects interact with their mediated environment. We have come to a moment where images are no longer representing so much as intervening on our daily lives, creating, for example, systems of surveillance around us.

In the case study of the barcode scanner, we observe a system of total surveillance that oversees the transfer of goods down a logistical pipe. The Amazon warehouse illustrated a space where scanners were no longer used for their representational capacities, but for their machine communication capacities. Scanners became an infrastructural mediator that created the framework of how goods were tracked. This case study is emblematic of the very basic ways in which control is maintained over dispersed objects and processes. Humans are not observers of the scanning, but operators of scanning, themselves merely a component of a much larger system. The scanners never directly operate on humans, but human actions are nevertheless shaped and disciplined by the presence of the scanners. Scanners and their resultant algorithmic actions trigger the subsequent reactions of humans, displacing the human as the node of decision-making.

Algorithms form the basis of the invisible decision-making in the machine-centered communications chain. They encode the invisible ideologies, judgments, and distinctions that are drawn when invisible images are processed through them. Algorithms represent a process of abstraction, not unlike the process of measurement that forms the core of how a scanner operates. These algorithms come into being as the practical interpretation of a larger theoretical idea, the gap between which encodes another level of ideology that must be uncovered. Algorithms are the product of materials, power relationships, and enormous human labor, and it is important to disentangle these elements to understand how these algorithms work within the system of machine-machine communications. One of the areas that this project did not have space to address was the hidden work of algorithms. Understanding how the work of scanners contribute to preprogrammed sets of actions and triggers will be crucial to painting the entire picture of how machine-centered communications operate as a structure of power. The aim of this future work will be to understand the whole chain from how the object is constructed by the scanner to the end where the scan is mobilized. A missing piece of this is the algorithmic and software component, which I will address in future iterations of this project.

Among the implications of my research is that media like the scanner are moving us away from representation towards operable systems. These new systems encode within them new ways of being in the world that are ultimately shaped by the values embedded in these machine-machine communications. It is necessary to observe and deconstruct the determinations and judgments that are encoded in these systems, as human subjects are being increasingly decentered from these systems of operations. Human subjects, within these machine-centered communications systems, are merely an operable part of the whole rather than the central observer who makes choices and determinations. We are observing a new paradigm where the agency of the subject is conferred upon the invisible work of the algorithm, the whole process of making judgments already done before the human steps onto the scene. As subjects, we are worked over by the logic of these systems, overcome by a larger structure against which tactical resistance will offer no answer.

Media History

The second theme of this dissertation is the role of the scanner in media history. The first chapter details the development of the scanner and pays particular attention to the evolving intermedial understanding of scanning by the inventors and engineers that created it. Their attempts to characterize this transformative process relied heavily on borrowing metaphors from other media. Whether called telephotography or radiovision, the process of scanning betrayed this split notion of medium-as-transmission and medium-as-storage. Only by combining the two do the engineers find an adequate way of describing the work of the scanner as images transmitted over a distance. Eventually, the scanner would come into its own as a mediating process and the term scanner would eclipse all the previous intermedial terms used. More than a simple description, the effort to combine storage and transmission was fundamentally about the discovery of a new method for the management of data over time and space.

I examined the role of the scanner in the history of science in the second chapter, particularly how the development of the particle accelerator—a special form of scanner—produced a genealogy of instruments that contributed both to media and scientific history. The scientific community investigated the science of particles, which lead to the creation of various particle accelerator technologies. Some of these particle accelerators, like the spinthariscope, would go on to become optical parlor toys while others, such as the cathode ray tube, would eventually be incorporated into the invention of television. Increasingly powerful particle accelerators would appear on the scene, such as medical particle accelerators that produce ions that are injected into the body to visualize the tissues of the brain in MRI scanning. Examining this historical trajectory of scanning via the particle accelerator illustrated the ways that scanners remain entangled in both media and scientific history.

The third and fourth chapters of this project investigate the separate historical trajectories of how the bar code scanner and the motion capture scanner developed. In both these examples, the scanner came into being independently from the first invention of the facsimile. The barcode scanner took as its inspiration the use of celluloid film for looped audio tracks combined with telegraphic morse code. Motion capture technology looked to camera techniques that broke down motion into its basic components. Each scanner case study in this dissertation followed its own historical trajectory, in isolation from one another. What they share in common is a manner of technical operation as well as the same socio-technical mode of mediation. Scanners represent a case of convergent evolution, where the same technologies emerge in response to similar kinds of needs.

An implication of this work is that the mediating process of scanning represents, despite its somewhat fragmented nature, something of continuity rather than a disjuncture in writing media history. Scanners share a form of genealogical continuity with the camera and telegraph, as the scanner was first a method to transmit photographs over telegraph wire. Scanning is a figurative child of these two media and bears the traces of their influence in its operation. Moreover, as a genealogical model, I have argued that not all instances of the scanner are connected to each other beyond sharing the same mode of operation. Scanners operate as a form of technical format or technological trope. Continuity is maintained in the sense that the model of scanning can be taken up in response to situations where measurement is called for, even though not all scanners follow one another in a neat, unbroken line of succession. Scanners exist as a kind of convergent evolutionary model rather than a linear genealogical one. They exist together by their common way of mediating, which is to transform the material into the virtual.

