The Evolving Technoculture of America: Understanding the Impact of the Laser on the Relationship Between Technology and Culture, 1960-2000

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Abstract

This thesis investigates the American public's general reactions to and reception of the laser from 1960 to 2000. By analyzing newspapers, popular magazines, industry magazines, and scientists' memoirs, I explain how the media understood the laser during each decade. The common trends I discover in the media are, to a certain extent, related to the public's understanding of the laser. I seek to answer two questions. First, did the public reception to the laser affect future development of laser technology? Second, why did the commercial sector invest so heavily in research and development of a technology initially developed for the military and academic research? Within each of the three chapters, I ask questions specific to the history of the laser for that time period. Some of the topics investigated in depth include the impact of science fiction's portrayal of laser-like death rays before and after the invention of the laser, the laser's role in medicine, the laser's role in entertainment, the impact of the Strategic Defense Initiative on the public's perception of the laser as a weapon, and the rise of CD and DVD technology.

I discovered that the public's view of lasers was heavily influenced by the military and the growing popularity over time of laser technology in the public sphere. The language employed by journalists may be a reflection of Americans' reception of laser technology. While it is possible that journalists use language to shape the public's perception of laser technology, my argument presupposes that the language employed by journalists is more of a reflection of the general understanding of lasers by its audience. My analysis of this language revealed that Americans were generally intrigued with lasers in the 1960s and 1970s, but became more indifferent to lasers in the 1980s and 1990s. By the 1990s, lasers were commonplace in America, usually as components in larger systems. The popularity of such technologies as laser printers, CD and DVD players, and laser pointers contributed to the perception of lasers as mundane.

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Introduction

The twentieth century was one of the most important time periods for science, particularly physics and chemistry. Great physicists like Albert Einstein, Niels Bohr, Erwin Schrödinger, and Max Planck were responsible for the creation of quantum theory and the early development of quantum mechanics. Quantum mechanics explains the interactions between, and the dual wave/particle nature of, energy and matter. Early research succeeded in explaining the nature of light and the structure of the atom, particularly regarding electron behavior. At first glance, this may not seem like an especially important breakthrough, but these discoveries of modern physics affect our lives more than most people realize.

While plenty of discoveries in modern physics do not have a noticeable impact outside of academia, quantum mechanics research was responsible for many of the great inventions of the last century. Some notable technologies include the radio, transistor, television, computer, medical imaging technology such as the MRI, atomic and nuclear bombs, the microwave oven, photovoltaic technology such as solar panels, and the laser. Furthermore, quantum mechanics has also improved some existing technologies. Examples of this include telecommunication and time standards. Optical fiber and lasers are used to transmit Internet and voice data at the speed of light around the planet and atomic clocks keep time more accurately. Economists estimated that in 2009, technologies derived from quantum mechanics accounted for thirty percent of the American gross national product.[1] These technologies are so engrained in our daily lives that it would be difficult to imagine living without them.

This thesis will focus on the laser since its earliest appearance in America in 1960. Laser

1 Tim Folger, "Is Quantum Mechanics Tried, True, and Wrong?" *Science* 324 (2009): 1512-13.

is an acronym for light amplification by stimulated emission of radiation. What that long phrase means is that atoms that make up a particular material in a laser called the gain medium are excited from an external energy source, which causes the atoms to emit light. The gain medium is located inside the laser cavity, or resonator. A laser resonator allows for specific frequencies of light to form standing waves, or waves that are stationary. For the sake of simplicity, I describe lasers in terms of light particles, not light waves. According to quantum theory, electrons in each atom can possess certain discrete amounts of energy. Electrons prefer to stay in their lowest energy state, but can be moved to a higher energy state if they are stimulated with an amount of energy equal to exactly the difference between two or more energy levels. In the case of the laser, electricity or light provides the energy to excite the electrons in the atoms of the gain medium. Excited electrons return to their lowest energy state after a very short delay. In order to conserve overall energy, since energy cannot be created or destroyed, the electron can emits a photon – or particle of light – when it returns to the lowest energy state. The emitted photon carries energy equal to the difference between the energy state the electron was at when excited and the ground state. If this emitted photon hits another ground-state electron, it will excite the electron and, after a short delay, another identical photon will be emitted. The purpose of the external energy source, called a pump, is to get the majority of the gain medium electrons in the exited state the majority of the time, a phenomenon which is called a population inversion. This is because an interesting phenomenon occurs when a photon hits an already excited electron. When a photon collides with an excited electron, the electron immediately returns to the lower energy state and emits a photons of equal energy to the incident photon and, most importantly, the photon is emitted in the exact same direction. This is what is called stimulated emission of radiation. A simple example of a laser resonator is a cylinder with mirrors on each end. Photons that hit the non-mirror walls of the cylinder are absorbed by the walls and converted to heat. Photons that hit the mirrors on each end reflect back and forth with almost no loss in energy. The goal of a laser is to get enough photons bouncing back and forth between the mirrors through stimulated emission so that some of the photons can escape the cylinder. One of the two mirrors is partially reflective (usually about 99% reflective), but once enough photons hit that mirror, some escape. Since these photons that do manage to escape have been bouncing back and forth inside the laser cavity almost perfectly parallel to the cylinder walls – and since light generally travels in a straight line – they exit the laser in a nearly straight line. This is what is meant when people describe lasers as having "tightly focused beams." Laser beams do diverge, or grow wider, over distance, but they remain thin longer than light from other sources, like light bulbs. A beam is called collimated if it spreads slowly over distance. Also, because the light is collimated, the energy is concentrated over a very small area. This is what allows powerful lasers to easily cut through metal, for example.

Two questions guide my investigation into the history of the laser. First, did public reception of the laser affect future development of laser technology? The military funded much of the earliest laser research in the 1950s with the goal of using the technology to improve communications and to make weapons.[2] But language employed by journalists imply the public's understanding of the laser changed over time and was heavily influenced by laser applications. Historian Rebecca Slayton investigates the symbolism of the laser from the 1960s to the late 1980s in "From Death Rays to Light Sabers: Making Laser Weapons Surgically

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2 Descriptions of the early goals for lasers in the United States Military, including the military's response when scientists were unable to produce a viable laser weapon, see Robert W. Seidel, "How the Military Responded to the Laser," *Physics Today* 41 (1988): 36-42.

Precise."[3] Her conclusion is that Americans initially understood the laser to be a dangerous technology, capable of irradiating large areas of land. But as people discovered new applications of lasers, the public perception changed to one of precision and cleanliness. Indeed, the American government took advantage of this new perception when promoting the laser defense systems developed for the Strategic Defense Initiative during the Reagan Administration. Second, why did the commercial sector invest so heavily in research and development of a technology initially developed for the military and academic research? While scientists began research on the predecessor to the laser in 1951, the earliest publication of the theory of the laser did not appear until December 15, 1958, based on Einstein's prediction of stimulated emission in 1917.[4] It took nearly two more years before Theodore Maiman demonstrated a working laser, despite several scientists' participation in an intense race to build the first laser. Among these scientists were Charles H. Townes, Gordon Gould, and Theodore Maiman. Townes was a physics professor at Columbia who wrote the first publication describing laser theory while working at the prestigious Bell Laboratories. He was also responsible for the development of the maser, the predecessor to the laser which used microwaves instead of light. Even though the term "laser" was derived from maser (the 'm' standing for microwave), Townes referred to the laser initially as an optical maser. Journalists also regularly referred to the laser in the early 1960s as an optical maser. Gould was a former graduate student of Townes' who left Columbia after several years spent on a thesis which no longer interested him. An inventor and entrepreneur at heart, Gould dedicated his time after Columbia to developing a working laser at a small military contracting

3 Rebecca Slayton, "From Death Rays to Light Sabers: Making Laser Weapons Surgically Precise," *Technology and Culture* 52 (2011): 45-74.

4 Charles H. Townes, *How The Laser Happened: Adventures of a Scientist* (New York: Oxford University Press, 1999), 95. The maser, which stands for microwave amplification by stimulated emission of radiation, was the predecessor to the laser. A maser emits amplified microwaves using similar physics to that of a laser.

company after learning about laser theory from Townes. Maiman received his B.S. from the University of Colorado at Boulder and his Ph.D. from Stanford University, both in physics. While working independently from the research at Columbia and Bell Labs, Maiman shocked the scientific community when he successfully built the first working laser on May 16, 1960 while working for Hughes Research Laboratories.[5] Throughout the 1960s, scientists and engineers discovered several new types of lasers. Some of the main types invented in the 1960s were the gas, solid-state, and semiconductor lasers. These differed in size, color of emitted light, and applications. But from the most basic level, the difference between these is the type of gain medium they employ: a gas, a solid usually in the form of a crystal, or a semiconductor material. These successes launched the field of optics, or the physical study of light, back into the forefront of physics research after decades of study with few breakthroughs.[6]

The United States Military and the American Telephone and Telegraph Company (AT&T) were early researchers into laser technology. The military carried out its own research internally but also funded external research groups. The military funded external laser research through the Advanced Research Projects Agency (ARPA), which was created to "nourish crazy ideas that might just be feasible, high-risk projects with a high potential payoff."[7] ARPA funded the company Gould was working for with a grant of $999,008 in 1959 to investigate the use of the lasers for "communications, for marking targets with bright spots for weapons to home on, and for measuring the range to targets for other weapons."[8] In the commercial sector, Bell Labs, a research subsidiary of AT&T, saw lasers as a useful tool for transmitting telephone signals much faster than previously possible using electrical signals.

5 Jeff Hecht, *Beam: The Race to Make the Laser* (New York: Oxford University Press, 2005), 3-6.
6 Ibid.
7 Ibid., 74.
8 Ibid., 76.

Shortly after Maiman built the first laser, however, his assistant, Irnee D'Haenens, described it as "a solution looking for a problem."[9] This famous quote challenged scientists, engineers, medical researchers, and inventors to discover applications of laser technology. Even though this quote was well-known in the laser industry, lasers found uses almost immediately.[10] In 1960, General Motors and General Trading Company installed the first bar code scanners. In 1970, a few Kroger stores installed barcode scanners to improve accuracy and speed at the checkout counter. The Radio Corporation of America (RCA) owns the patent for the laser scanner.[11] While RCA was a large corporation at the time and also participated in telecommunication research like AT&T, they were not involved in the invention of the laser. This is one example of many such companies that embraced laser technology in the 1970s and can be used to track the early shift of laser technology to the commercial sector. RCA saw the potential in the laser and the laser scanner since they purchased the original patent from the Philadelphia Storage Battery Company.[12]

This thesis aims to study the technoculture, or relationship between – and politics of – technology and culture, in the United States since 1960 with the laser as a case study. The laser is a particularly fascinating subject for such a study due to the American public's common misunderstanding, fear, awe, and mystique of the laser.[13] Science fiction created the idea of a weapon using directed radiation such as a laser and this image had a striking impact on Americans.[14] In fact, these types of weapons can be seen as far back as 1898 in H. G. Wells' *The*

9 Ibid., 9.
10 This quote appears in virtually every historical account of the laser and many early news articles.
11 Tom Reynolds, "History of Barcode Scanners," National Barcode, http://www.nationalbarcode.com/History-of-Barcode-Scanners.htm, accessed December 7, 2010.
12 Ibid.
13 Slayton, "Death Rays." Slayton maps the dynamic history of the public's perception of the laser through analysis of language used by journalists, government officials, scientists, and engineers.
14 Death ray appears time and time again in articles throughout the history of the laser, though its appearance

War of the Worlds. The first time the laser appeared in visual media was during the famous scene in the 1964 film *Goldfinger*, where James Bond is strapped to a table while a laser beam slowly moves towards him, ready to cut him in half.[15] When these images are placed in the context of the Cold War between Russia and the United States, it is easy to see why Americans feared the government was researching "death rays" during the 1960s, a fear which was repeatedly confronted and allayed by the government.[16] The atomic bomb received similar attention by Americans during the Cold War. The difference between the death ray and the atomic bomb is that the laser was a brand new technology and it was unclear if the Soviet Union was also developing death ray technology of their own. In response to the bomb, children practiced hiding under their desks as a defensive practice. But in the case of a death ray, how should the people protect themselves? I analyze the relationship between development of laser technology and its impact on society and how society in turn affects the development of technology. I analyze the language used in newspaper and magazine articles to explain how Americans perceived the laser throughout the forty years this thesis covers. I argue that the laser, a device first discovered by experimental physicists and originally thought of as being used as a research tool, became one of the most commercially successful technologies. The laser, achieved its immense success among modern technologies due to its many applications discovered by entrepreneurs and corporations.

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declines during times of peace in America. This trend is discussed throughout this thesis.

15 Mark Wolverton, "A Solution for Almost Everything: 50 Years of the Laser," *American Heritage of Invention & Technology* 25 (2010): 34.

16 Richard D. Lyons, "Physicists Hear of a Strong Laser," *The New York Times*, April 30, 1970.

Most research on the history of the laser focuses almost exclusively on either the origins of the laser from the 1950s to 1970 or the use of lasers by the United States military. In addition to historical studies by Jeff Hecht, Joan Bromberg, and Rebecca Slayton, some of the important scientists involved with laser development have written books, usually memoirs, describing their experiences leading up to and shortly after the invention of the first working laser in 1960.[17] These texts are excellent sources for understanding the historical context during the invention period. It is important to keep in mind the impact of the Cold War and the purpose of the companies and government which initially funded laser research and development. The security surrounding military laser research affected how and when newspapers referred to lasers as death rays.

Other studies focus on specific applications of lasers. While these sources occasionally focus on the social impact of the applications, they usually are written for a technical audience, not the general public. An example of this is an article in the *Bulletin of the Atomic Scientists* titled “Lasers for Missile Defense.”[18] This article describes the military's goals for using lasers to shoot down enemy missiles, but addresses the shortcomings which prevented successful implementation of such a device. The article contains no information about the public's perspective of this research. Other examples include articles on medical procedures using lasers with surgeons as the target audience.[19] I use these types of sources as references for the applications of lasers and laser technology in commerce and military.

17 Some of these publications include Hecht, *Beam*; Jeff Hecht, *Laser Pioneer Interviews* (Torrance, CA: High Tech Publications, 1985); Joan Lisa Bromberg, “Amazing Light,” *American Heritage of Invention & Technology* 7 (1992): 18-26; Joan Lisa Bromberg, *The Laser in America 1950-1970* (Cambridge: MIT Press, 1991); Townes, *How The Laser Happened*; and Theodore Maiman, *The Laser Odyssey* (Blaine, WA: Laser Press, 2000); Slayton, “Death Rays.”

18 Daniel Kaplan, “Lasers for Missile Defense,” *Bulletin of the Atomic Scientists*, May 5-8, 1983.

19 Daniele Aron-Rosa and Jean-Jacques Aron, “Lasers in the service of ophthalmology,” *Impact of Science on Society* 31 (1981): 217-24.

The last main category of secondary sources is articles in popular science magazines or newspapers. These focus on the history of the laser and target the general public more than the previously mentioned sources as an audience, but rarely state explicitly the public's response to the laser. In order to determine the state of the public opinion, I analyze the language employed by journalists from the 1960s to the early 2000s. Newspapers are the most useful primary sources for understanding the popular perception and reception of laser technology at a broad level. This is because major national newspapers like *The New York Times* and *The Washington Post* reach a broader audience than most popular science magazines like *Popular Science* and *Scientific American*. The language used in these newspapers, however, cannot be used to stand in for the opinions of all Americans. Indeed, despite a diverse group of readers, no single newspaper or magazine is catered to all Americans. The demographic of *The New York Times* in 2009 shows that the majority of its readers are middle class and college educated.[20] For this reason, I speak in generalizations when describing the views of the populace. Newspaper articles are especially useful because they also often include some descriptions about why the public should care about the new technology. These descriptions can be analyzed to glean the level of comfort and familiarity with laser technology by the public.

It is important to note that language employed by journalists does not always reflect the understanding or perception of lasers by the public. Sometimes journalists may use language to define a standard method to describe lasers and how Americans should understand the technology. Regardless of these reasons, however, journalists should use language Americans can understand and, therefore, the language to some degree reflects the understanding of lasers

20 "*New York Times*: Adult Demographic Profile," www.nytimes.whsites.net/mediakit/pdfs/newspaper/MRI_NYTreaderprofile.pdf.

by the readers.

A substantial social history of the laser in America has not yet been written over this time span. Historical accounts of the laser as a whole tend to be little more than timelines of inventions.[21] When these recent texts go into detail, however, they describe the events surrounding the creation of the theory of quantum mechanics, which predicted the laser, and the invention of the first working laser. They also focus on the prominent researchers of laser technology in the 1950s and 1960s. The reason this is a hot topic is because the exact inventor is not quite clear, and there is some controversy about how much credit should be given to each of the physicists who contributed to the discoveries leading to the creation of the laser. This controversy seems to be quite dramatic based on the texts I have encountered. Indeed, even Townes, the man generally credited with the creation of laser theory based on his previous microwave research, wrote a book in 1999 titled *How the Laser Happened: Adventures of a Scientist*.[22] Some of the other contributors to early laser theory published books describing their role in the process. Due to the early time period and the different focus of most of these texts, I use them to help establish the historical context for the rest of the paper.

The relationship between culture and laser technology has a level of feedback that has not yet been researched from a historical perspective. By that, I mean that the way laser technology is received by the public is noticed by the people developing new laser technology. They use this information to determine what type of product or technology to develop next. Indeed, commercial successes and failures often provide direction for future technological research and development. The success of DVD players, for example, characterized the decisions of the

21 Wolverton, "Solution."
22 Townes, *How the Laser Happened*.

various film publishers regarding when to release their films on DVD. Another example of this feedback deals with the collective imagination of the people and how this drives innovative ideas for laser use. This can be explained in how scientists responded to the public's perception that lasers would be used as death rays in the 1960s and 70s. Scientists made it clear to the public that lasers were not being developed for weaponry. Instead, they stressed the medical advancements which the laser made possible.

Finally, I hope that my background in history and electrical engineering has allowed me to bridge the gap between the technical details of laser development and history to write a compelling argument which will track and explain the public's perception of lasers and to explain why certain applications were more successful than others.

Chapter Outline

This thesis is chronological and focuses on the time span of 1960 to 2000. By writing chronologically, I am able to more easily trace the changing public understanding of the laser and any cultural ramifications. The laser's change from purely scientific and military use to the inclusion of commercial use is clear when written in a chronological form. While I present some technical details throughout the thesis to explain new technologies, this introduction contains the most detailed explanation of laser operation.

The first chapter covers the time period from 1960 to 1970. The purpose of the chapter is to investigate why smaller laser companies were founded and why the public became less aware of military laser research. The chapter additionally describes the impact of portrayal of death rays in science fiction to the general understanding of lasers by Americans. Thanks to the many applications of lasers outside of weaponry, Americans started to see the laser as a useful technology.

The second chapter spans 1970 to 1990. Due to the rapid growth of the laser industry, many new applications were created during this time period. Unlike many of the inventions of the 1960s, these devices were actually used by many Americans. Devices like the Compact Disc player and laser printers helped Americans become more accustomed to lasers as an increasingly common technology. The common cultural portrayal of the laser as a weapon grew popular once again thanks to President Reagan's Strategic Defense Initiative, which became known colloquially as Star Wars. The chapter also describes the change in commercial laser technology from an industry struggling to find a consumer base to one in high demand. Misunderstandings about lasers in the late 1970s resulted in a significant decline in the demand for lasers as the military decreased its support of laser technology.[23] By the late 1980s, however, the Compact Disc player helped to fill the commercial void.

The third chapter covers the decade of the 1990s. By the early 1990s, the laser industry was no longer held back by fear or misunderstanding of lasers. Americans knew that the SDI project could not produce any lasers for missile defense any time soon. Dermatology began to use lasers for quick cosmetic procedures like tattoo and hair removal. The CD continued to grow in popularity, especially after the invention of a recordable and rewritable disc. In the late 1990s, the DVD began to replace the VHS for home video. By analyzing language used in news and magazine articles, I argue that the laser during the 1990s became commonplace. It was no longer a fascinating new technology and, instead, was as mundane as the computer. This is based in part by the lack of technical descriptions of laser systems.

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23 Barnaby Feder, "Market Challenges for Lasers," *The New York Times*, April 28, 1982.

Chapter One:
A Solution Looking for a Problem – Early Adoption of Laser Technology

> *On this site in May 1960 Theodore Maiman built and operated the first laser. A number of teams around the world were trying to construct this theoretically anticipated device from different materials. Maiman's was based on a ruby rod optically pumped by a flash lamp. The laser was a transformative technology in the 20th century and continues to enjoy wide application in many fields of human endeavor.*[24]
>
> – IEEE Milestone: First Working Laser, 1960, Malibu, CA
> Dedicated November 23, 2010

Theodore Maiman brought into the world a new light source when he successfully tested the first working laser on May 16, 1960 at the Hughes Research Laboratories in Malibu, California.[25] The race to build the laser had been won by an unexpected participant. Although it took two years for scientists to transform Charles Townes' laser theory into reality, the scientific community was quick to question the laser's usefulness. Irnee D'Haenens, an assistant to Maiman, famously described the laser as “a solution looking for a problem,” a statement which would set the tone for laser research for the first half of the decade, and justifiably so.[26] So much time and money went into development of the laser that surely science had entered a new era after scientists demonstrated the first working lasers. Gordon Gould perhaps exaggerated the usefulness of the laser more than the other laser researchers, thus grabbing the attention of the United States military that funded him. In 2003, Townes recalled hearing the famous statement as both a joke and a challenge; a challenge, he described, that resulted in several applications in

24 “Milestones: List of IEEE Milestones,” IEEE Global History Network, accessed March 31, 2011, http://www.ieeeghn.org/wiki/index.php/Milestones:List_of_IEEE_Milestones. The Institute of Electrical and Electronics Engineers is the global professional organization for electrical and electronics engineers.
25 Jeff Hecht, *Beam: The Race to Make the Laser* (New York: Oxford University Press, 2005), 3-6.
26 Ibid., 9.

the first few years of the 1960s.[27]

While Townes was correct that the laser was quick to find applications, scientists only discovered new ways to create lasers in 1960, rather than discovering applications for lasers. In 1960, Peter Sorokin and Mirek Stevenson of IBM demonstrated a new laser they built that used calcium fluoride as the gain medium, rather than ruby in Maiman's design. Also that year, Bell Laboratories researchers Ali Javan, William Bennett, and Donald Herriott developed the first helium-neon laser.[28] Another technological breakthrough was the invention of the semiconductor laser in 1962 by Robert Hall of General Electric.[29] These three examples indicate that early breakthroughs in laser technology took place in the large industrial laboratories of America, not in the military or in "smaller" companies. By smaller companies, I mean those without the substantial funding characteristic of the research labs of the monolithic corporations like IBM, AT&T, and GE.

By the mid- to late-1960s, however, smaller companies developed several practical applications of lasers. In fact, during the 1970s, smaller companies developed most new laser applications known to the general public.[30] This chapter investigates the shift of laser

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27 Charles Townes, "The First Laser," in *A Century of Nature: Twenty-One Discoveries that Changed Science and the World*, ed. Laura Garwin and Tim Lincoln (Chicago: Univ. of Chicago Press, 2003), 107-112. Townes explains that researchers created many new lasers quickly after Maiman's ruby laser. Though people debate whether Townes or Maiman is the "father" of the laser, Townes honors Maiman here, saying "Maiman's paper is so short, and has so many powerful ramifications, that I believe it might be considered the most important per word of any of the wonderful papers in *Nature* over the past century." The paper to which he refers is Maiman's technical report of the world's first laser. *Nature* is generally considered one of the most prestigious interdisciplinary scientific journals in publication.

28 Ibid. The helium-neon laser (commonly pronounced "hee nee" after its elemental abbreviation of HeNe) is a popular laser due to its low power, pure frequency, narrow beam width, and low cost among gas lasers. These lasers emit a red beam and are common in laboratory experiments.

29 Ibid. Semiconductor lasers are of the type most people see and use. Common uses of the semiconductor laser include laser pointers, bar code scanners, and optical disc readers/writers. The most common type of semiconductor laser is the diode laser, which can be very small in size. Semiconductor lasers are the cheapest of all types of lasers and require little power.

30 Chapter Two of this thesis covers the laser applications and developments of the 1970s and 1980s. Large companies were still involved in research, especially electronics manufacturers, but the laser industry in America was made up of "more than 3000" companies by the end of the 1980s. Bill Slocum, "A Promising Youngster

development away from the large industrial laboratories and into the smaller companies of America. Also during this time period, military research into the laser became less known to the public due to a combination of secrecy and the failure to develop a death ray. I argue that public intrigue with the laser, fueled by science fiction novels and motion pictures, provided publicity for the laser industry. Also, after the first few years of development in the 1960s, smaller companies were able to experiment with lasers since the big industrial labs and universities completed much of the rigorous research which was necessary to start the laser industry in the first place. The laser was a technology ripe for experimentation not just by scientists, but also by engineers and inventors.[31]

The State of the Art of Death Rays

Lasers may not have been a reality until 1960, but they existed in the works of science fiction for decades. Examples of lasers and laser-like weapons in science fiction are so numerous that only some of the most popular examples will be described here.[32] These examples, combined with some claims of inventors and scientists to have developed death rays,

Called Photonics," *The New York Times*, February 7, 1999.

31 In Ronald M. Benrey, "PS Builds a LASER . . . and so can you," *Popular Science*, November, 1964, 62-64 and 224-230, http://www.popsci.com/archive-viewer?id=MyYDAAAAMBAJ&pg=62&query=laser, Benrey calls upon electronics hobbyists to build their own laser and "join in the search" for practical applications. This article reflects the view that the laser was still "a solution looking for a problem." Even though Columbia-Presbyterian Hospital demonstrated a tumor treatment using a laser in 1961 (see n. 57 below), *Popular Science* believed that the laser still had potential that could be discovered even by hobbyists. As it turns out, they were correct. Later in this chapter and Chapter Two, I present several examples of laser applications discovered by individuals experimenting with lasers.

32 Laser-like weapons also appeared before 1960 in the following books: *Edison's Conquest of Mars* by Garrett P. Serviss (1898), *When the Green Star Waned* by Nictzin Dyalhis (1925), *David Starr, Space Ranger* by Isaac Asimov (1952). Laser-like guns appeared in the following films: *Forbidden Planet* (1956) directed by Fred M. Wilcox and *Teenagers from Outer Space* (1959) directed by Tom Graeff. For a compilation of laser-like weapons in science fiction, see Kevin Kelly, "The Secret Origin of the Ray Gun in Science Fiction," io9.com, last modified March 24, 2008, http://io9.com/#!371411/the-secret-origin-of-the-ray-gun-in-science-fiction.

fostered the image that the government and researchers meant for the laser to be a weapon.[33]

One of the first appearances of a laser-like weapon in science fiction was the Heat-Ray of H. G. Wells' 1898 science fiction novel, *The War of the Worlds*. This novel is told by an unnamed narrator who describes his experiences in the suburbs of London as Earth is invaded by hostile Martians. Wells depicts the Martians as sometimes using three legged vehicles called tripods. The tripods all have one appendage that is armed with a "Heat-Ray." Wells provides a description of this deadly weapon:

> It is still a matter of wonder how the Martians are able to slay men so swiftly and so silently. Many think that in some way they are able to generate an intense heat in a chamber of practically absolute non-conductivity. This intense heat they project in a parallel beam against any object they choose, by means of a polished parabolic mirror of unknown composition, much as the parabolic mirror of a lighthouse projects a beam of light. But no one has absolutely proved these details. However it is done, it is certain that a beam of heat is the essence of the matter. Heat, and invisible, instead of visible, light. Whatever is combustible flashes into flame at its touch, lead runs like water, it softens iron, cracks and melts glass, and when it falls upon water, incontinently that explodes into steam.[34]

The many iterations of *The War of the Worlds* depict the Heat-Ray inconsistently. In the 1953 film adaption, the Heat-Ray fires red sparks from the parabolic mirror. This film also added an additional weapon called the disintegrator ray, which fires green energy bolts that cause the target to instantly disintegrate, leaving behind only ashes or a stain. Additionally, illustrations included in the several editions of the book worldwide depict the Heat-Ray emitting a visible beam of energy.[35] Even though the novel describes the Heat-Ray beam as invisible, it is understandable why it is usually depicted as visible. Indeed, a beam of directed energy could be invisible, but it would be more exciting for the viewer of the films or images to see the beam.

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33 For several examples of news articles reporting on the dangers of lasers in the 1960s, see n. 4 in Rebecca Slayton, "From Death Rays to Light Sabers: Making Laser Weapons Surgically Precise," *Technology and Culture* 52 (2011): 46.

34 H. G. Wells, "Book One: Chapter Six: The Heat-Ray in the Chobham Road," in *The War of the Worlds* (Wikisource, 2007), http://en.wikisource.org/wiki/The_War_of_the_Worlds/Book_1/Chapter_6 .

35 "The War of the Worlds – Interior Illustrations," last modified January 23, 2006, http://drzeus.best.vwh.net/wotw/illus/interior.html .

The visual depictions of the Heat-Ray as tight beam of energy that travels in a straight line is consistent with real lasers. The main difference is just that light can only be seen when it enters the eye either due to aiming the light directly into the eye or by reflection of the light. Thus, a beam would not be visible along its path unless there was something present in the air to reflect the light, such as heavy mist or dust.[36]

A more recent example of a laser-like weapon in science fiction is the Stiletto from Arthur C. Clarke's *Earthlight*. This weapon, described as a “solid bar of light stabbing at the stars,” fires molten metal with enough energy that it appears as a laser beam until it hardens inside its target.[37] While not a beam of light used in a laser, the visual depiction of the Stiletto is similar to a laser.

The popular science fiction comic strip *Flash Gordon* also included a laser-like weapon. The titular character used a hand-held ray gun, which fired a focused beam of energy. This laser-like weapon became iconic of the comic, as evident by the creation of ray gun toys and models. *Flash Gordon* first appeared in 1934 and is still syndicated today in some newspapers.[38] In addition to the comic format, *Flash Gordon* has appeared in several other media, including a television series from 1954-1955, an animated series from 1979-1982, a 1980 motion picture, and a live-action television series that began in 2007 and is still being produced as of 2011.[39]

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36 Since the visual effect of seeing the beam along its entire path is attractive, even scientific journals take pictures of laser systems in such a way that the beam's path is illuminated. This is usually accomplished by taking a long exposure image while someone moves a notecard or other reflective material along the path of the beam. The beam is cropped and then inserted into a short-exposure shot of the system as a whole.

37 Arthur C. Clarke, *Earthlight* (New York: Ballantine Books, 1955). Interestingly enough, a new weapon is currently under development by DARPA that is inspired by the Stiletto. This weapon, titled MAHEM (Magneto Hydrodynamic Explosive Munition), uses electromagnets to fire self-forming metal rods which pierce heavy armor. http://www.darpa.mil/tto/programs/mahem/

38 Jim Keefe is the current comic strip author of *Flash Gordon*, which is syndicated online and in some newspapers by King Features Syndicate, Inc.

39 King Features Syndicate, “Welcome to FlashGordon.com!” accessed February 4, 2011, http://www.flashgordon.com.

While the story has been re-imagined over the years, Flash has always used a ray gun weapon. Toy models of the ray gun have been produced since 1948 and older models are considered collector's items.[40] The popularity of these ray gun toys suggests children's fascination with the fantastic laser-like weapon. Journalists often made use of the popularity of characters like Flash Gordon and Buck Rogers, another science fiction comic strip character who used a laser-like weapon, to describe lasers in the news.[41]

One last example of a laser-like weapon in fiction comes from the 1951 film, *The Day the Earth Stood Still*. This motion picture tells the story of an alien visitor, Klaatu, and his robot assistant, Gort. Klaatu visits the United States to warn all the nations of the dangers of atomic technology, particularly regarding atomic weaponry. Klaatu gives the president of the United States an ultimatum that if the nations of Earth continue to use atomic power for destructive means, the planet will be destroyed by other extraterrestrials. The robot Gort is equipped with a laser-like weapon that is used early in the film to disintegrate the weapons of some United States soldiers. Gort is a metallic, humanoid robot and the laser is emitted from a visor located on his face. The weapon was highly advertised through its depiction across most of the the theatrical advertisement poster.[42] Furthermore, this film had a moderately high income of $1.2 million from theaters and $1.85 million from rentals.[43] This was the most popular motion picture to depict a laser-like weapon prior to the invention of the ruby laser in 1960.

Considering the great popularity of Arthur C. Clarke as an author and *The War of the Worlds*, science fiction fans were aware of the concept of laser-like weapons. Also, the many

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40 "Gallery Rayguns," accessed February 4, 2011, http://www.toyraygun.com/flashgordon.html.

41 Slayton, "Death Rays," 46. "In the United States, 'death rays' were usually associated with Buck Rogers or Flash Gordon – characters that appeared both in science-fiction comics and on the silver screen during the 1920s."

42 Wikipedia, http://en.wikipedia.org/wiki/File:Day_the_Earth_Stood_Still_1951.jpg, accessed February 6, 2011.

43 "The Day the Earth Stood Still (1951) – Box office / business," The Internet Movie Database, http://www.imdb.com/title/tt0043456/business, accessed February 6, 2011.

iterations of *The War of the Worlds* – including films, radio dramas, and graphic novels – bombarded popular culture with with the Heat-Ray. *The Day the Earth Stood Still* provided another visual depiction of a laser-like weapon to the public. *Flash Gordon* was particularly important in promoting the idea of a laser as a weapon considering the continuous publication of the comic since 1934 and its popularity with children. By 1960, Americans had been exposed to several imaginings of a directed beam of energy, and in each case it was depicted as a weapon. But surely science fiction alone could not plant the idea of the "death ray" in the American public.

Prior to 1960, several scientists were also working on developing their own laser-like weapons. Nikola Tesla claimed to have developed a charged particle beam projector which he called the teleforce. This device was meant to emit charged tungsten or mercury particles at a very high velocity using electrostatic repulsion. Tesla introduced the teleforce to the public on July 11, 1934, but a full scale implementation of the device was never built.[44] Tesla described four key inventions required for the operation of the teleforce. First, the teleforce required an apparatus to emit the charged particle beam in free space, rather than in a vacuum. Tesla claimed to have successfully built a new type of vacuum tube that was open to the atmosphere on one end, but was a vacuum on the other end. Second, the teleforce required a process to generate a voltage of around 60 million volts in order to propel the particles at high velocity. Tesla determined that a device similar to a Van de Graaf generator could be used, but it would be very large (on the scale of a power plant). He also claimed to have accomplished this. Third, a method to amplify the force generated by the prior invention was required. This can be

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44 "Beam to Kill Army at 200 Miles, Tesla Claims On 78th Birthday," *New York Herald Tribune*, July 11, 1934. This article describes the potential of the teleforce device using Tesla's words. The reporter does not question the viability of such a weapon.

compared to the gain medium used in a laser cavity. Tesla used small electrodes in a vacuum to produce this effect. Finally, the teleforce required a device to produce a massive electrostatic repelling force to act as the firing mechanism of the weapon. This was the key component that Tesla did not invent before his death in 1943.[45]

Even though Tesla was unable to build a fully functional teleforce apparatus, he predicted that it would eliminate wars as we know them. This death beam, as he called it, could be capable of destroying enemy planes hundreds of miles away and could even target infantry. He envisioned these teleforce devices as being deployed around the perimeter of a nation to form an impregnable boundary. For this reason, the teleforce device was occasionally dubbed the peace ray.[46]

Tesla was likely the closest of all inventors to creating a working energy beam weapon, but a few others also received media attention for trying. Perhaps the most famous person to have claimed to invent a death ray was Harry Grindell Matthews of England. Formally trained as an electronic engineer, Matthews spent much of his early career inventing technology which he hoped to sell to the British military. While he claimed to have invented a radio telecommunication system for aircraft and a remote control system for controlling unmanned vehicles, the British military never used his technology. In an act that would characterize much of his death ray years, Matthews refused to demonstrate his inventions if any experts were present. Yet despite this mindset and a lack of scientific explanation to back up the death ray, the media continued to appear convinced that his device was real. One article from *Time* states that Matthews' "has perfected a principle by which airplanes and other engines can be stopped in full

45 Ibid.

46 "Tesla Invents Peace Ray," *New York Sun*, July 10, 1934. This article describes the journalists present at Tesla's annual birthday interview as "rather bewildered." No doubt his device was described in a highly technical fashion, but the article presents no skepticism regarding the teleforce.

operation through an invisible ray. He has demonstrated its efficacy with but a quarter kilowatt of power on engines in the laboratory, and needs only to strengthen its current for operation at a greater distance to bring airplanes in flight to a full stop and send them crashing to earth."[47] Matthews repeatedly tried to sell his device to the British Navy but was unsuccessful as he could never convince the navy that his device was not mere trickery. Considering that contemporary physicists and the military were never convinced of the legitimacy of his death ray, Matthews can be considered little more than an intelligent con artist who knew enough about engineering to keep up the show. To keep media attention on him, Matthews left England for France and, later, America. Each time, he claimed to have received competing bids for his technology in France and America. These were lies likely to persuade Britain to offer a higher sum for his technology than the other false bids.[48] After traveling to France, Matthews received offers from several British entrepreneurs to keep the technology in Britain, but each time Matthews refused. He even produced a film in France, titled *The Death Ray,* as a marketing tool.[49] In America, the organizers of the Radio World's Fair offered Matthews $25,000 to demonstrate the ray to spectators at the fair, but he refused, claiming that he was not authorized to demonstrate his device outside of England. In the end, he was never able to close a deal with any potential buyer for his death ray. Nonetheless, the media commonly referred to him as the "famous inventor" of the death ray.[50]

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47 "Invisible Death," *Time*, April 21, 1924.
48 "Diabolical Rays," *Time*, June 9, 1924.
49 "The Death Ray," The Internet Movie Database, http://www.imdb.com/title/tt0303894/, accessed February 6, 2011.
50 "Luminaphone," *Time*, November 23, 1925. For a history of the life of Matthews, see Jonathan Foster, *The Death Ray: The Secret Life of Harry Grindell Matthews* (Inventive Publishing, 2009), web book, http://www.harrygrindellmatthews.com/inventive.asp. At the end of the "Death Ray 1924" chapter, Foster states "[t]here has always been some doubt as to whether Matthews ever actually invented a 'Death Ray'." He goes on to cite a French patent for "remote projection of invisible high frequency electricity," patented by a close associate of Matthews, but such a device has never been adequately tested.