Virtualization of the Material

This project has been thematically concerned with the transformation of materiality into virtual forms of information. Each case study examines a different manner in which the material is constructed as an object and made legible to established systems of knowledge. Facsimiles function as an interface for representing images across great distances, converting them into electrical impulses and then translating them back into physical form. The particle accelerator is a method to detect objects at increasingly small scales and relating them back as measurements. The barcode mediates the material and virtual through the use of physical barcode symbologies that connect the material object to its data body. And motion capture technologies transform the process of motion itself into digital forms via scanning cameras. These scanning technologies function as an interface in a chain of media that renders the object of the scan into a new form that can take on new virtual life among other forms of media.

The notion of virtuality, in the case of the scanner, retains a relationship between the scanned object and its virtual counterpart, one of a referent and its reference. This referential relationship remains a deeply constructed one that does not emerge as a natural consequence of scanning. The scanner's actual physical interaction with material objects lends the process of scanning the illusion of an easy, transparent connection between the object and its virtual body. It would seem on the outside that the precise purpose of the scanner is to produce a form of information about the scanned object, so it should follow that there must be meaningful relationship between the object and the information produced. This relationship, however, requires situated, cultural work to make operational. It is precisely this perceived referential relationship that lends the products of scanning their power to operate as statements in circulations of knowledge.

Motion capture technologies (mocap) embody this uneasy reference-referent relationship through the laborious process of rendering time-lapsed spatial data into a stable representation of motion. The discourse circulating around mocap characterizes this technology as a technique that is finally able to free performers from the limitations of their physical bodies. When wearing a mocap suit, the actor can embody anyone or anything. Chapter four has shown this not to be true, as motion capture actors must still somehow match the height and dimensions of the character being portrayed, whether this is done by casting the right physical match or outfitting the actors with prosthetic extensions. Once the motion is captured, the motion data must be used to animate CGI characters, a process which requires a great deal of interpretation by the animators. This process of rendering motion into virtual image leads to a discursive conflict between mocap actors, who argue that the technology is merely a channel for their acting, and animators, who argue that the technology is deeply interpretive. These clashing discursive positions illustrate the struggle to define motion capture and claim rhetorical territory over how the process itself mediates between the material and the virtual.

The relationship between scanning and its objects, however, is not a straightforward one and ultimately bear important implications on how we understand materiality itself. Although the scanner is one of the mediating processes that captures a sense of "what is out there," scanned images do not share an identity with the scanned object. Whether it is a photograph or a human being, scanning actively constructs the objects it scans *as objects*. Rather than preexisting the scan, the object is actively constructed in the process of scanning. It is called into being by the process of scanning. The scanner defines the nature of the object as having certain qualities that make it readable by the scanner. Scanning already exhibits a bias towards what is legible or not legible to the system of scanning. Scanners are configured with a particular material in mind and are not able to exceed their parameters. Thus the scanner produces two objects through scanning, the object of the scan and the image of the scan. Scanning shapes our notions of the material in particular ways—what it is, how we are able to interact with it, and how we value it.

I have, across the different thematic areas in this conclusion, drawn out the major underlying concerns and questions present in this dissertation. The most pressing of these concerns is the manner in which these systems of scanning shape what we know. Scanners operate in a deeply ideological environment of sighted knowledge and are themselves major contributors to systems of knowing. Rather than a transparent channel through which material objects become virtual information, scanning is process of abstraction and construction. The object does not precede the scan, but is produced during the scan. The scanner thus constructs the material object as a knowable thing and brings it into circuits of knowledge via measurement. Once in circulation, the scanned image produces the object of knowledge as a thing upon which epistemological transactions can take place. Scanning opens up the object through its scan and renders it into something legible and that can be operated upon. Thus the operation of sight via the scanner is already caught up in a prior level of ideological construction before it becomes visible to the observer. Scans serve as inscriptions that bring the colonizing eye into new places to produce new forms of knowledge and power.

Ultimately, the treatment of scanning as a unique mediating process opens up new ways to approach the mediation of the material into the virtual. Not only is scanning an under-studied technology, it performs critical functions in today's media ecology. Acting as a relay point within various media infrastructure, scanners act as the point of contact between material objects and virtual systems of control. Scanners become part of machine-centered systems that use invisible images generated by scanning to trigger computational actions. Scanners serve as visualization systems that bring new objects of knowledge into being, transporting these new inscriptions into the broader circuits of knowledge circulation. By addressing scanning as its own process, this project reveals the emergence of other modes of knowing through media as an extension of man.

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