Dr. Edwin R. Scott was another inventor who claimed to have invented a directed-energy weapon. Using this weapon, which he called the "death stroke" or "canned lightning," he claimed to have burned holes in steel plates two inches thick at a distance of one mile. Additionally, he claimed to have killed animals and trees from several miles away.[51] It is important to note that this device used no beams or rays; however, the death stroke appeared as a competitor to Matthews' death ray as a futuristic directed-energy weapon.[52] Scott's weapon received less media coverage than Matthews' death ray because Scott kept his research somewhat secret from the public. This secrecy is common among inventors wishing to develop technology primarily for military use. All that was claimed by Scott was that his weapon used directed ultraviolet rays to increase the electrical conductivity of the air to help guide a bolt of lightning to a target. In this regard, the device was not primarily a ray. Still, Scott was adamant in his assertion that the death stroke was invented before Matthews' death ray.[53]

Despite the unsuccessful attempts by many inventors in the 1920s and 1930s to create a death ray, the U.S. military continued to encourage the development of a death ray until the invention of the first laser. The military funded its own research into laser development through ARPA, but they also solicited the services of the National Inventors Council.[54] The Council was a "go-between for military experts with impossible requests and civilian inventors with impossible devices."[55] The council accepted proposals by inventors and filtered them for feasibility. The council considered only about 4% of all submitted proposals feasible, and they

51 "Death Stroke," *Time*, August 10, 1925.
52 "Denies Britisher Invented 'Death Ray'," *The New York Times*, September 5, 1924.
53 Ibid. "Edwin R. Scott . . . challenged the assertion of Mr. Grindell-Matthews . . . that the latter was the first to develop a 'death-ray' that would destroy human life and bring down planes at a distance."
54 As mention in the Introduction, the Advanced Projects Research Agency (ARPA) was a research agency funded by the United States military to research technology with a high risk of failure to produce results, but with great potential rewards. The organization is now called DARPA (D for defense).
55 "Goals are Listed for U.S. Inventors," *The New York Times*, November 3, 1957.

passed on most of these feasible proposals on to the military. The council system was successful in leading to the invention of the mine detector, the mercury dry cell battery, an electrical firing device used in bazookas, and several other technologies. A *New York Times* news article quotes some of the postings by the council, some of which range from obviously feasible to completely outrageous. The death ray is, understandably, one of the more outrageous of these, described as a method to "prevent an overwhelming number of enemy troops overrunning an army position."[56]

The fact that the military sought death ray technology through both internal research and by funding outside research groups is indicative of the perceived strategic value of such a weapon. It also indicates that the military was convinced of its feasibility, likely based on the work of the inventors mentioned earlier. Despite the urgency displayed by the military to obtain death ray technology, they did not fund the aforementioned inventors, likely because they realized that their claims were bogus. Also, even though Gould exaggerated the uses of the laser for the military, his ARPA-funded project was initially aimed only at creating a working laser, regardless of its usefulness as a weapon. But considering Bell Laboratories' continuing research into laser communications, they believed the laser would still be useful as a communication tool, even for the military.[57]

And so, on the eve of the invention of the ruby laser in 1960, the state of the art of the death ray was practically at the same state as it was when it existed only in the imaginations of science fiction authors. Despite several appearances of laser-like weapons in science fiction and

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56 Ibid.

57 The benefits of laser communication through free space is that it cannot be intercepted unless equipment is placed directly in line with the beam and the bandwidth of a laser is very high, thanks to the high frequency of light. Free space optical communication was never implemented in the military because fiber optics communication was more efficient. Still, space-based satellites sometimes use free space optical communication.

the dedicated work by several inventors to make the weapon a reality over the course of a half century, the laser appeared in 1960 with few known uses, none of which included weaponry. Indeed, the laser was "a solution looking for a problem."

The Laser's New Focus

Three major factors contributed to the shift of laser investment from the military and large industrial labs to smaller companies and research centers in the United States: the lack of a death ray, the fact that much of the groundbreaking research had been completed, and that Americans seemed to view the laser as a technology of precision, not destruction. In the case of the military, no death ray was ever invented. ARPA was successful, however, in inventing communications and targeting systems using lasers. But the military was still most interested in the potential of laser weaponry. In 1962, Major General August Schomburg, head of the Army Ordnance Missile Command, made the following statement: "I feel as do others here that the laser may be the biggest breakthrough in the weapons area since the atomic bomb."[58] During the 1960s, "the Army spent $8.8 million on high-energy lasers, which they divided about equally between in-house and externally funded research."[59] The purpose of this research was to develop rangefinders and laser blinding weapons. The rangefinders were successful, but the weapons were not.[60] The Air Force became the main source of funds for laser research in the 1970s and 1980s. The Air Force focused on developing space-based laser weapons and lasers for missile defense. This technology would become a major component of Reagan's Strategic Defense

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58 Robert W. Seidel, "How the Military Responded to the Laser," *Physics Today* 41 (1988): 36.
59 Ibid., 39.
60 Ibid., 38-39.

Initiative in the 1980s.[61] Unfortunately, "the Air Force's focus on applications of the laser in space was at best premature and at worst unproductive of any practical devices."[62] However, laser research in the military did not end.

In the wake of the Vietnam War and breakthroughs of laser technology in the 1960s, the military continued its research into laser technology. These include LADAR (LAser Detection And Ranging), laser communication technology, and missile targeting systems.[63] By 1970, the military was aware of the potential of the laser in a variety of applications which would not be realized until much later, if at all as of 2011. Indeed, military laser research blossomed during the Vietnam War and remained strong throughout the Cold War as scientists and engineers discovered new uses for lasers and fears of Soviet death rays and other advances loomed large. Among these new research topics were laser-induced plasma, laser fusion for energy reactors and bombs, and tactical laser weapons "with an output of about five megawatts or more to instantly vaporize objects on which they focus."[64] But just how aware was the American public of military laser research?

The key difference between military research into laser technology in the 1960s and the 1970s is the level of secrecy. In the 1960s, the invention of the laser was well documented and published in popular newspapers and magazines. The military did not hide its desire for a death ray during the 1960s and earlier. But research beginning in 1968 and continuing into the 1970s was conducted by ARPA, and its "security level was comparable to the World War II atomic bomb project."[65] This so-called "Eighth Card" project was meant to investigate the usefulness of

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61 Chapter Two covers the SDI project in greater detail.
62 Seidel, "Military," 39.
63 Edgar E. Uslamer, "Laser – The Weapon Whose Time Is Near," *Air Force & Space Digest* 53 (1970): 28. LADAR is a radar-like technology which uses lasers instead of microwaves or radio waves.
64 Ibid.
65 Ibid., 30.

lasers not only as weapons, but also as tools to solve advanced engineering problems facing the military. The total investment of laser research and development into laser weaponry from 1968 to 1970 exceeded $100 million.[66] While this research did not result in a spectacular death ray, it did result in breakthroughs in guidance and control systems. However, these kinds of developments are not always memorable to a non-technical audience. Even by 1970, some Americans believed that the military was developing a death ray and surely would not be as interested in improvements to missile targeting systems. A *New York Times* article in 1970 states that "scientists appearing at a news conference on laser developments emphatically denied that lasers were being built to be used as 'death rays,' about which there has been much speculation."[67]

As smaller companies continued to grow in the 1970s and 1980s, the United States military still dominated money spent on laser development. By 1980, the military spent about $453 million on low-power laser research and development, which totaled about 60% of the entire laser market.[68] But since much military laser research was classified, smaller companies developed new technologies based on their own creative designs, rather than trying to develop death rays or other technology for use in the military.

Among the large industrial labs, Bell Laboratories and IBM dominated laser research. While some other big companies invested in laser technology – such as the purchase of the patent for a laser scanner by RCA – Bell and IBM were the only major labs involved in active laser research. Bell Labs' goal with laser research was to develop technology to benefit AT&T. More specifically, Bell Laboratories was researching a method to communicate and send data

66 Ibid.
67 Richard D. Lyons, "Physicists Hear of Strong Laser," *The New York Times*, April 29, 1970.
68 Seidel, "Military," 42.

faster than with traditional electrical signals. The laser was the key component for that method to work. In an early experiment to test the usefulness of the first working ruby lasers as Bell Laboratories – as well as to generate great publicity in a fierce competition in which Bell worked hard to make it appear that they had invented the first laser before Maiman – they fired a beam from a radio tower to another tower over a twenty-five mile distance. This experiment was successful as the scientists on the receiving tower did detect the beam, but the experiment was complicated, and it was clear that sending beams through air was not the future of communication technology. Optical fiber would later be used as the medium to carry laser beams over long distances to transmit data for communication. Another important result of Bell Labs' test was that it diverted the public attention away from death rays. Even *Time*, the magazine that published so many articles covering the death ray developments of inventors earlier in the century, did not report anything about the potential for the ruby laser as a death ray when reporting on Bell Labs' success.[69] This omission is indicative of the shift of the popular perception of the laser. Indeed worthy of attention was that "The Telephone Company" developed a laser for communication of all things. In that same *Time* article, they reported on other potential uses of lasers, including the ability to move satellites between orbits and to control chemical reactions.[70] The invention of the helium-neon laser at Bell Labs also received media attention for its uses in communication in a *New York Times* article titled "Bell Shows Beam of 'Talking' Light."[71] The helium-neon laser was a breakthrough for three reasons: it was the first continuous wave laser, the first laser that used a gas as a gain medium instead of a crystal, and it used electricity as its energy input instead of the flash from a light used in the ruby

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69 Hecht, *Beam*, 206.
70 Ibid.
71 Ibid., 218.

laser.[72] Media coverage of Bell Labs' successes with lasers likely fueled much of the early interest in lasers by smaller companies in America. American inventors and entrepreneurs had finally been exposed to some of the potential of the laser to solve all kinds of problems.

IBM was also researching laser technology in 1960. Immediately after recreating Maiman's ruby laser, IBM physicists turned their attention to calcium fluoride crystals doped with uranium atoms. According to their research, uranium contained four energy levels which could be used in lasing (the act of emitting laser light). Technical details aside, using a four-level system is significantly easier to create the population inversion of energized atoms required for lasing than a three-level system, of which the ruby laser was a type.[73] IBM's success was truly a breakthrough because their system required about 1/500th as much input light than the ruby laser and could output a continuous beam, rather than a series of fast pulses.[74] However, despite the importance of this four-level laser, the calcium fluoride laser never found any practical uses, although several other four-level lasers eventually did.[75] IBM received little media coverage regarding laser research after the invention of the four-level laser.

As early as 1962, lasers began to enter the commercial sector. The helium-neon laser first found a market in academics as both a research tool and a demonstration tool for classrooms. In 1969, the first laser barcode readers, which used a helium-neon laser, were implemented by Computer Identics at a General Motors plant in Michigan and a General Trading

72 Continuous wave lasers emit light constantly, as opposed to discrete pulses of light.
73 The number of levels corresponds to the number of discrete energy levels the electrons in the gain medium can possess.
74 Ibid., 210. Lasers require an optical "pump" or input energy source to begin the process of lasing. Older lasers typically used a light source to excite atoms in the gain medium, which would quickly relax and emit light of their own. The pump must be able to excite enough atoms to produce light that can pass through a semi-reflective mirror at the output end of the laser cavity. Lasers can be produced to output a continuous light wave or to pulse on and off quickly. Both method have their uses, but Maiman's ruby laser worked by emitting pulses, not a continuous wave.
75 Ibid., 218.

Company distribution center in New Jersey.[76] These scanners exposed dozens of plant and distribution center workers to lasers. Kroger was the first company that directly served the public to install laser barcode readers in the early 1970s. The supermarket industry was so interested in the new bar code technology that an independent study was conducted by McKinsey & Company to determine the cost-benefit of installing the new devices. The study concluded that the supermarket industry would save an estimated $150 million a year from the laser barcode scanner.[77]

Lasers were quickly embraced by medicine as a new surgical and diagnostic tool. The first test of a laser on a patient took place in December 1961. Doctors at Columbia-Presbyterian Hospital in New York used a ruby laser, similar to the one designed by Maiman, to successfully destroy a retinal tumor of a patient.[78] The inventor of this medical laser was Dr. Charles J. Koester of American Optical Company. Several other companies were also involved in the race to develop medical laser technology as the potential of the laser in medicine had already been proven.[79]

The invention of the laser diode in 1962 by Robert N. Hall at General Electric and Marshall Nathan at IBM further expanded the commercial opportunities for lasers.[80] The device was much smaller than the other lasers previously invented. To transmit data, the diode laser, which converts electrical current directly into light, quickly adjusts the brightness of its beam to

76 Tony Seideman, "Barcode History," Barcoding Incorporated, http://www.barcoding.com/information/barcode_history.shtml, accessed February 17, 2011.
77 Ibid.
78 Mark Wolverton, "A Solution for Almost Everything: 50 Years of the Laser," *American Heritage of Invention and Technology* 25 (2010): 40.
79 Harold M. Schmeck Jr., "Light Beam Used in Eye Operation," *The New York Times*, December 22, 1961.
80 Robert N. Hall et al., "Coherent Light Emission From GaAs Junctions," *Physical Review Letters* 9 (1962): 366-369. Teams at MIT Lincoln Laboratory, Texas Instruments, and RCA Laboratories also researched laser diodes, but GE and IBM were the first to build working laser diodes.

represent data. Initial tests revealed that a single laser diode circuit was capable of carrying twenty television channels, or 20,000 telephone conversations, simultaneously.[81] The laser diode became increasingly important in the 1970s and 1980s when the laser was used in CD players, laser pointers, laser shows, and other technologies.

While breakthroughs in laser science exposed many people to lasers and their many uses, depictions of lasers in television via *Star Trek* also exposed many to the new technology. In *Star Trek*, which aired originally from 1966 to 1969, lasers take the role of most of the weapons, both ship-mounted and hand-held. The iconic phasor gun even stands for photon maser.[82] Considering that most early laser research used the term optical maser because the maser was a more widely understood technology that emitted microwaves instead of light, photon maser can be considered synonymous. Just as laser-like weapons and technology were popular staples of science fiction and appeared as early as the late 1800s, so too did television and film commonly depict lasers as weapons. Even though the original *Star Trek* series lasted only three years before it was canceled, it had developed a cult following which only grew as the show was syndicated through the late 1960s and 1970s.[83] Considering the many technological innovations inspired by science fiction, the exposure of lasers in *Star Trek* surely inspired some people to think about the laser as a viable technology for commercial uses.[84]

Another famous visual depiction of the laser was seen in the 1964 James Bond film

81 "A Diode Converts Current to Light," *The New York Times*, July 10, 1962.

82 Articles in the 1960s generally described the laser as a maser that uses light instead of microwaves. Indeed, that is an appropriate description of the laser. The language implies that Americans were at least somewhat familiar with the term maser. The name photon maser can, therefore, be considered an equivalent name to laser. Before laser was coined, scientists, including Townes and Maiman, referred to it as an optical maser.

83 Luaine Lee, "'Star Trek' turns 40," *San Jose Mercury News*, August 18, 2006.

84 While it is unlikely anyone will mention *Star Trek* as an inspiration in scientific publications or press releases, a search for laser and Star Trek in *The New York Times* on ProQuest from 1960 to 1990 reveals dozens of articles. A reading of twenty articles selected at random revealed the trend that journalists described laser light shows as being similar to laser battles in *Star Trek*.

Goldfinger. One of the most iconic scenes from the movie depicts the spy strapped to a metal table while a laser moves slowly from the bottom of the table upward on a path to cut Bond in half. While Bond escapes without damage, as expected, the laser still cut through the lower portion of the metal table. The original novel used a table saw as the laser had not been invented at the time of publication in 1959. The screenwriter of *Goldfinger*, Richard Maibaum, chose to use a laser as he believed audiences would find the saw to be "old-fashioned, hackneyed and ludicrous."[85] The futuristic laser would keep audiences on the edge of their seats. Even though it would take a few years for most Americans to be aware of laser technology and some of its uses after the invention of the laser, the silver screen was one of the most effective media through which to expose the public to the newly invented technology.[86]

Thanks to news coverage and other media, Americans were increasingly exposed to the laser through the 1960s. The laser was originally developed as a research instrument in laboratories and as a weapon in the military. The laser received extensive coverage, often of a sensational nature, in newspapers and magazines in the United States. Perhaps this is what happens when the advent of an apparatus comes from the imagination of artists, as was the case with lasers in science fiction. Or perhaps it is due to the flashy nature of the device itself. The maser was no secret, but was undoubtedly less known by the public overall. But the laser took the basic principles of the maser and shifted the range of electromagnetic radiation from microwaves to optical frequencies. To non-scientists, the device was a new light source, a new method by which humanity manipulated light, a new level of human mastery over the natural world. Most early descriptions of lasers in articles and magazines emphasize that lasers are

85 Richard Maibaum, "James Bond's 39 Bumps," *The New York Times*, December 13, 1964.
86 Wolverton, "Solution," 34.

unique in that their light is "in phase;" that is, peaks of the light waves line up with peaks and that valleys line up with valleys.[87] But this description means little to people unaccustomed to the technical details of electromagnetic waves. Indeed, the most fascinating part of the laser is actually seeing the collimated, narrow beam of light. Simply seeing a laser in action enlightens the viewer to two of the laser's most unique characteristics: the directionality of the beam and the intensity of the beam spot. It does not take an engineer or scientist to think up potential uses of the laser upon noticing these two characteristics. So what does all this mean exactly?

The laser was embraced by the commercial sector in the 1960s for three reasons. One, lasers had been exposed to a significant portion of the American public via film and television. At this point, articles still described the laser as a "futuristic" technology. Sure, people knew it existed in the 1960s, but its uses in fiction were far from the reality of the state of the art of laser technology. When art imagines the future of technology, it becomes cemented in the imagination of at least some of society, no matter how far-fetched it may be. Consider, for example, time travel and warp drives for traveling faster than light. Modern science implies that both of these technologies are impossible to achieve and yet discussions about their viability, from a conceptual standpoint, occur quite commonly, even among scientists. Scientists debate about the implications of Einstein's theory of relativity with regards to time travel. Indeed, Mexican theoretical physicist Miguel Alcubierre claimed to have determined how to achieve faster than light travel from a theoretical standpoint.[88] Consider also the iconic lightsaber of *Star Wars* fame. It is no stretch of the imagination to predict that even non-science fiction fans would

87 In the Introduction, I described how lasers work and described light in terms of particles called photons. But, according to quantum mechanics, all matter also has a wave nature. For anything larger than the atomic scale, we cannot see the wave nature of matter, but light can also be considered a wave. Light waves are usually drawn as sinusoidal waves.

88 Gregory Mone, "The Warp Drive," *Popular Science*, May, 2006, http://www.popsci.com/military-aviation-space/article/2006-05/warp-drive.

notice and be quite excited if a lightsaber were actually invented. The point is that seeing lasers in action through visual media got people talking about the laser and its uses. New inventions using lasers, therefore, might interest the public to a greater extent than technologies not featured in entertainment.[89] One *New York Times* article describes the advances in laser communication:

> "Technology has taken man to the point in communications where the science fiction of ten years ago is the reasonable solution of next year. The perfect case in point is the laser. Any science fiction buff will identify the laser as the death ray and do-it-all device of this brand of literature only a few years ago. Today the world 'laser' has been dropped from the science fiction lexicon because it has done on an experimental basis many of the things only writers of fantasy had thought it could do."[90]

Second, much the "hard work" of laser research had already been completed by the mid-1960s by ARPA and the big industrial labs. Investors and entrepreneurs, therefore, did not always need to hire a team of PhDs to discover new uses for lasers. Adopting currently existing lasers for applications such as laser welders and cutters, for example, does not require as high of a research and development budget as developing a new type of laser.. Surely few, if any, scientists were involved with choreographing laser light shows for concerts and discos, for example. Considering the huge potential for lasers to solve all kinds of problems in industry and the fact that most of the physics had been completed, investors were more willing to fund new laser ventures. Also, unlike many new technologies, lasers were not prohibitively expensive shortly after their invention. The helium-neon laser was so cheap to produce that companies sprang up to produce them for high school physics demonstrations. Indeed, for as little as $100 in 1969, HeNe lasers were available for demonstrations in holography and laser theory.[91] High

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89 Maya Pines, "The Laser Lights Up the Future," *The New York Times*, September 8, 1963. "Military men on both sides of the Iron Curtain undoubtedly are deeply interested in laser light's ability to vaporize the toughest materials. This science-fiction aspect of laser beams has led to much talk about their potential uses as 'death rays.'"

90 William D. Smith, "New Ways of Talking: Electronic Pulses Hold the Key," *The New York Times*, January 30, 1966.

91 "Under-$100," *Popular Science* 194 (1969): 92.

school demonstrations are an effective method of exposure for laser technology to a young generation. They provide a sense of comfort with technology that comes from use in a learning environment. And while I will later argue the importance of CD players as one of the most influential pieces of laser technology in popular use, it is noteworthy that from as early as the late 1960s, many high school physics students were already given hands-on experience with lasers and that their experience would have influenced their acceptance and understanding of future laser technology.

Third – and perhaps most important – the American public stopped associating lasers with death rays. By around 1965, there is a clear decline of the use of "death ray" in news articles describing lasers. A search for "death ray" in *The New York* Times using ProQuest yielded the following number of matches: twenty-seven from January 1, 1960 to January 1, 1965 and twelve from January 2, 1965 to January 1, 1970.[92] This is likely because articles on lasers had begun focusing on their myriad uses outside of the military and that the laser as a weapon in and of itself was never made a reality, remaining instead within the realm of fiction. This does not mean, of course, that everyone was comfortable with lasers. Indeed, even today some people surely do not trust lasers due to their potential for injury. But considering the often sensational nature of news, the news media must have found that this style of reporting on the laser no longer resonated with the public. This suggests that Americans were skeptical of lasers as death rays. News articles mentioned death rays late in the 1960s only in the context of military technology or breakthroughs in laser power. The association of the laser with the death ray was one of the largest obstacles facing commercial investment in laser technology for public use.[93]

92 As mentioned in Chapter Three, death ray has a resurgence in the public lexicon during the 1980s thanks to the Strategic Defense Initiative's research into laser defense systems, but decreases again in the 1990s.

93 Feder, "Market Challenges."

By 1970, the laser changed the world of science and engineering, and Americans knew it. Science fiction depicted laser-like weapons as early as the late 1800s. Famous inventors and scientists worked on developing a death ray decades before Charles Townes discovered maser and laser theory. The laser found practical uses in a variety of industries very shortly after Maiman created the first laser in 1960. After just a few years, small companies found new uses for lasers and discovered a consumer base, the American public, that saw the laser as an iconic creation of the Space Age. The amazing ability to harness light into a coherent, focused beam was a phenomenal breakthrough in physics and one of the first useful forms of technology that came out of the relatively new branch of physics known as quantum mechanics. Science fiction depicted laser-like weapons visually thanks to film.

The technoculture of America changed as a result of the introduction and development of the laser in the 1960s. Lasers were first born in the imaginations of science fiction authors and filmmakers. But scientists were able to create real lasers, even if they were not used as weapons initially. Seeing an aspect of science fiction becoming a reality is not common. Time and time again, popular magazines and news articles mention that the laser is no longer science fiction and that what was science fiction years ago is reality today. An important consequence of this was an increased awareness among the populace of new technology. Science and engineering grew to an unparalleled level of prestige and value during the twentieth century in America mainly due to technological developments for warfare, the development of quantum mechanics, and the technologies born of the Space Race. Lasers fit into each of these three categories and, as such, the laser was an iconic scientific development of the century.

The popularity of the laser – fueled by fiction, news coverage, and introduction in the classroom – made investment into the technology popular as well. The commercial sector invested heavily into laser technology. Not only was the laser a versatile technology which helped solve many problems in industry, but new technologies could also be developed which relied upon the laser. By the end of the decade, Americans no longer saw the laser as a weapon; they had read of its uses in medicine. Most of the hard work in laser development had been completed; new uses required some tweaking, but not teams of scientists. While industry focused on altering current laser technology to solve industrial problems, university laboratories continued to improve laser quality and develop new lasers. As laser technology continued to find commercial uses, Americans saw the laser more often. As Americans became more accustomed to laser technology, lasers started to become more popular in culture. Science fiction took the laser and used it as the staple weapon for infantry and starships. In the 1970s, lasers appeared in discos and concerts and grew to become a new form of art. The 1960s established the laser as a key modern technology which would continue to find uses in research and commerce into today.

Chapter Two:
From "Star Wars" to the Walkman –
The Cultural Popularity of the Laser in the 1970s and 1980s

I clearly recognize that defense systems have limitations and raise certain problems and ambiguities. If paired with offensive systems, they can be viewed as fostering an aggressive policy, and no one wants that. But with these considerations firmly in mind, I call upon the scientific community in our country, those who gave us nuclear weapons, to turn their great talents now to the cause of mankind and world peace, to give us the means of rendering these nuclear weapons impotent and obsolete.[94]

–Ronald Reagan

By 1970, the laser was established in America as a popular technology in culture, industry, and the laboratory. But the laser's cultural popularity exploded in the twenty year period from 1970 to 1990. If the trend of research interest in the laser during the 1960s is defined by a shift from the big industrial labs to smaller companies, the period from 1970 to 1990 is dominated by commercial interest in laser technology. Laser companies discovered several uses for both semiconductor and gas lasers during these two decades. But unlike the 1960s, some inventions of these twenty years, like the Compact Disc player, entered the homes of many Americans. This meant that Americans began using laser systems themselves for the first time.

Unlike the previous decade, this twenty-year period saw the introduction of real lasers for use in entertainment, as opposed to lasers depicted by special effects in television and film. Two popular forms of lasers in entertainment were laser light shows and holography exhibits. Light shows used moving lasers of various colors, often choreographed to music, to create a unique visual experience. Holograms are three dimensional images recorded on a light-sensitive film,

94 Ronald Wilson Reagan, "Address to the Nation on National Security (March 23, 1983)," Miller Center of Public Affairs, accessed March 6, 2011, http://millercenter.org/scripps/archive/speeches/detail/5454.

often a transparent piece of glass coated in a photosensitive film, that can be rotated and observed by a viewer as if he or she is looking at the actual object itself. While the phenomenon of holography had been around since 1948, University of Michigan researchers Emmett Leigh and Juris Upatnieks created the first transmission hologram with a laser in 1962.[95] Laser light shows accompanied high-profile musicians like Pink Floyd and The Who, which exposed many people to lasers in person for the first time.[96]

The laser videodisc and compact disc players are among the most iconic laser technologies that emerged during this period. Unlike laser light shows and hologram exhibits, optical disc players grew to become the most common laser technology in America.[97] For this reason, Americans became most accustomed to interacting with laser technology through this

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95 For a brief history of holography, see Emmett N. Leith, "Chapter 39: Optical Holographic Imaging," in *The Handbook of Surface Imaging and Visualization*, ed. Arthur T. Hubbard (Boca Raton, Florida: CRC Press: 1995), 537 and Mirco Imlau et al., "Holography and Optical Storage," in *Springer Handbook of Lasers and Optics*, ed. Frank Träger (New York: Springer Science+Business Media, 2007), 1207. The first hologram required a laser to view the recorded image, but Yuri N. Denisyuk created the first transmission hologram viewable with white light also in 1962. Transmission holograms are made by using appropriate optical lenses to widen a laser beam and then shining that beam onto an object. The light that reflects off the object shines on a recording medium, typically a piece of glass with a developing agent on the side facing the object. Since all light from a laser is in phase, distance can be represented by recording the change in phase at a particular location. Since the object recorded in holography is three dimensions, the reflected light waves travel different distances to the recording medium. The developing agent records this phase information. To view the hologram, a laser is shined through the glass plate. The developed film changes the phase of the laser accordingly as it passes through the glass. When it reaches the viewer's eyes, the image has the appearance of depth. White light holograms like the one developed by Denisyuk, reflect white light back to the viewer, but the light is split up into a rainbow. This type of hologram is often used on credit cards or the currency of some nations as a form of security, as they cannot be reproduced with standard printers.

96 David Kushner, "How Laser Shows Get Their Dazzle," *The New York Times*, September 24, 1998. Ivan Dryer, "the unofficial father of laser light shows . . .started a company called Laser Images in 1971 and began presenting his own shows, set to recorded music – he dubbed them to Laserium shows – in the planetarium at Griffith Observatory in Los Angeles. While Pink Floyd's Dark Side of the Moon played, for example, fans watched a display of laser lights choreographed to fit the moods and themes of the music."

97 A report on a hologram exhibit at the Port Washington Library is given in David L. Shirey, "Holograms that Fascinate Eye and Mind," *The New York Times*, September 9, 1979. The article describes the debate about the nature of holograms. "Are they more a product of science than of art, or a happy combination of both? Are conventional scientific and artistic definitions even necessary in experiencing and classifying these works, which produce three-dimensional imagery through the use of lasers beams?" The Massachusetts Institute of Technology opened their Museum of Holography in 1977. This museum closed in 1992, but hologram exhibits are a permanent part of the MIT Museum. For more information, see "History of the Museum of Holography," MIT Museum, accessed March 30, 2011, http://web.mit.edu/museum/pdf/Museum_of_Holography_History.pdf.

medium during this period, even if they were not aware of the laser's presence. Lasers increasingly became components of larger systems. For this reason, consumers became comfortable with lasers as a concept through larger systems much like how consumers became comfortable with the concept of a transistor through the use of computers.

Visual media continued to depict lasers during this period. *Star Trek* and *Star Wars* were two of the more popular science fiction productions to regularly depict laser weaponry. In 1966, NBC first aired *Star Trek*, but its popularity did not take off until after the cancellation of the original series and its syndication during the early 1970s. While the original series developed a cult following in the 1970s, a new series did not appear until the late 1980s.[98] Much more popular, however, was *Star Wars*, which saw the release of three films from 1977 to 1983. Unlike *Star Trek,* this series enjoyed immediate popularity. In fact, the series was so popular that the United States Strategic Defense Initiative (SDI) was known colloquially as Star Wars.[99] This ambitious initiative was meant to use a variety of cutting edge technologies to shield America from Soviet nuclear missiles. Among the many technologies were an X-ray laser and a chemical laser. While these lasers were not the primary focus of the project, their futuristic nature garnished them with much attention, especially when laser experts claimed that they were unfeasible. This chapter investigates the language used in newspaper and magazine articles reporting on the SDI project and how it shaped the public's perception of lasers as weapons. Articles describing lasers in medicine and entertainment provided the public with an image of the laser as clean and precise.

The purpose of this chapter is to explain why the laser became a symbol of cutting-edge

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98 See n. 83 in Chapter One evidence of *Star Trek*'s cult following.
99 See n. 94 below for the origins of the public use of Star Wars as a name for the Strategic Defense Initiative.

technology. These twenty years were a transitional stage in the history of the laser. Laser technology continued to grow and became more visible in the public sphere. Americans, therefore, had to solidify their understanding of the laser as a technology by mixing their image of the laser as a weapon of science fiction and the SDI project with the useful nature of lasers in medicine and entertainment. The examples mentioned above, in addition to other technological breakthroughs that were made possible by the laser, solidified the laser as one of the core technologies of American society. Computers, music and video, medicine, and telecommunication all relied upon the laser to some degree. In other words, technological developments introduced during this period of twenty years have cemented themselves so strongly in America that most of us could not imagine living in a world without such technologies. Developments during this period were the precursors to such commonplace technologies as high-speed Internet, Blu-Ray technology, 3-D motion pictures, and the computer itself.

The Miracle Technology

The laser quickly transmogrified from "a solution looking for a problem" to a versatile technology with uses in a wide variety of applications. The early use of lasers in medicine proved that lasers were not destined to remain in the laboratories of university physicists. Non-research oriented industries also quickly utilized lasers for uses such as communication, construction, and metal cutting. Researchers developed cutting-edge lasers almost in parallel to their utilization in industry. As uses for lasers in industry increased, the likelihood that Americans read about or used lasers increased. In the case of the laser, it found many uses in industry both as a tool in itself as well as a component of a larger system. The many new uses of lasers helped change the public understanding of the laser from a powerful and dangerous technology to a clean, surgically precise tool, especially since many uses of lasers improved efficiency and improved medical care.[100] One of the more important uses of the precise nature of lasers is the use of lasers to pattern the billions of transistors present in current computer processors. Modern computers rely on cutting edge processors, which rely on lasers to be produced.

In early 1970, the laser was still too expensive for most people to purchase a stand alone laser. There was also little reason for Americans to own a laser if it was not used for research or development. For this reason, science fiction and news reports of lasers in industry and science were the main avenues by which Americans were exposed to lasers in the 1970s. One of the prominent laser researchers, Arthur L. Schawlow, built a hand-held laser device into a toy ray gun for use in demonstrations. The device cost $1000 to make in the late 1960s.[101] But, like many technologies, the cost of lasers decreased quite rapidly over time. In fact, diode lasers, such as the ones used in CD players, now cost about $5 for a single laser, and mere cents if thousands are purchased at once. But despite the high cost of lasers in the 1970s, some artists began experimenting with them. Artist John Anther worked with scientist Tracy Kinsel to develop a device that "produces a glowing, moving red pattern that looks like the school-book diagram of an atom being orbited by its electrons" synchronized to music.[102]

That lasers were the solution to several medical disorders furthered the notion of the laser

100Rebecca Slayton offers a persuasive argument about this shift in perception of the laser by Americans in Rebecca Slayton, "From Death Rays to Light Sabers: Making Laser Weapons Surgically Precise," *Technology and Culture* 52 (2011): 45-74.
101Jeannette Smyth, "The Laser: Shedding Light on Science," *The Washington Post*, January 21, 1970.
102Ibid.

as a miracle technology. One use for lasers in medicine is the removal of port-wine stains. These are purplish birthmarks on the face or neck that affect roughly one in seventy-five Americans. The color comes from an unusually high concentration of blood vessels just below the surface of the skin in affected areas. While not medically dangerous, these birthmarks can cause psychological damage due to the unattractive nature of the marks. By taking advantage of the monochromatic nature of lasers and a phenomenon known as resonance, a blue-green laser is shone onto the mark. Since the resonant frequency of blood cells matches the frequency of the laser used, nearly all the energy of the concentrated beam is absorbed by the cells, causing them to vaporize. The heat absorbed also damages the blood vessels, which results in cauterization. The technique, which requires a local anesthetic to prevent the patient from feeling pain due to the 10 to 30 degree increased temperature of the skin, leaves a scab that takes a few weeks to heal. After healing, the skin gradually returns to a color very near the normal color of the person's skin, requiring little more than make up to make the skin look completely normal.[103] While port-wine stain treatment was popular, it was far from the most useful medical application of lasers of the time.

The 1970s saw many breakthroughs in laser treatment for blindness. One common cause of blindness is diabetic retinopathy. This is a complication which causes bleeding within the eye as a result of diabetes and can lead to blindness. In 1976, doctors estimated that 300,000 Americans faced a high risk of losing their sight to diabetic retinopathy.[104] Using the same principle as the treatment for port-wine stains, doctors used a green argon laser or white xenon arc light to burn away blood vessels in the eye. Early test results were positive. The original

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103Matt Clark, Dan Shapiro, and Richard Manning, "Port-Wine Stains," *Newsweek*, January 23, 1978.
104"A Laser for Blindness," *Newsweek*, April 19, 1976.

study used the technique on one eye and left the other eye alone as the control. After two years, 16% of the untreated eyes went blind compared to 6% of the treated eyes.[105] Considering the high risk of diabetes in America, this medical treatment was big news.

Another common cause of blindness treatable by lasers is age-related macular degeneration (AMD). This disease, which used to be called senile macular degeneration in the 1980s, was and still is the leading cause of blindness among the elderly. The disease causes deterioration of the macula, the region of the retina responsible for sharp vision. In 1982, the statistic was that 16,000 Americans lost their site as a result of AMD. Due to the pressing importance of this disease, twelve medical centers in the United States researched laser treatment in the late 1970s and early 1980s. The treatment, called photocoagulation, uses an argon laser to destroy blood vessels near the macula in order to prevent blood or fluid from these vessels from leaking into the macula, which actually causes the blindness. The treatment cost $950 per eye treatment took only ten minutes to complete in the 1980s. Even though the treatment was only successful if used early, a study showed that 83 percent of patients who were treated within two weeks of the onset of the disease retained their vision. The results were so successful that Johns Hopkins canceled the study two years prior to completion so they could offer the treatment to anyone with the disease.[106]

In addition to treating AMD and diabetic retinopathy, doctors also used lasers to treat some forms of glaucoma and detached retinas during the 1970s.[107] Lasers are particularly successful in eye surgery because they are non-invasive and highly accurate, thanks to the small spot size of the beam. Also, due to the relative ease of the procedure and speed, the cost was not

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105Ibid.
106Jean Seligmann and Mary Hager, “Saving Sight With a Laser,” *Newsweek*, May 17, 1982.
107Ibid.

very high; most of the cost was meant to offset the price of the equipment. The likely reason that medical applications for lasers were discovered so quickly after the invention of the laser was because the physics behind most of these treatments are similar. Most of these surgeries rely upon the basic principles of resonance. Materials absorb more energy from certain frequencies of light, called the resonant frequencies, than other frequencies. For example, by determining the resonant frequency of blood vessels, that frequency of electromagnetic radiation – which happens to be in the optical range in this case – can be used to vaporize blood vessels while leaving surrounding tissues unharmed. But despite the success of lasers in treating certain visual impairments, lasers could not treat every form of blindness.

For this reason, some companies experimented with the laser to develop other devices to assist the visually impaired. The United States Department of Veterans Affairs developed a walking cane that used three lasers to help detect obstacles. One beam shoots at head level, one straight ahead from the cane, and one at ground level. If the top two beams are broken, the cane emits a buzzing sound to alert the user to a potential obstacle like a tree branch that would be missed by a traditional cane. If the bottom beam is broken, it buzzes to alert the user to a potential hole in the ground. While the device cost $2700 in 1981, it was still an earnest attempt by the government to take advantage of the range-finding ability of lasers to help people.[108]

The many medical advances credited to the laser helped create an image that the laser was not only a useful technology, but a lifesaving one as well. Slayton writes, “Importantly, the laser was seen as a progressive technology because it had become a symbol of clean precision and speed. The laser's popular image reinforced long-standing narrative links between medicine

108Matt Clark and Mariana Gosnell, “Light for the Sightless,” *Newsweek*, December 7, 1981.

and warfare."[109] Twenty years after the invention of the laser, the technology had already been adopted to remove life-threatening tumors and large birthmarks and to treat eye complications that would otherwise result in blindness. Tattoos were no longer permanent as lasers could almost completely erase most of them. Medical uses of lasers would continue to flourish, and new developments are even made as of 2011. When articles described lasers in medicine, they emphasized the precision and clean nature of lasers.[110] The many medical breakthroughs in the 1970s using lasers were responsible for planting this association in the minds of Americans.[111]

Lasers in Entertainment

One of the most influential uses of lasers has been in entertainment. In particular, lasers have been used in art, most commonly in laser shows, and have been responsible for the development of new entertainment technology, such as the Compact Disc player. Other than appearances in film, lasers in entertainment in the 1960s tended to be the subject of artists experimenting with laser shows and holograms. But the laser in the next two decades changed the way Americans experienced audio and visual entertainment.

The mid 1970s were experiencing "a home-entertainment revolution" thanks to several new innovations in electronics.[112] Among these new technologies was the advent of pay-cable,

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109Slayton, "Death Rays," 70.

110For early examples of lasers in surgery and descriptions of their precision, see "'Light Ray' – Fantastic Weapon of the Future?" *U.S. News & World Report*, February 17, 1962 and "The 'Miracle Ray' Is Coming of Age," *U.S. News & World Report*, February 25, 1963. Examples in the 1970s and 1980s can be seen in the other articles cited in this chapter which describe laser medical techniques.

111Slayton, "Death Rays," "Though laser weapons remained experimental, 'precision' applications of the laser grew common in the 1970s, and the laser eventually became a metaphor connoting both precision and speed."

112Harry F. Waters and Ann Ray Martin, "Video's New Frontier," *Newsweek*, December 8, 1975.

which began with HBO in 1975.[113] New projection technology greatly increased the size of televisions to greater than eighty inches. Another new technology was the videodisk. Videodisk referred to the proprietary Laserdisc (LD) style of optical disc media invented by the Music Corporation of America (MCA). MCA invented the technology in 1958 using a transparent disc, but they invented a more effective reflective disc in 1969.[114] Philips worked with MCA in developing LD technology. The discs were read by a semiconductor laser operating at a wavelength of 780 nanometers, which corresponds to near infrared (just outside the visual range). RCA was also working on their own optical disc media during the 1970s. This differed, however, by using a stylus instead of laser. The RCA device operated similar to a record player, but with higher resolution. While the first actual demonstration of a film played from a Laserdisc was on December 18, 1978, experts predicted the new technology to be a major component of the home-entertainment revolution in 1975. As we now know, the stylus system developed by RCA lost the competition to the LD system. Lasers can be focused to a much smaller spot and read smaller areas than physical styli, resulting in higher memory capacity for optical discs. Lasers also allowed the additional functionality of pausing the video or playing in slow motion, which was not possible with the stylus system. The benefits of the laser helped it win over the stylus. The technological superiority of the laser system came at a lower cost in the long run as well. After making up costs for research and development, a laser diode would be cheaper than the larger stylus simply based on material cost. In the end, LD technology took a total of $200 million to perfect, but the investment was definitely worthwhile considering it was also the precursor to the much more popular Compact Disc format.[115]

113Pay-cable offered premium television channels to consumers for an additional monthly cost.
114David Paul Gregg and Keith O. Johnson, "Video Signal Transducer Having Servo Controlled Flexible Fiber Optic Track Centering" (US Patent 3,530,258 filed June 28, 1968).
115Waters, "Video's New Frontier."

The Compact Disc (CD) player was one of the most popular laser devices to the public during these twenty years. Sony and Philips jointly designed the Compact Disc format in the late 1970s for the purpose of playing audio stored on an optical disc similar to the LD format used for video. The first major test of the CD technology took place on March 8, 1979. The technology was capable of playing higher quality music than ever before thanks to its high sampling rate of 44,056 hertz (number of data read cycles per second). Sony did not release the CD player in America until 1983, but some reporters predicted the CD player would "eventually make current record players obsolete" a year prior.[116] Early competition among CD player manufacturers was fierce as they constantly developed new features for their players, such as track looping and error-correction. After all, each player could play the discs with the same quality, but only the best models included error-correction circuitry. This technology played dirty and lightly scratched discs as if they were flawless thanks to the ability to store a few seconds of the audio in advance to a circuit which would made adjustments such as extending sounds over moments of silence due to a damaged part of the disc. The first generation of CD players were quite expensive at $600-800, but this cost decreased in a couple years thanks to the success of the technology and emphatic support by record label companies.[117]

Semiconductor lasers worked well for optical disc readers as they were much smaller and consumed less power than gas or solid-state lasers. They were also the cheapest type of laser. Data on CDs is stored in indentations on the disc called pits and the non-indented surrounding areas are called lands. The technique of using a laser to read the pits and lands of a disc relies upon the characteristic of lasers as producing light in phase. When the beam reflects off a pit,

116"Gadgets of the Future," *Newsweek*, August 9, 1982.
117Hans Fantel, "How to Choose a CD Player," *New York Times*, April 1, 1984.

the distance between the laser and the disc surface is slightly greater than when the beam reflects off a land. This distance causes a change in the phase of the beam, which results in interference in beam which is detected by a photodiode, a light detector, located near the laser.[118]

Thanks to large investments in CD technology by music labels, the CD player quickly took off in the American market. As early as 1984, music labels began releasing CD versions of their new recordings alongside record and cassette formats. The biggest supporter of the new CD format was Telarc, a classical recording company, which started releasing their recordings on CD before any other format in 1984. RCA was another big supporter, but they tended to release CD recordings shortly after the LP versions. In response to the growing popularity of CDs, RCA began a mail-order service just for CDs which included not only their recordings, but also those of most other major labels.[119]

Considering that RCA was the developer of the unsuccessful stylus method of reading optical media in the 1970s, their heavy investment in CDs and their CD mail-order service show that they were convinced CDs were the future of music. This is an example of the public's reaction to a technology affecting the direction of industry. Audiophiles were impressed with the quality of sound recorded on CDs from the earliest demonstrations of the technology.[120] The cost to invest so heavily in CD technology was high, but RCA clearly predicted that the CD would be the dominant audio medium in the future. In hindsight, of course, they were correct in their prediction.

The CD was the successor to the cassette as the primary audio medium in America and

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118Phase is defined as the fraction of a wave cycle which has passed at a certain point. If the point used for measurement is a photodiode located very close to the laser, changes in phase correspond to changes in distance that the laser travels when reflecting off the disc.

119Gerald Gold, "Words Cast Their Spell," *New York Times*, November 18, 1984.

120Fantel, "CD Player."

remained dominant until the rise of MP3 players in the last decade. Even still, CDs remain popular as of 2011, and even though some recordings are released only electronically, CD recordings are generally the only physical release of recordings today. Sony invented the first CD player and portable CD player in 1982 and 1984, respectively. Since then, nearly every consumer electronics company has produced CD players. The CD was the first audio medium available to consumers that was capable of playing sound across the entire range of human hearing. The sampling rate for CDs were initially 44,100 samples per second, compared to the 20,000 samples per second of the audio cassette. The sample rate is what determines the highest frequency of sound capable of being played; the highest frequency is one half of the sampling rate. Therefore, CDs were capable of playing sound in excess of 20,000 hertz, which is roughly 2,000 hertz above the typical threshold of human hearing. By allowing the full range of audio to be recorded and played back correctly, the CD provided the best quality of recorded audio available until the advent of the MP3 and other digital recordings. This breakthrough in audio technology by Sony and Philips has been honored by the premier professional association for the advancement of electrical technology, the Institute of Electrical and Electronics Engineers (IEEE), as a milestone of technological achievement:

> On 8 March 1979, N.V. Philips' Gloeilampenfabrieken demonstrated for the international press a Compact Disc Audio Player. The demonstration showed that it is possible by using digital optical recording and playback to reproduce audio signals with superb stereo quality. This research at Philips established the technical standard for digital optical recording systems.[121]

The undeniable success of the CD was not limited just to the audio realm. Computers have used CDs for data just as much, if not more, than audio. Even though the CD was originally developed for audio, Sony and Philips once again set a standard when they invented

121“Milestones: Compact Disc Audio Player, 1979,” IEEE Global History Network, accessed March 5, 2011, http://www.ieeeghn.org/wiki/index.php/Milestones:Compact_Disc_Audio_Player,_1979.

the CD read only memory (CD-ROM) format in 1985. With a data capacity range of 650 to 900 megabytes, the first CD-ROMs had a larger memory capacity than computer hard drives in the late 1980s and early 1990s. The necessity for CD-ROMs increased as software sizes increased. As such, most computers came with a CD-ROM drive standard by the mid 1990s. Floppy disk drives continued to come standard as well, but began to be phased away in the 2000s as floppy disk memory capacity became impractical. As of 2011, CD-ROMs are still the primary method of software delivery.[122]

Philips and Sony changed the worlds of computing and music when they discovered this new use for lasers. A similar technique to the one employed by CD players was used by the military for range-finding and guidance systems. But since military technology was not well-known to the public at the time, the CD laser was one of the first popular uses of the laser that that took advantage of the phase nature of lasers.[123] Prior to this, most uses of lasers in industry and medicine took advantage of the laser's condensed energy for cutting and burning or the ability for lasers to send light through optical fiber. Therefore, the CD player and CD-ROM drive were one of the most popular early uses of the laser that was completely safe for popular use, and it was used for entertainment no less. By the end of this two decade period, magnetic media such as audio cassettes and floppy disks were still popular, but optical disc developments continued to increase the popularity of CDs, which led to the eventual downfall of magnetic media.[124]

Turning to another sector of the entertainment industry, science fiction continued to

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122While DVD-ROM drives are very common in PCs today, the CD-ROM drive is the only universally standard drive. Operating systems are stored on CD-ROMs, which add to the necessity of the CD-ROM drive.

123For a brief description of phase, se n. 95 above.

124The downfall of VHS is discussed in Chapter Three. While not explicitly stated there, the CD replaced the tape cassette as the standard medium for audio storage for the same reasons that DVD replaced VHS.

depict lasers. In television, one of the most popular science fiction shows that used lasers as weapons was *Battlestar Galactica*. This show was the the most expensive television series ever produced at the time. The first seven hours of recording alone cost $7 million, "more than twice the average prime-time production tab."[125] This show was riding on the success of *Star Wars* and *Star Trek*, which increased the popularity of science fiction in America. *Star Wars*, in particular, enjoyed great success and popularity. According to the box office tracking web site Box Office Mojo, the first three films, all released during this two year period, are ranked 4th, 44th, and 32nd, respectively, for the most successful box office performances in America.[126] Both *Star Trek* and *Star Wars* are cultural icons in America and around the world as two of the most famous science fiction series. Lasers appear in both series as a primary weapon for both starship and hand-held uses.

The Strategic Defense Initiative

As mentioned before, most new laser technology invented by the United States military was classified and unknown to the public. However, one project was particularly famous: the Strategic Defense Initiative (SDI). The goal of this initiative was to improve military defense technology to "maintain [America's] strength in order to deter and defend against aggression – to preserve freedom and peace."[127] This goal was to be accomplished through a combination of ground- and space-based defense systems meant to guard against nuclear missiles. Among these many systems were a few directed-energy weapons. Chief among these were a nuclear

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125Harry F. Waters, Martin Kasindorf, and Betsy Carter, "TV Blasts Off!," *Newsweek*, September 11, 1978.
126"All Time Domestic Box Office Results," Box Office Mojo, accessed April 1, 2011, http://boxofficemojo.com/alltime/domestic.htm.
127Reagan, "National Security."

explosion-powered X-ray laser and a deuterium fluoride chemical laser. These lasers, however, were far from ready to be used for shooting down enemy missiles in the 1980s. Indeed, even in 2011, America does not have a laser system capable of protecting America against nuclear missiles. The impracticality of the SDI project was questioned by the public and Democratic Senator Ted Kennedy. In response to President Reagan's 1983 speech calling for support by the public for the SDI program, Kennedy "characterized the speech as 'misleading Red-scare tactics and reckless Star Wars schemes.'"[128] This was the first time the SDI program was associated with *Star Wars*, but the name would stick and become the colloquial name for the project thereafter. The program received scrutiny for its high cost and unrealistic goals. In fact, the "'Star Wars' venture [was] one of the biggest research programs in the history of Western civilization, an effort rivaling the Manhattan Project, which gave birth to the first nuclear weapon, and the Apollo moon program."[129]

The X-ray laser was the most publicized of the directed-energy weapons in the "Star Wars" project. In electromagnetic radiation, the amount of energy in each photon – the basic particle of radiation – is directly proportional to the frequency of the radiation. X-rays have much higher frequency than visible light and infrared used in other types of lasers. The idea was that a large array of high energy X-ray lasers orbiting the planet would be able to destroy several nuclear missiles at once, whereas lasers in the optical range might not. A big problem, however, was how to pump, or power, the X-ray lasers. The pumping method chosen was to detonate a nuclear bomb within the satellite. But this turned out to be a difficult method to measure as measurement devices were not able to withstand the detonation. As a result, the X-ray laser was

128Lou Cannon, "President Seeks Futuristic Defense Against Missiles," *The Washington Post*, March 24, 1983.
129William J. Broad, "The Secret Behind Star Wars," *New York Times*, August 11, 1985.

never implemented in the SDI project. The X-ray laser research was not all in vain. Discoveries made during its research resulted in the creation of a laboratory X-ray laser for use in biological imaging, the development of new computation tools for modeling plasma physics, and the creation of the electron-beam ion trap research facility which has made several improvements in cancer detection.[130]

The chemical laser was the second main laser weapon developed for the SDI. The deuterium fluoride laser, named the Mid Infrared Advanced Chemical Laser (MIRACL), was tested in 1985. The laser was capable of producing a beam with power greater than one million watts for 70 seconds, which makes it the most powerful continuous wave laser in America.[131] While never deployed for use in SDI, the Air Force fired MIRACL at an aging Air Force satellite and verified that the satellite was "illuminated," but not damaged by the beam.[132]

As early as 1983, experts began to question the feasibility of the SDI program. It was a major expense for the military and risked starting a new arms race. The American Physical Society unanimously agreed that laser technology could not advance fast enough to build a reliable missile defense system in the timeline established by the SDI Organization.[133] The missile shield was never deployed as intended, but the SDI program was not canceled. It was renamed the Ballistic Missile Defense Organization in 1993 and again renamed as the Missile Defense Agency in 2002.

Despite the many failures of "Star Wars," the program was widely publicized in America. The media was fascinated with the new futuristic defense program which promised to use

130Joseph Nilsen, "Legacy of the X-Ray Laser Program," *Energy and Technology Review* (November 1994): 13-14.
131"Mid Infrared Advanced Chemical Laser (MIRACL)," Federation of American Scientists, accessed March 6, 2011, http://www.fas.org/spp/military/program/asat/miracl.htm.
132"In Test, Military Hits Satellite Using a Laser," *The New York Times*, October 21, 1997.
133Raoul Rosenberg, "The many phases of SDI," *Bulletin of the Atomic Scientists* 44 (1988): 4.

weapons of science fiction to guarantee peace between the East and the West.[134] Newspapers interviewed individual scientists involved in the project and depicted them as humorous and happy people, not unlike the rest of Americans. The personal lives of the scientists in the O Group in charge of the project were exposed in the press. One article describes Peter Hagelstein, the scientist who came up with the idea behind the X-Ray laser, as “a scientist for whom music and literature, as well as the ironies and ambiguities of life, are not mere distractions from the all-consuming goal of uncovering the powerful abstractions of science. He ran marathons in college and was on the swim team. He played the piano. He played the violin in a string quartet during his freshman year at the Massachusetts Institute of Technology, joining its symphony orchestra.”[135] Only a few scientists were truly popular in America that century, but they were few and far between. The intricate detail in describing the daily life of several scientists on the SDI project was something new in American media.[136] That journalists described these scientists in such detail was testament to the growing interest in the Star Wars project. Not only were people interested in lasers, but now they wanted to learn about the brilliant minds making use of them for practical applications (even if the applications were a bit unfeasible at the time). For this reason, the SDI program was the most influential use of laser technology in the United States military during these two decades.

Without a doubt, the most influential laser technologies from 1970 to 1990 were the CD player, the CD-ROM drive, and the Strategic Defense Initiative, but new uses for lasers continued to be discovered during this period. In popular culture, it is common to see a laser-

134Articles that covered the Star Wars project quickly adopted language that implied that the public was familiar with the goals of the project to guarantee peace between America and the Soviet Union.
135Broad, “Star Wars.”
136Ibid.

sight used on guns, particularly sniper rifles. Entrepreneur Charles Goff developed the first laser-sight in 1977 for .22 automatic rifles for the police and foreign governments. He discovered that the use of a laser sight greatly increased the accuracy of the user. Interestingly enough, police in Florida claimed that criminals quickly learned of the dangers of a police officer with a laser-sight and surrendered more often when facing the "Buck Rogers" gun.[137] A scientist even discovered that lasers can clean stone artwork and buildings from stone blight. In 1972, John Asmus, a physicist from the University of California San Diego, shone a laser on an encrusted gargoyle. The decay on the stone absorbed the light and vaporized, while the white stone underneath reflected the beam with no damage to itself. Even though this occurred in Venice, Asmus developed a larger version of his laser art cleaner which was used on dozens of the world's most prized buildings and pieces of art.[138] The laser cleaner was significantly cheaper and faster than hiring a team of professional art restorers.[139] Thanks to lasers, many of the most susceptible artworks in the world need not fear decay.

Lasers began entering the daily lives of many Americans outside of entertainment during these twenty years. The laser printers we see so often in offices are also products of the 1970s. IBM invented the ultra-fast printers, which were implemented by newspapers and print companies almost immediately. While expensive, the ability to print as many as 20,000 lines of text a minute set the laser printer ahead of all competitors in terms of speed and quality of print. Bell Laboratories managed to successfully transmit voice, data, and video signals via lasers in optical fibers under the streets of Chicago in 1978. By 1980, they planned on implementing a fully-functional system in a major city. In response to daily interactions with lasers by many

137"The Buck Rogers Gun," *Newsweek*, July 25, 1977.
138Charles Panati and Dewey Gram, "Have Laser, Will Travel," *Newsweek*, March 28, 1977.
139Michael Ruby et al., "Lasers Go to Work," *Newsweek*, September 11, 1978.

Americans, the government enacted safety standards for lasers in 1976. These standards primarily involved classifications of lasers and proper signage to denote any dangers they present. To assist with this effort, some optics corporations began producing education safety videos and seminars to further reduce any risk of dangerous lasers.[140]

If the 1960s established the laser as a technology with much potential in a variety of industries, the 1970s and 1980s established the laser as one of the most important modern technologies responsible for many technological advances and breakthroughs. By the end of the 1970s, over 100 laser-making companies were in business with total sales for commercial applications at $200 million a year.[141] When research, military, and medical uses are included, lasers were a $1 billion annual business, and economists predicted the business to grow to $20 billion by 2000. [142] The benefits of lasers started to outweigh their high cost. Some semiconductor lasers, like those used to read CDs, were relatively cheap even when they first entered industrial use in supermarket scanners, but General Motors saw fit to spend $2 million on seventeen lasers in just three of its plants. These lasers were used to treat cast-iron by heating it up extremely fast, which resulted in a stronger metal.[143]

Predictions of the state of the art of electronics and other modern technology that were to change the lives of Americans by 1990 included several emerging fields of engineering, and almost all of them depended on the laser. One prediction was that computer terminals would be "commonplace home appliances" for affluent societies.[144] The growth of computer popularity depended upon two important technologies: the CD-ROM and the integrated circuit (IC). The

140Ibid.
141Ibid.
142Tom Nicholson and Evert Clark, "Patents: The Laser Man," *Newsweek*, January 16, 1978.
143Ruby, "Work."
144Peter Gwynne et al., "Wonders of '89," *Newsweek*, November 19, 1979.

CD-ROM became the necessary medium for commercial data distribution before the Internet was fast enough to handle digital distribution. As laser technology improved, so too did CD-ROM drive speeds. Integrated circuits, the technical term for electronic chips, are the guts of a computer. In order to improve computer speed, more transistors are needed in some of the ICs, especially the processor. Lasers are a key component of patterning transistors in ICs, especially once the transistor count grew beyond one million per processor. In hindsight, this prediction was correct. Computers may not have been commonplace in households by 1989, but they definitely were in the 2000s.

Another prediction was that the biggest stress on technological progress in the United States was going to be on "better ways to transmit and exploit information and on the use of ingenuity to replace dwindling resources."[145] The growing investment in fiber optics by AT&T worked towards achieving this goal. While optical fiber has always cost more than copper wire of the same length, the fact that fiber can transmit thousands of times more information over longer distances without having to pass through a signal repeater makes fiber a better deal overall. This is why telecommunication companies have worked to replace traditional phone and data lines with optical fiber in America and under the oceans.

The same article states that engineers predicted that many of the major breakthroughs during the 1980s and onward would come from five new fields: microprocessors, fiber optics, superconductivity, space technology, and recombinant DNA.[146] Of these five, the first four regularly make use of lasers. The use of lasers in microprocessors is the same as in integrated circuits. Fiber optics makes use of lasers of lasers to transmit signals. Superconductivity in

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145Ibid.
146Ibid.

actual applications tends to use liquid nitrogen or other traditional methods of cooling, but research increasingly uses lasers to reach temperatures near absolute zero. Space technology makes use of lasers in communication and manufacturing. Therefore, many of the emerging technologies of the 1980s and 1990s that promised to change the lives of Americans could not exist without the laser.

From 1970 to 1990, the laser cemented itself as a technology of precision to Americans. It made common appearances on film and television through science fiction. It was responsible for several medical breakthroughs. It improved the efficiency of a variety of industries through its variety of uses. It entertained people in laser light shows and holographic exhibitions. It revolutionized television, music, and computing through optical disc technology. Entrepreneurs kept discovering new uses of lasers from gun-sights to tools for art restoration. The commercial sector invested hundreds of millions of dollars. The United States government believed the laser would guarantee peace between America and the Soviet Union. The laser had come a long way from "a solution looking for a problem." The 1990s would see the necessity of the laser as a component in dozens of technologies Americans could not see themselves without.

Chapter Three:
A Solution for Almost Everything –
The Permanence of the Laser in America

> *I didn't know there was going to be a supermarket scanner. I didn't know there would be a home compact disc. But it was clear that if you could make such a clear and coherent light, it would be a technological breakthrough.*[147]
>
> – Theodore Maiman

The laser's potential as an invaluable tool with myriad uses was discovered in the 1970s and 1980s. During those twenty years, entrepreneurial engineers, scientists, and inventors expanded the reaches of the laser industry from the laboratories of universities and big corporations to other industries like medicine and entertainment. In fact, most laser companies began as independent start-ups.[148] The American public was bombarded with the laser. They saw it in science fiction shows and movies such as *Star Trek*, *Star Wars*, and *Battlestar Galactica*. They heard about, and sometimes experienced firsthand, the revolutionary new medical techniques made possible by the laser. They listened to recorded music with never-before-heard quality thanks to laser disc players. They watched their government tout the benefits of the Star Wars program, which promised to use lasers and ballistics to guarantee safety to all Americans from Soviet nuclear attacks.

The laser industry, which economists predicted to reach $20 billion by 2000, was certainly on an upward trend by 1990, when sales of laser equipment reached $750 million in the West and "systems containing lasers was much higher, probably several billion dollars."[149] The

147Don Colburn, "Laser Evolution: From 'Death Ray' to a Life-Saving Tool," *The Washington Post*, July 16, 1986.

148Jeff Hecht, *The Laser Guidebook* (New York: McGraw-Hill, 1992) 6-7. The two largest laser companies in the 1990s, Spectra-Physics Inc. and Coherent Inc. started this way as well. Some large companies, like IBM, added laser divisions.

149Ibid. Laser equipment is defined as lasers, laser power supplies, and optical equipment necessary for the desired growing revenue of the industry reflected the continuous discovery of new uses for lasers and breakthroughs in laser technology which outweighed challenges that faced the industry. The lingering perception of the laser as a dangerous device hurt non-medical laser sales for industry giants Spectra-Physics and Coherent as late as 1982. Coherent executives noted that demand for lasers in the medical industry continued to grow, but all other industries experienced a noticeable demand stagnation which the executives attributed to lingering worries of the dangers of lasers.[150] By the late 1980s, however, Americans became increasingly aware of the safe uses of lasers. Rebecca Slayton argues that the many non-weapon uses of lasers caused Americans to view the laser as a clean, surgically precise technology, which was a far cry from the explosive and violent death rays from science fiction. And even though this perception of the laser was paradoxically linked to weaponry through the Strategic Defense Initiative, the focus of the defensive, not offensive, nature of SDI lasers perpetuated the image of lasers as a technology which need not be feared.[151] As the Cold War came to a close, laser research started to move away from the military sector as large research laboratories sought commercial uses for laser technology developed initially for the military.[152] Additionally, thousands of scientists and engineers in the defense industry moved to the commercial sector as a result of the shrinking of the defense industry. This resulted in a decline of laser weapon research and a surge of commercial laser developments.[153]

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operation of the laser, such as mirrors and lenses. "Systems containing lasers" describes electronic devices which utilize one or more lasers as necessary components of the device.

150Barnaby J. Feder, "Market Challenges for Lasers," *New York Times*, April 28, 1982.

151Rebecca Slayton, "From Death Rays to Light Sabers: Making Laser Weapons Surgically Precise," *Technology and Culture* 52 (2011): 71.

152Malcolm W. Browne, "Laser Weapon Obliterates Graffiti, Not Missiles," *New York Times*, April 21, 1996. Lawrence Livermore National Laboratory was in the process of "convert[ing] many technologies developed for military purposes, including high-power lasers, to commercial uses." This lab was one of the partners in the SDI project and worked on both ballistics and directed-energy weapons for the initiative.

153Several examples of new companies in a variety of industries founded by scientists and engineers who formerly worked in defense can be seen in William J. Broad, "Defining the New Plowshares Those Old Swords Will

The rapid growth of the laser industry characterized the history of the laser in the 1990s. This growth was a result of an influx of talented scientists and engineers who left the defense industry as well as the continued growth of several integral technologies, such as the Compact Disc and medical lasers. During this decade, the diode laser – which is the most common type of laser in systems used by consumers – sold more units than all other non-diode lasers combined.[154]

This chapter investigates the consequences of the popularity of diode lasers and new and improved medical procedures which incorporated lasers. In particular, I analyze the language used to describe laser technology during the 1990s in the media. Newspaper and magazine articles on laser technology described lasers differently in this decade than those prior. Instead of describing the operation of lasers and what makes them different from older technology – as was the case in articles from the previous three decades – articles in the 1990s presuppose a level of basic knowledge among the American public of lasers.[155] The second half of this chapter investigates why the Digital Versatile Disc (DVD) replaced the LaserDisc (LD) and VHS as the standard format for home video. The DVD was a success due to a combination of factors including convenience for the user, the low cost of laser diodes, and unusual cooperation among

Make," *The New York Times*, February 5, 1992.

154For sales data and comparisons, see Robert V. Steele, "Review and forecast of laser markets – Part II: Diode lasers," *Laser Focus World* 36 (2000). In the late 1990s, diode lasers were most commonly used in telecommunication and optical data storage. In telecom, diode lasers were used as the light source for fiber optic data transmission as well as the pump for fiber amplifiers, which amplify a currently existing data signal that has lost a significant amount of power by transmitting over a long distance in an optical fiber. "In 1999, diode lasers used in telecom accounted for 68.7% of the overall market, or $2.8 billion. . . . The increase over 1998 was an astounding 58.1%." In the optical data storage market, sales of lasers for use in CD technology grew $79 million, or 181%. The use of lasers in CD-ROM drives declined for the first time in 1999 as sales of DVD-ROM drives grew in popularity. Additionally, CD-RW drives dropped to below $300, which caused sales to accelerate in the late 1990s.

155A search for "light amplification by stimulated emission of radiation" in *The New York Times* from January 1, 1960 to December 31, 1999 on LexisNexis resulted in the following number of matches: 53 articles in the 1960s, 14 articles in the 1970s, 13 articles in the 1980s, and just 3 articles in the 1990s.

the largest computer hardware companies.

From Magnificent to Mundane

When the laser first appeared, it was a tool of physicists at universities and in the military. While Americans were exposed to lasers in supermarket scanners, some medical procedures, and news reports of military research, the popular perception of the laser was as a futuristic, destructive technology.[156] In these early years, journalists often made use of analogies to science fiction characters Buck Rogers and Flash Gordon when describing lasers. These descriptions resonated with the public as both Buck Rogers and Flash Gordon were popular and both characters wielded laser-like ray guns.[157] Despite the medical industry's early adoption of the laser – a mere one year after its invention – some Americans still associated the laser with death rays. Theodore Maiman recounted a conversation with actress Bette Davis in the 1960s in which she asked him "How does it feel to have made something that brings such destruction to the mankind?"[158] But in the 1970s, Maiman noticed people associating the laser with its many medical applications.[159] The media once again associated the laser with weaponry in the 1980s thanks to the Strategic Defense Initiative, hence the colloquial name "Star Wars." But in the 1990s, the Cold War ended and the government drastically cut the defense budget.[160] As a result of these cuts and the growing success of diode lasers thanks to telecommunication and compact

156Slayton, "Death Rays," 46. Slayton provides several examples from *U.S. News & World Report* in the 1960s about the popular perception of the laser as a "death ray."
157Ibid.
158Colburn, "Laser Evolution."
159Ibid. "Instead of accusing him of inventing the death ray, people started coming up to him and saying things like, 'Oh, I want to thank you. My grandmother's eyes were saved.'"
160Budget cuts for a variety of research programs involved in defense are detailed in Broad, "Plowshares."

disc applications, the laser "became a metaphor for precision" among the populace.[161] This idea of precision came about due to the many common uses of lasers in the daily lives of Americans.

Dermatology was one of the newest medical industries to take advantage of the laser. Unlike most laser medical treatments in the past decades, dermatological use of lasers was meant to offer cosmetic convenience. Dermatologists first used lasers to remove port-wine stains, purplish birthmarks that tended to cover a large portion of the neck and face. The purpose of that treatment was to remove the psychologically damaging effects of the birthmarks. But in the 1990s, dermatologists and anyone else who could afford the equipment used them to remove body hair and tattoos.[162] Lasers for use in cosmetic dermatology were popular even among physicians due to the high profitability of most of the procedures. Hair removal on the upper lip cost $1000 to $3000 and it was a quick and low-risk procedure. The convenience of laser hair removal, in particular, was a selling point of the procedure to Americans. Laser companies offered their devices to doctors at reduced prices in exchange for holding demonstrations of the technology. Due to the quick profit of the procedures and fierce competition among cosmetic laser manufacturers, doctors and manufacturers bombarded beauty magazines with advertisements and dermatologists filled their offices with brochures. The competition among advertisers created an environment full of "hype and gimmickry" to serve Americans "looking for a quick [cosmetic] fix."[163]

161 Slayton, "Death Rays," 71. Slayton argues that Americans saw the laser as a symbol for both precision and as a weapon during the 1980s. In the 1990s, Americans still viewed the laser as precise, but the idea of the laser as a weapon changed. As will be explained later in this chapter, the weapon nature of lasers in the 1990s was generally limited to laser mounts on weapons for accuracy and the danger that laser pointers posed to the human eye.

162 Ellen Tien, "Beauty's Bomb, but How Smart?" *The New York Times*, August 30, 1998. "[L]aser hair removal, tattoo removal, facials and peels don't require a medical license; the equipment can be deployed by anyone who has the $40,000 to $250,000 to buy it."

163 Ibid.

A common trend in articles that discuss dermatological lasers is the lack of detailed explanation as to how the technology works. When the port-wine stain removal procedure was discovered, articles explained how the coherence of light is the requisite characteristic of the laser which allowed it to remove the marks.[164] But articles from the 1990s rarely use more than a sentence or two to explain the procedure. And even these explanations describe the overall experience more than how the laser works or why the laser is necessary.[165] The vague descriptions indicate that Americans possessed a significant level of comfort with lasers. They may not have fully understood how lasers worked, but journalists and doctors did not believe that Americans needed detailed explanations of the sort that were provided in the decades prior. Considering the importance of medical procedures, vague explanations of lasers in these treatment descriptions indicate the level of trust in lasers more than a vague description regarding how a laser reads a CD. Interestingly, Americans must have placed enough trust in laser technology and/or their doctors, because the Food and Drug Administration issued warnings to doctors in 1996 to stop using unapproved lasers for photorefractive keratectomy, a procedure to improve nearsightedness. Some doctors imported cheaper lasers from Europe and did not go through the proper procedure to use them on their patients for research. One doctor even

164Matt Clark, Dan Shapiro, and Richard Manning, "Port-Wine Stains," *Newsweek*, January 23, 1978.

165In the lengthy Tien, "Beauty's Bomb," a doctor describes a particular hair removal machine: "It has the longest wavelength, the deepest penetration, and once you've done it three times, you've hit all the follicles." The mention of wavelength in that quote is the extent to which the article describes the science of the laser. While surely most Americans did not, and still do not, know that wavelength is directly related to penetration depth, the doctor's language implies some comfort with laser terminology among the populace. Simply mentioning "wavelength" acts as a sort of check-off that the device is scientifically sound. Another article, "What's Wrong With Laser Surgery for Snoring," *The New York Times*, September 21, 1993, mentions that lasers have been used to treat snoring, but makes no attempt to explain how the procedure works. Still another article, Joe Donnelly, "One Doctor's Undyeing Dedication; Steven Snyder: A Leading Light in Tattoo Removal," *The Washington Post*, July 12, 1994, describes the laser tattoo removal procedure as follows: "Snyder's lasers smart-bomb the cells housing the pigment. This breaks up the inky epidermal cells and allows the body's own 'scavenger cells' to carry the pigment away to lymph nodes." This short description in an otherwise lengthy article implies that the public was aware that ink of a certain color will absorb the energy from lasers of a similar color, while the surrounding skin reflects most of the energy.

admitted to building his own laser which he believed was "in the best interest of [his] patients."[166]

Further evidence that America had grown accustomed to lasers was the episode surrounding the dangers of laser pointers and the subsequent legislation around the country to ban sales of laser pointers to minors. Prices of laser pointers dropped in the 1990s as sales of diode lasers continued to grow exponentially. Laser pointers vary in brightness and color, but all are low power devices that, in the 1990s, were a little smaller than a pen. Long-range laser pointers tended to be more expensive, costing between $50 and $100 in 1998.[167] Short-range pointers were significantly cheaper, costing as little as $15.[168] The range of laser pointers is the maximum distance at which the spot can still be seen in normal light conditions. The low cost of some pointers helped them become popular among children and teenagers.[169] Even though most people knew what lasers looked like by the 1990s, the laser pointer was the only way most people ever wielded one. For this reason, it is easy to understand why such a device would have been an attractive toy for both adolescents and adults. The problem, however, was that people were not knowledgeable of the dangers of laser pointers. While no laser pointers have ever been strong enough to burn skin, they can pose a threat to the human eye. The concentrated energy of a laser pointer can permanently damage the retina if shined upon the retina long enough. As laser pointers became popular in schools, incidents of eye damage due to laser pointers

166"Eye Doctors Told Not to Use Unapproved Lasers to Treat Myopia," *The New York Times*, July 27, 1996.

167Donna Greene, "Move to Ban Laser Pointers For Minors," *The New York Times*, June 14, 1998. The two laser pointers described in this article are from Staples. The $51.99 device is red and has a range of 100 meters. The $79.99 pointer is also red, but with a range of 125 meters.

168"Student's Eye Is Burned In Laser Pointer Incident," *The New York Times*, December 22, 1998.

169Ibid. This article describes an incident in Maple Park Middle School in Kansas City in which a seventh grader permanently damaged his retina after another student shined a laser pointer into his eye. After that incident, the school decided to confiscate laser pointers from all students. In that school year alone, they confiscated "at least 100" pointers.

increased.[170] Even when laser pointers were not shined into the eyes of other students, many schools added them to their list of banned items, citing that their use was often inappropriate and distracting.[171]

People who shined lasers at police officers faced more serious consequences. The gun laser-sight invented in 1977 became so popular that many police officers were trained to recognize a laser dot as a sign that someone was aiming a gun at them. For this reason, shining a laser at a police officer can result in arrest.[172]

In light of the potential dangers due to inappropriate use of laser pointers, several jurisdictions passed or attempted to pass legislation to ban the sale of laser pointers to minors. In 1998, New York City banned the sale of laser pointers to minors, prohibited anyone under twenty from carrying them on school grounds unless necessary for an assignment, and banned anyone from aiming a laser at police officers, emergency workers, or their vehicles.[173] *The New York Times* reported, however, that there were no citations or arrests one month after the regulations became law.[174] The newspaper had no articles reporting on the efficacy of the laser pointer laws thereafter.[175] This lack of articles shows that the public, at least in New York City, felt safe enough with laser pointers that they did not demand stricter enforcement of the regulations. Currently, the most common restrictions on laser pointers in America prohibit the sale of lasers to

170For some examples, see Ibid. and Greene, "Move to Ban Laser Pointers."

171Sandra Evans, "Kids With Laser Pointers," *The Washington Post*, December 1, 1998. This article describes the immature uses of laser pointers by students, from shining them at moving vehicles and at other students' foreheads. More antics are presented in Ann O'Hanlon, "High-Tech Troublemakers; Students Playing With Laser Pointers Worry School Officials," *The Washington Post*, May 7, 1998.

172For two examples of men arrested for shining lasers at police officers in 1997, see "Man Using Laser Pen Is Arrested in Harlem," *The New York Times*, April 28, 1997 and Kit R. Roane, "Man Is Arrested After Laser Sight Is Aimed at Officers in Brooklyn," *The New York Times*, October 12, 1997. Both of these articles describe the danger felt by the officers when they discovered the laser spot on their bodies.

173Neil MacFarquhar, "City Council Votes to Limit Laser Sale," *The New York Times*, December 18, 1998.

174Donna Greene, "Laxity in Laser Law Enforcement," *The New York Times*, January 17, 1999.

175This is based on a search on LexisNexis using the terms laser and law.

minors, shining lasers at police and emergency workers, and shining lasers at aircraft.[176] As for federal regulation, lasers fall under FDA jurisdiction. The FDA adopted standards in 1976 to classify lasers by wavelength and output power. The FDA requires that warning labels be fixed upon all lasers or laser containers denoting their classifications.[177]

In the 1990s, the laser printer became commonplace in the office. Laser printers in the 1990s were capable of printing crisper images faster than ink jet and dot matrix printers. By employing basic principles of electrostatics, a voltage source uniformly covers the surface of a rotating cylinder with electrostatic charge. A laser shines across the surface of the charged cylinder and removes the charge where the beam lands. Toner is then exposed to the cylinder and is attracted to the remaining charged portions of the cylinder. Finally, the cylinder rolls across paper, transferring the toner to the page in the process. The crisp image is a result of the precision of the laser. As is the case with most technologies, the cost of monochrome laser printers dropped since its invention in 1969.[178] In the mid 1990s, black-and-white laser printers cost less than $700, which made them comparable to ink jet printers. For this reason, laser printers were very popular both in the office and at home, so long as color was not required.[179] At over $10,000 for a color laser printer, most people turned to ink jet printers to meet their color

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176For a compilation of laser laws at the state, county, or city level, see "Laser Pointer Safety – U.S. laws for lasers and pointers," LaserPointerSafety.com, http://www.laserpointersafety.com/rules-general/uslaws/uslaws.html, accessed March 29, 2011.

177"CFR – Code of Federal Regulations Title 21," U.S. Food and Drug Administration, last modified April 1, 2010, http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?FR=1040.10.

178Edwin D. Reilly, *Milestones in Computer Science and Information Technology* (Westport, CT: Greenwood Press, 2003), 152. The laser printer was invented by Gary Starkweather of Xerox in 1969. Xerox produced the first working version of Starkweather's printer in 1971. According to Peter H. Lewis, "2 New Laser Printers From Apple," *The New York Times*, July 17, 1990, monochrome laser printers for Windows cost less than $1500 in 1990.

179Joshua Mills, "How Much Printer Do You Need?" *The New York Times*, February 8, 1994. "Most shoppers prefer to shop in the $300-to-$700 range, and those who want true laser-quality printing forget the color." Color laser printers were very expensive with the cheapest at $12,499. For the popularity of black-and-white laser printers in the office, see Laurie Flynn, "Is the Black-and-White Printer a Goner?" *The New York Times*, May 20, 1996. "Black-and-white laser printers remain the norm in office printing."

needs. But for monochrome printing, Americans grew accustomed to seeing laser printers in the workplace. Advertisements and articles that described laser printers avoided technical descriptions of their operation. Instead, they focused on cost and speed in pages per minute.[180] Therefore, the laser printer was another example the laser aspect of the technology no longer fascinated Americans. Instead, the technology was as commonplace as a computer.

The Compact Disc format remained the standard for audio and data during the 1990s. The CD's popularity grew exponentially in the 1990s. By the end of the decade, "modest estimates placed the number of audio CD's and other types of optical disks . . . in the tens of billions" with "[m]ore than two billion audio CDs . . . sold each year in the United States alone."[181] At first glance, it may seem as though the CD format has not evolved since its creation, especially considering that it is still the most common method of data storage for physical software distribution. But several variations on the CD format were invented in the 1990s, including CD + Graphics, Super Audio CD, and Super Video CD. These formats are largely unknown to most Americans, however, because they either were not commercially successful in America or because they made such minor changes to the CD standard that the official format name appeared only in technical documentation.[182] CD-ROM technology

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180 Evidence of this is shown in the two articles cited in n. 197. Additionally, the 16 *Newsweek* articles found on LexisNexis by searching "laser printer*" from 1990 to 2000 mention the printer in passing as a commonplace technology.

181 Michel Marriott, "With Plenty of Shine and Spin, CD's Weave Tapestries of Data," *The New York Times*, September 23, 1999.

182 The CD-Text format allocates additional space on a disc for information about the album, song, artist, etc., which are displayed on compatible CD players. This format is the standard for audio CDs today, but is rarely referred to as CD-Text, rather than CD, because the format still plays the audio on any CD player and the added text is a minor adjustment to a standard CD format. The video CD formats (Video CD and Super Video CD), as well as the Super Audio CD format, were largely popular in Southeast Asia. A search for each of these formats in *The New York Times* using LexisNexis from 1980 to 2011 resulted in 25 or fewer articles each. In the case of Super Video CD, only a single article was found. See Scot Meyer, "Versatile Video CD's Get a Foothold in U.S.," *The New York Times*, April 26, 2001 for an example of language used to describe Video CDs in a manner that implies the lack of common knowledge of the format in America.

improved by increasing read speed, which increased the speed at which a CD-ROM drive copies information from the disc to the computer. This speed increase was unnecessary in audio CDs because the data capacity remained roughly the same and there is no need to read audio data significantly faster than it is played to the listener.[183]

The most notable breakthrough in CD technology was the ability to write discs with the CD Recordable and ReWritable (CD-R and CD-RW) formats.[184] With about 700 megabytes of data per disc, CDs offered over 480 times as much data as a floppy disk. The convenience of this extra memory came at a cost, though. Even by the end of the 1990s, CD-RW drives cost around $300 each. They still became standard in newly built computers, but they were an expensive upgrade for currently existing computer systems. As such, there was some resistance to switching to the new format, especially considering how the floppy disks had been the standard since the early 1980s and required no extra software to use.[185] Ultimately, files and programs

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183The technical specifications for virtually all variations of the CD are currently the intellectual property of Sony and Philips. Therefore, access to the specifications are not free (currently the specifications for CD with a CD-Text addendum cost $5000). Some variation in data capacity for CDs exists, but the variation is small. If the capacity is increased too much, standard CD readers cannot properly read the discs.

184For the up and coming popularity of the CD-RW drive and format, see Michel Marriott, "CD-ROM Drive Maker Strives for a Quick Burn," *The New York Times*, November 11, 1999 and Leonard Wiener, "To CD-R or CD-RW? Best to know before you buy," *U.S. News & World Report*, September 4, 2000. For evidence of the increased popularity of CD-RW technology from laser industry journal *Laser Focus World*, see n. 147 above. For a prediction of the eventual replacement of the floppy disk by CD-RW and flash memory, see Michel Marriott, "Memory Takes New Shape," *The New York Times*, April 1, 1999. It is difficult to quantify popularity of computer hardware due to the nature of the personal computer industry. As common components of computers – such as processors, memory, and disc drives – improve, these improved components very quickly become standard in prebuilt personal computers by nearly all PC manufacturers. For this reason, newspapers and industry journals contained little mention of a strong public desire for recordable CD drives; the new drives simply started to replace older CD-ROM drives. Articles, instead, focused on improvements to CD-RW drives and educated consumers about the new recordable disc technology. Thus the popularity of the recordable disc is evident in the fact that recordable disc drives became standard on prebuilt PCs since their price dropped exponentially in the late 1990s and early 2000s.

185Marriott, "Memory" describes the capacity of CDs and cutting-edge flash memory in numbers of floppy disks. In "In Praise of Floppies," *The New York Times*, December 9, 1999, a reader writes to the editor in defense of the floppy disk as a convenient method to transfer small files back and forth across computers. The imagery of the floppy disk still remains today as ubiquitous with saving files on computers, as evident by the ever persistent floppy disk icon seen on the vast majority of computer software. Greenberg, "'Burning'," (n. 199 below) compares CD-R and CD-RW to floppy disks.

grew increasingly larger and phased out the floppy disk drive in the 2000s. But even the laser technology involved in CD-RW drives became a mundane detail to the public. Descriptions of recordable disc technology in the 1990s focused almost exclusively on the novel material design of the disc, rather than the higher power requirements of the laser.[186] Thanks in large part to the commercial success of the CD during the 1980s and 1990s, Americans no longer considered the CD and CD-ROM to be a fascinating and cutting-edge technology that was dependent upon the unique characteristics of lasers, even when burning CDs at home became a reality. Sensational descriptions of lasers as a whole were on the decline, and they were virtually void in the case of CDs.

The End of Analog Video

Prior to the invention of the Digital Versatile Disc (DVD) format in 1995, the most common home video medium was the VHS tape. Even though the LaserDisc (LD) format offered superior video and sound quality than VHS, the format remained popular among only a small group of collectors who totaled only around "2 percent of the size of the VHS market. . . . [E]ven at its height in the 1990s, it never reached more than two million players in the United States."[187] The LD format never took off in America for a few reasons. First, the technology was very expensive compared to VHS; "the first laser disk players cost more than $200 more than

186Peter H. Lewis, "The ABC's of CD's: Read-Only, Recordable and Rewritable," *The New York Times*, December 9, 1999. "[CD-RW discs] use slightly more powerful lasers that heat a silvery recording layer of silver, antimony, indium and tellurium, altering its reflectivity. The tracks are erased, or more accurately, annealed, by reheating the laser with the laser, in effect transforming the silvery alloy back to its original crystalline state." This description assumes that the public knows that lasers can be used to heat up a material. For an example of an article that describes the cost and new functionality of CD-R and CD-RW, but leaves out any mention of the laser, see Daniel Greenberg, "CDs without the music store; 'Burning' your own discs on your PC or stereo," *The Washington Post*, January 30, 1998.

187Julie Flaherty, "Bittersweet Times for Collectors of Laser Disk Movies," *The New York Times*, April 29, 1999.

VCRs."[188] Second, the discs were cumbersome at a diameter of twelve inches. Disc size alone prevented the LD from being integrated as a form of data storage akin to the CD-ROM, as the large discs would not fit inside a typical computer case. LaserDiscs differed from VHSs in that they could store both analog and digital data, as opposed to only analog on VHS. Video was recorded in analog and audio recorded in digital or audio. The benefit of digital audio was that it provided the same quality as the CD. Analog storage of video technically allows for higher resolution of data as each location on the disc can be read as a value spanning a wider range than just one or zero, as is the case with digital representation. But because the LD standard was never improved since the 1970s, the size of each track of data was never reduced to match improvements in laser technology. For this reason, LDs could store a maximum of 60 minutes of video on each side of the disc. Rotating and replacing discs during a video was an inconvenience that also prevented the format from replacing VHS. In the end, the DVD format became the first optical medium to replace the VHS.

Several factors were responsible for the success of the DVD over the VHS. Unlike the VHS, the DVD format was universally supported by the largest computer hardware companies in the world. When the VHS was first developed in 1976 by Victor Company of Japan (JVC), Sony had already released a magnetic recording a year prior called Beta.[189] Even though Beta was considered the standard home video recording format in Japan, VHS improved upon the Beta format. A VHS tape had an initial capacity of two hours, as opposed to Beta's limit of one hour. Additionally, JVC developed a method to reduce crosstalk on the VHS, something Sony did not

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188Ibid.

189"Milestones: Development of VHS, a World Standard for Home Video Recording, 1976," IEEE Global History Network, accessed March 30, 2011, http://www.ieeeghn.org/wiki/index.php/Milestones:Development_of_VHS,_a_World_Standard_for_Home_Video_Recording,_1976.

accomplish.[190] The success of the VHS meant that Sony lost nearly all of the video market and consumers who owned Beta players had to purchase a VCR if they wished to purchase new videos. In these so-called format wars, both consumers and companies risk losing money invested in a particular technology if it loses the war. In the case of the DVD, the computer and entertainment industries wished to avoid another format war.

In September 1994, entertainment providers Columbia Pictures (owned by Sony), Disney, Music Corporation of America/Universal, Metro-Goldwyn-Mayer/United Artists, Paramount, Viacom, and Warner Bros. (owned by Time Warner) formed the Hollywood Digital Video Disc Advisory Group. The purpose of this group was to create a standard for the next-generation optical video disc. Their demands included capacity for a full-length feature film one a single side of one disc, superior picture quality to LaserDisc, copy protection, and the ability to accommodate three to five languages per disc. This call was met with two competing formats: Multimedia Compact Disc (MMCD) developed by the partnership of Sony and Philips and Super Disc (SD) developed by an alliance of Hitachi, Panasonic, Mitsubishi, JVC, Pioneer, Thomson, and Toshiba. All in all, Sony and Philips attracted the support of 14 electronics companies and the SD Alliance attracted ten. When these competing camps increasingly turned their attention to data storage, five computer companies formed a technical working group in April 1995 to deal with the MMCD and SD groups. These computer companies were Apple, Compaq, Hewlett Packard, IBM, and Microsoft. This working group defined specifications for a single disc standard that included one format for both video and data, a drive with backwards compatibility with CDs and CD-ROMs, and a drive with similar cost to CD-ROM drives. Most importantly,

190Ibid. Crosstalk occurs when two recording heads read or write the same magnetic media very close together. This can result in interference in the magnetic fields used to read/write the medium. Crosstalk in video playback causes some overlap of images, resulting in a distorted image.

however, the computer companies refused to decide which format to support, SD or MMCD, requiring instead that the competing disc companies create a single format. After months of deliberation, the two competing disc factions came to a consensus on December 12, 1995. The new standard met the minimum requirements of both the entertainment and computer industries and included interactivity, which allowed users to interact with the disc content via a remote control. All the disc companies came together and formed a single alliance, the DVD Consortium. Despite the length of competition among the disc companies, neither side lost a sizable investment as the final DVD standard took advantage of the MMCD's data storage method and the SD's material manufacturing technique and error-correction.[191] Thanks to the eventual universal consensus, the DVD had support from the biggest companies in entertainment, computer technology, and disc drive technology. The LD format did not enjoy this much investment, and the film companies were ready to move beyond the VHS. Indeed, “Hollywood, especially Time Warner, wanted to sell its zillions of old movies in a new form – just as music companies did when CDs came along.”[192]

The DVD had a bumpy start, but by 1999, it was in position to overtake VHS. During 1997, many disc drive manufacturers claimed they would have a DVD-ROM drive available by the end of the year, a claim they did not fulfill. By the end of 1998, one million DVD players had been sold in America, six million DVD-ROM drives had been sold, and Warner Home Video made $170 million in DVD sales.[193] The next year turned out to meet predictions as the “year of

191Jim Taylor, *DVD Demystified*, 2nd ed. (New York: McGraw-Hill, 2001, 45-51.

192Johnnie L. Roberts, “The Disc Wars,” *Newsweek*, August 26, 1996. This article describes the creation of the DVD as something desired more by manufacturers than by consumers. Additionally, Roberts reports that even though the DVD format was supported by some of the biggest entertainment companies, many smaller companies refuse to produce their films on DVD until the standard includes protection against piracy and has region codes to prevent videos sold in one part of the world from playing in another.

193Taylor, *DVD*, 73.

the DVD." Every film publisher was onboard with DVD and recordable DVD drives were on schedule. By the end of 1999, over four million DVD players and 40 million PCs with DVD-ROM drives were sold. Over 50 million DVD videos were shipped during the holiday season alone.[194] The upward trend of the DVD market continued until it eventually overtook VHS in weekly rentals (28.2 million to 27.3 million, respectively) in June, 2003.[195]

Even though it took six years for the DVD to outperform the VHS in terms of sales, the success was virtually inevitable. The strong support from Hollywood, the major computer companies, and the biggest electronics companies gave the DVD format a massive amount of funding. The discs provided superior audio and video quality than VHS and LD. The capacity was higher than LDs, even though DVDs are digital, because DVD standards took advantage of improved laser technology, which allowed for the data to be printed much smaller than in LDs. Interactivity on DVDs meant that users could view extra content, change languages and subtitles, and skip around to different chapters. These were all improvements over VHS. Just like VHS, but unlike LD, DVDs were recordable and the cost of DVD-R technology decreased quickly.[196]

Lasers in the 1990s had become as "mundane" as some other high-tech devices, like the microchip. The dazzle of the laser had waned after decades of sensationalist reporting on the extraordinary potential for lasers as weapons, a potential that has yet to be realized on the scale

194Ibid., 80.

195"It's unreel: DVD rentals overtake videocassettes," *The Washington Times*, June 20, 2003. The DVD maintained its lead in rentals over VHS ever since.

196Wilson Rothman, "Burn-Your-Own-DVD's: First, Mind the Format," *The New York Times*, September 5, 2002. "Most desktop-system offers now include an optional DVD recorder." The cost of the three computers tested by Rothman were $1999, $2999, and $1349. As mentioned in n. 198 above, the fact that PC manufacturers commonly offered DVD-R drives indicates that the cost had decreased low enough that the manufacturers expected a significant percentage of consumers would purchase the drives.

of those articles.[197] Scientists and engineers still improved lasers and developed new ones altogether in the 1990s, but the lasers Americans saw in their daily lives did not drastically change. The lasers used in cosmetic surgery were novel, but did not evoke the same response of the laser as a miracle technology as the first lasers were used in medicine in 1961. The CD continued to grow in popularity, but Americans were accustomed to them by the 1990s. The DVD was new to those who owned VCRs, but the language used in reports of DVDs lacks the excitement used to first describe CDs.[198] Laser printers were a common piece of the office landscape. Laser pointers became popular among young students and even resulted in a few incidents of damaged eyes due to exposure to the beams. But other than the outcry among schools and legislators to ban their sale to minors, these incidents received little coverage. The New York City ban on laser sales to minors was never even imposed a month after becoming law. Incidents of people being arrested for shining lasers at police officers were relegated to the small side columns of the major newspapers. Whereas laser weapon development was a characteristic of the past two decades, military use of lasers in the 1990s mainly included laser-guidance systems for missiles, technology which has existed since the 1980s. What was noticeably absent, however, was any mention of death rays.[199]

197Jeff Hecht, "Ray Guns Get Real," *IEEE Spectrum* 46 (2009): 28-33. "Laser weapons, like flying cars, have been demonstrated many times, but in the real world their problems have always outweighed their benefits – literally."

198In addition to all sources presented thus far regarding the laser, see Peter M. Nichols, "Home Video," *New York Times*, May 16, 1997 and Peter M. Nichols, "Fast Forward: Laser or DVD?" *New York Times*, January 9, 1998. In "Home Video": "DVD players and disks . . . are said to offer superior picture and sound." There are no exciting descriptions of a brand new technology. In "Fast Forward": "Now there is DVD, which its proponents say presents a better image than the laser[disc]."

199A LexisNexis search for laser and weapon in *The New York Times* during the 1990s returned over 500 matches. A survey of 25 random articles over the entire decade returned articles that only mentioned lasers for use in laser-targeting systems. A search of death ray and laser returned three articles. William J. Broad, "Defense Industry Goes Hustling To Make a Buck Without the Bang," *New York Times*, April 8, 1990 and Anthony Ramirez, "Laser Benefits Now Closer to Home," *New York Times*, July 22, 1992 both mention that the laser has proven to be used in just about everything but as a death ray. The third article, William J. Broad, "From Fantasy to Fact: Space-Based Laser Nearly Ready to Fly," *New York Times*, December 6, 1994, reports on the United States Airborne Laser. This laser has an output of over 2 million volts and uses the chemicals hydrogen and fluorine as a gain medium, rather than a crystal or semiconductor. At the time of that report, the laser had been tested eleven times.

Conclusion

The focus of the laser industry shifted throughout the forty years after its invention. Always a tool of research in universities, only its academic role remained constant. The United States Military dominated laser research during the early years in the 1960s. In the 1970s, they shrouded their research in secrecy comparable to the Manhattan Project. The Strategic Defense Initiative sought to use lasers to shield America from Soviet missiles. But by the end of the Cold War, the laser could no longer serve as a symbol of American military technology and investment into lasers decreased. The Airborne Laser still remains an active project as of 2011, but the government has greatly reduced its funding over the last few years. Americans were heavily influenced by the military' investment into the laser over the years. With the exception of the highest period of secrecy in the 1970s, journalists' use of language suggests Americans associated the laser with death rays during periods of high military funding of laser technology. Even when Reagan used the laser as a symbol of surgical precision, Americans still associated the laser with destruction. Science fiction shared responsible with the military for the lingering notion of the laser as a death ray. Even after laser applications proved to be beneficial to society time and time again, science fiction tended to depict lasers almost exclusively as weapons. As a result, the public's perception of lasers as weapons shifted from one of of uncontrollable destruction to one that was surgically precise.

The commercial sector also influenced the American understanding of lasers. From the first test of a laser in medicine in 1961, commercial uses of lasers never included weaponry. An inventor created the laser-sight for guns in the 1970s, but a laser gun itself was never produced.

The laser is still operable as of 2011, but has never proven to be a viable missile defense system. Despite the fact that "experts agree [it] doesn't work," the Pentagon's 2011 budget of $9.9 billion includes $50 million for the Airborne Laser. "Mr. Gates and the Pentagon Budget," *New York Times*, May 17, 2010.

Some of the most noticeable commercial applications of lasers from 1960 to 2000 to Americans were laser printers, laser pointers, CD players and CD-ROM drives, DVD players and DVD-ROM drives, and applications in medicine. These applications served to entertain Americans, made computer data storage more convenient, and solved some medical problems. As such, Americans in the 1990s saw lasers as a useful technology, rather than one to be feared. To reflect the commonplace nature of lasers in society, journalists neglected to explain technical details of laser technology like they once did in the prior decades. The popularity of consumer products that contain lasers led to unprecedented growth in the semiconductor laser industry. This caused the industry to shift its focus to low-power semiconductor applications for the most part. High-power lasers had their place in industry, but low-power applications dominated the market.

Regardless of whether the laser was seen as magnificent or mundane, it remained a symbol of cutting-edge technology. The laser was responsible for so many new applications, from medicine to art restoration, from laser gun-sights to laser light shows, and from range detectors to laser pointers. The laser became synonymous with precision of the highest degree. The laser seemed to improve any technology to which it was added, because adding a laser added unmatchable precision and speed. Lasers, of course, do not automatically make systems better and must be used properly. But after decades of reading about the successes of lasers and by using lasers and laser systems, Americans associated lasers as fast and precise. If a laser was involved in something new, there was no problem convincing Americans it would work. Some experts immediately believed that the lasers in the SDI project were not viable, but news articles showed little skepticism until the late 1980s and early 1990s. Articles were also on the side of the few inventors who claimed, without any evidence, to have developed death rays. The

LaserDisc video format was a commercial failure in America, but when the DVD was on the horizon, journalists compared the two incessantly. Even though VHS was always more popular than LD in America, articles in the 1990s used language that implied that LD would eventually overtake VHS in popularity due to the superior video quality of LD. The only time journalists seemed to portray lasers negatively was during the episode of laser pointer incidents damaging eyes in schools. Even to this day, there are few safety regulations on lasers. Other than mandatory warning signage and a prohibition on importing laser pointers over a certain power level, there are no mandatory background checks or age restrictions when purchasing potentially dangerous lasers.

The overall history of the laser in America was a sensational one. Reporters described the laser as the solution to many problems. Some were as mundane as data storage while others promised perpetual peace between the East and the West. Americans were interested in, and sometimes feared, the potential of lasers. But the vast majority of laser applications help Americans. As lasers became more common in daily life, usually as a component of larger systems, the fascination with lasers began to diminish. This arc of excitement and eventual indifference is common to modern technology. For example, the computer experienced a similar arc in America. Once just a tool of scientists and bankers, computers rapidly grew in popularity after Apple released the first personal computer and after prices began to drop. But unlike the computer, the laser was a single device, not a system of many other devices. A proper analogy would be to compare the laser to the transistor. Indeed, the transistor is one of the greatest inventions of the last century, but hardly elicited such an interest by the public as the laser did. This is why it is important to understand the public response to the laser throughout its history.

The laser is unique in that nobody knew what the laser could be used for back in 1960. Most major technological breakthroughs have a goal in mind when research is begun. But the success of the laser can serve as an example that sometimes research for the sake of research can change society.

Bibliography

Primary Sources:

"A Diode Converts Current to Light." *The New York Times*, July 10, 1962.

"A Laser for Blindness." *Newsweek*, April 19, 1976.

"Beam to Kill Army at 200 Miles, Tesla Claims On 78th Birthday." *New York Herald Tribune*, July 11, 1934.

"Bell Labs: Imagination Inc." *Time*, January 25, 1982.

Benrey, Ronald M. "PS Builds a LASER . . . and so can you." *Popular Science*. November, 1964, 62-64 and 224-230.

Broad, William J. "Defense Industry Goes Hustling To Make a Buck Without the Bang." *The New York Times*, April 8, 1990.

__________. "Defining the New Plowshares Those Old Swords Will Make." *The New York Times*, February 5, 1992.

__________. "From Fantasy to Fact: Space-Based Laser Nearly Ready to Fly." *The New York Times,* December 6, 1994.

__________. "The Secret Behind Star Wars." *The New York Times*, August 11, 1985.

Browne, Malcolm W. "Laser Weapon Obliterates Graffiti, Not Missiles." *The New York Times*, April 21, 1996.

Cannon, Lou. "President Seeks Futuristic Defense Against Missiles." *The Washington Post*, March 24, 1983.

"CFR – Code of Federal Regulations Title 21." U.S. Food and Drug Administration. Last modified April 1, 2010, http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?FR=1040.10.

Clark, Matt, Dan Shapiro, and Richard Manning. "Port-Wine Stains." *Newsweek*, January 23, 1978.

__________ and Mariana Gosnell. "Sight for the Sightless." *Newsweek*, December 7, 1981.

Clarke, Arthur C. *Earthlight*. New York: Ballantine Books, 1955.

Colburn, Don. “Laser Evolution: From 'Death Ray' to a Life-Saving Tool.” *The Washington Post*, July 16, 1986.

“Diabolical Rays.” *Time*, June 9, 1924.

“Death Stroke.” *Time*, August 10, 1925.

“Denies Britisher Invented 'Death Ray'.” *The New York Times*, September 5, 1924.

Donnelly, Joe. “One Doctor's Undyeing Dedication.” *The Washington Post*, July 12, 1994.

Evans, Sandra. “Kids With Laser Pointers.” *The Washington Post*, December 1, 1998.

“Eye Doctors Told Not to Use Unapproved Lasers to Treat Myopia.” *The New York Times*, July 27, 1996.

Fantel, Hans. “How to Choose a CD Player.” *The New York Times*, April 1, 1984.

Feder, Barnaby J. “Market Challenges for Lasers.” *The New York Times*, April 28, 1982.

Flaherty, Julie. “Bittersweet Times for Collectors of Laser Disk Movies.” *The New York Times*, April 29, 1999.

Flynn, Laurie. “Is the Black-and-White Printer a Goner?” *The New York Times*, May 20, 1996.

“Gadgets of the Future.” *Newsweek*, August 9, 1982.

“Goals are Listed for U.S. Inventors: Council Seeking Death Ray and Greaseless Bearing for Armed Forces.” *The New York Times*, November 3, 1957.

“Going Laser.” *The Economist* 262 (1977): 115.

Gold, Gerald. “Words Cast Their Spell.” *The New York Times*, November 18, 1984.

Greenberg, Daniel. “CDs Without the Music Store: 'Burning' your Own Discs on your PC or Stereo.” *The Washington Post*, January 30, 1998.

Greene, Donna. “Laxity in Laser Law Enforcement.” *The New York Times*, January 17, 1999.

__________. “Move to Ban Laser Pointers For Minors.” *The New York Times*, June 14, 1998.

Gregg, David Paul and Keith O. Johnson. “Video Signal Transducer Having Servo Controlled Flexible Fiber Optic Track Centering.” US Patent 3,530,258 filed June 28, 1968 and issued

September 22, 1970.

Gwynne, Peter, William J. Cook, Mary Hager, Gerald C. Lubenow, and Anthony Collings. “Wonders of '89.” *Newsweek*, November 19, 1979.

Hall, Robert N., G. E. Fenner, J. D. Kingsley, T. J. Soltys, and R. O. Carlson. “Coherent Light Emission From GaAs Junctions.” *Physical Review Letters* 9 (1962): 366-369.

Hughes, Frank. “Small Laser Firm Solves Big Problems.” *The Chicago Tribune*, January 18, 1970.

“In Praise of Floppies.” *The New York Times*, December 9, 1999.

“Invisible Death.” *Time*, April 21, 1924.

“In Test, Military Hits Satellite Using a Laser,” *The New York Times*, October 21, 1997.

“It's unreel: DVD rentals overtake videocassettes.” *The Washington Times*, June 20, 2003.

Jones, Stacy V. “Patents: Laser-Guided System for Landing Aircraft.” *The New York Times*, April 5, 1980.

Kaplan, Daniel. “Lasers for Missile Defense.” *Bulletin of the Atomic Scientists*, May 5-8, 1983.

Koepp, Stephen, Yukinori Ishikawa, and Thomas McCarroll. “And Now, the Age of Light.” *Time*, October 6, 1986.

Kushner, David. “How Laser Shows Get Their Dazzle.” *The New York Times*, September 24, 1998.

“Laser Pointer Safety – U.S. laws for lasers and pointers.” LaserPointerSafety.com. Accessed March 29, 2011, http://www.laserpointersafety.com/rules-general/uslaws/uslaws.html.

Lewis, Peter H. “2 New Laser Printers From Apple.” *The New York Times*, July 17, 1990.

__________. “The ABC's of CD's: Read-Only, Recordable and Rewritable.” *The New York Times*, December 9, 1999.

“'Light Ray' – Fantastic Weapon of the Future?” *U.S. News & World Report*, February 17, 1962.

“Luminaphone.” *Time*, November 23, 1925.

Lyons, Richard D. “Physicists Hear of a Strong Laser.” *The New York Times*, April 30, 1970.

MacFarquhar, Neil. “City Council Votes to Limit Laser Sale.” *The New York Times*, December 18, 1998.

Maibaum, Richard. “James Bond's 39 Bumps.” *The New York Times*, December 13, 1964.

Maiman, Theodore H. *The Laser Odyssey.* Blaine, Washington: Laser Press, 2000.

“Man Using Laser Pen Is Arrested in Harlem.” *The New York Times*, April 28, 1997.

Marriott, Michel. “CD-ROM Drive Maker Strives for a Quick Burn.” *The New York Times*, November 11, 1999.

__________. “Memory Takes New Shape.” *The New York Times*, April 1, 1999.

__________. “With Plenty of Shine and Spin, CD's Wave Tapestries of Data.” *The New York Times*, September 23, 1999.

Meyer, Scot. “Versatile Video CD's Get a Foothold in U.S.” *The New York Times*, April 26, 2001.

Mills, Joshua. “How Much Printer Do You Need?” *The New York Times*, February 8, 1994.

“Mr. Gates and the Pentagon Budget.” *The New York Times*, May 17, 2010.

Myers, Richard F., Ruth R. Perlin, James Wallace, and Alan Fusonie. “Laser Disk Systems for Bringing Images to the Scholar and Classroom: A Discussion.” *History Teacher* 24 (1991), 279-291.

Nichols, Peter M. “Fast Forward: Laser or DVD?” *The New York Times*, January 9, 1998.

__________. “Home Video.” *The New York Times*, May 16, 1997.

Nicholson, Tom and Evert Clark. “Patents: The Laser Man.” *Newsweek*, January 16, 1978.

O'Hanlon, Ann. “High-Tech Troublemakers.” *The Washington Post*, May 7, 1998.

“Optics: Pure Light for Practical Pictures.” *Time*, March 18, 1966.

Panati, Charles and Dewey Gram. “Have Laser, Will Travel.” *Newsweek*, March 28, 1977.

Pines, Maya. “The Laser Lights Up the Future.” *The New York Times*, September 8, 1963.

“Plastic Surgery: Laserasing Tattoos.” *Time*, October 20, 1967.

Ramirez, Anthony. “Laser Benefits Now Closer to Home.” *The New York Times*, July 22, 1992.

Reagan, Ronald Wilson. “Address to the Nation on National Security (March 23, 1983).” Miller Center of Public Affairs. Accessed March 6, 2011, http://millercenter.org/scripps/archive/speeches/detail/5454.

Roane, Kit R. “Man Is Arrested After Laser Sight Is Aimed at Officers in Brooklyn.” *The New York Times*, October 12, 1997.

Roberts, Johnnie L. “The Disc Wars.” *Newsweek*, August 26, 1996.

Rosenberg, Raoul. “The Many Phases of SDI.” *Bulletin of the Atomic Scientists* 44 (1988): 3-5.

Rothman, Wilson. “Burn-Your-Own-DVD's: First, Mind the Format.” *The New York Times*, September 5, 2002.

Ruby, Michael, Janet Huck, William Marbach, Ronald Henkoff, and Stephen H. Gayle. “Lasers Go to Work.” *Newsweek*, September 11, 1978.

Schmeck Jr, Harold M. “Light Beam Used in Eye Operation.” *The New York Times*, December 22, 1961.

Seligmann, Jean and Mary Hager. “Saving Sight With a Laser.” *Newsweek*, May 17, 1982.

Shirey, David L. “Holograms that Fascinate Eye and Mind.” *The New York Times*, September 9, 1979.

Slocum, Bill. “A Promising Youngster Called Photonics.” *The New York Times*, February 7, 1999.

Smith, William D. “New Ways of Talking: Electronic Pulses Hold the Key.” *The New York Times*, January 30, 1966.

Smyth, Jeannette. “The Laser: Shedding Light on Science.” *The Washington Post*, *Times Herald*, January 21, 1970.

Steele, Robert V. “Review and forecast of laser markets – Part II: Diode lasers.” *Laser Focus World* 36 (2000).

Stevens, William K. “With Cold War Over, Scientists Are Turning to 'Greener' Pastures.” *The New York Times*, October 27, 1992.

“Student's Eye Is Burned In Laser Pointer Incident.” *The New York Times*, December 22, 1998.

Taylor, Jim. *DVD Demystified*, 2nd Ed. New York: McGraw-Hill, 2001.

Tien, Ellen. “Beauty's Bomb, but How Smart?” *The New York Times*, August 30, 1998.

“Tesla Invents Peace Ray.” *The New York Times*, July 10, 1934.

“The Buck Rogers Gun.” *Newsweek*, July 25, 1977.

“The 'Miracle Ray' Is Coming of Age.” *U.S. News & World Report*, February 25, 1963.

“The War of the Worlds – Interior Illustrations.” Last modified January 23, 2006. http://drzeus.best.vwh.net/wotw/illus/interior.hmtl.

Townes, Charles H. *How The Laser Happened: Adventures of a Scientist*. New York: Oxford University Press, 1999.

Ulsamer, Edgar E. “Laser – The Weapon Whose Time is Near.” *Air Force & Space Digest* 53 (1970): 28-34.

“Universities: The Case for Secret Research.” *Time*, November 10, 1967.

Wall Street Journal Staff Reporter. “IBM Offers New Gear For Food Stores to Use at Checkout Stations.” *Wall Street Journal*, November 21, 1980.

“What's Wrong With Laser Surgery for Snoring?” *The New York Times*, September 21, 1993.

“Under-$100.” *Popular Science* 194 (1969): 92-93.

Waters, Harry F. and Ann Ray Martin. “Video's New Frontier.” *Newsweek*, December 8, 1975.

__________, Martin Kasindorf, and Betsy Carter. “TV Blasts Off!” *Newsweek*, September 11, 1978.

Wiener, Leonard. “To CD-R or CD-RW? Best to know before you buy.” *U.S. News & World Report*, September 4, 2000.

Wikipedia. Accessed February 6, 2011, http://en.wikipedia.org/wiki/File:Day_the_Earth_Stood_Still_1951.jpg.

Wells, H. G. *The War of the Worlds*. Wikisource, The Free Library, 2007. http://en.wikisource.org/w/index.php?title=The_War_of_the_Worlds/Book_1/Chapter_6&oldid=509002.

Secondary Sources:

"All Time Domestic Box Office Results." Box Office Mojo. Accessed April 1, 2011, http://boxofficemojo.com/alltime/domestic.htm.

Aron-Rosa, Daniele and Jean-Jacques Aron. "Lasers in the Service of Ophthalmology." *Impact of Science on Society* 31 (1981): 217-224.

Bromberg, Joan Lisa. "Amazing Light." *American Heritage of Invention & Technology* 7 (1992): 18-26.

__________. *The Laser in America, 1950-1970*. Cambridge, Mass.: MIT Press, 1991.

Folger, Tim. "Is Quantum Mechanics Tried, True, Wildly Successful, and Wrong?" *Science* 324 (2009): 1512-1513.

Foster, Jonathan. *The Death Ray: The Secret Life of Harry Grindell Matthews*. Inventive Publishing, 2009. Web book, http://www.harrygrindellmatthews.com/inventive.asp.

"Gallery Rayguns." Accessed February 4, 2011, http://www.toyraygun.com/flashgordon.html.

Hecht, Jeff. *Beam: The Race to Make the Laser*. New York: Oxford University Press, 2005.

__________. *Laser Pioneer Interviews*. Torrance, CA: High Tech Publications, 1985.

__________. *City of Light: The Story of Fiber Optics.* Boston: Academic Press, 1992.

__________. "Ray Guns Get Real." *IEEE Spectrum* 46 (2009): 28-33.

__________. *The Laser Guidebook*. New York: McGraw-Hill, 1999.

"History of the Museum of Holography." MIT Museum. Accessed March 30, 2011, http://web.mit.edu/museum/pdf/Museum_of_Holography_History.pdf.

Imlau, Mirco, Martin Fally, Hans Coufal, Geoffrey W. Burr, and Glenn T. Sincerbox. "Holography and Optical Storage." In *Springer Handbook of Lasers and Optics*. Edited by Frank Träger. New York: Springer Science+Business Media, 2007.

Kelly, Kevin, "The Secret Origin of the Ray Gun in Science Fiction." io9.com. Last modified March 24, 2008, http://io9.com/#!371411/the-secret-origin-of-the-ray-gun-in-science-fiction.

King Features Syndicate. "Welcome to FlashGordon.com!" Accessed February 4, 2011, http://www.flashgordon.com.

Lee, Luaine. “'Star Trek' Turns 40.” *San Jose Mercury News*, August 18, 2006.

Leith, Emmett N. “Chapter 39: Optical Holographic Imaging.” In *The Handbook of Surface Imaging and Visualization.* Edited by Arthur T. Hubbard, 537-555. Boca Raton, Florida: CRC Press, 1995.

“Mid Infrared Advanced Chemical Laser (MIRACL).” Federation of American Scientists. Accessed March 6, 2011, http://www.fas.org/spp/military/program/asat/miracl.htm.

“Milestones: Compact Disc Audio Player, 1979.” IEEE Global History Network. Accessed March 5, 2011, http://www.ieeeghn.org/wiki/index.php/Milestones:Compact_Disc_Audio_Player,_1979.

“Milestones: Development of VHS, a World Standard for Home Video Recording, 1976,” IEEE Global History Network. Accessed March 30, 2011, http://www.ieeeghn.org/wiki/index.php/Milestones:Development_of_VHS,_a_World_Standard_for_Home_Video_Recording,_1976.

“Milestones: List of IEEE Milestones.” IEEE Global History Network. Accessed March 31, 2011, http://www.ieeeghn.org/wiki/index.php/Milestones:List_of_IEEE_Milestones.

Mims, Forrest M. “The Evolution of Revolutionary Laser Weapons.” *Air Force Magazine* 54 (1972).

Mone, Gregory. “The Warp Drive.” *Popular Science*, May 1, 2006. http://www.popsci.com/military-aviation-space/article/2006-05/warp-drive.

Myers, Robert A. and Richard W. Dixon. “Who Invented the Laser: An Analysis of the Early Patents.” *Historical Studies in the Physical & Biological Sciences* 34 (2003): 115-149.

Nilsen, Joseph. “Legacy of the X-Ray Laser Program.” *Energy and Technology Review* (November 1994): 13-21.

Reilly, Edwin D. *Milestones in Computer Science and Information Technology*. Westporrt, CT: Greenwood Press, 2003.

Reynolds, Tom. “History of Barcode Scanners.” National Barcode. Accessed December 7, 2010, http://www.nationalbarcode.com/History-of-Barcode-Scanners.htm.

Seidel, Robert W. “From Glow to Flow: A History of Military Laser Research and Development.” *Historical Studies in the Physical & Biological Sciences* 18 (1987): 111-145.

__________. “How the Military Responded to the Laser.” *Physics Today* 41 (1998): 36-42.

Seideman, Tony. "Barcode History." Barcoding Incorporated. Accessed February 17, 2011, http://www.barcoding.com/information/barcode_history.shtml.

Slayton, Rebecca. "From Death Rays to Light Sabers: Making Laser Weapons Surgically Precise." *Technology and Culture* 52 (2011): 45-74.

"The Day the Earth Stood Still (1951) – Box Office / business." The Internet Movie Database. Accessed February 6, 2011, http://www.imdb.com/title/tt0043456/business.

"The Death Ray." The Internet Movie Database. Accessed February 6, 2011, http://www.imdb.com/title/tt0303894.

Townes, Charles. "The First Laser." In *A Century of Nature: Twenty-One Discoveries that Changed Science and the World*. Edited by Laura Garwin and Tim Lincoln, 107-112. Chicago: University of Chicago Press, 2003.

Wolverton, Mark. "A Solution for Almost Everything: 50 Years of the Laser." *American Heritage of Invention & Technology* 25 (2010): 23-43.