

August 2006 Draft: Do Not Believe, Internalize, or Cite

The Laser and its Implications: How Accurate Was Foresight in the First Ten Years?

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The Laser and its Implications: How Accurate Was Foresight in the First Ten Years?

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Note: I want to acknowledge the generous help of Jeff Hecht and Nick Taylor with this research. I also appreciate the reflections of Charles Townes on the range and significance of laser applications

Abstract

In the late 1950's it was becoming clear that the principles of the maser, a microwave-emitting device, could be extended to much shorter wavelengths, including that of visible light. This paper reviews the visions of the future uses of lasers that were presented to the general public from 1960, when the first laser was demonstrated, to 1970. Because we know how laser applications actually evolved over the succeeding 35 years, we can now systematically identify patterns in the errors of foresight that appeared in the 1960's. We can also begin to ask whether such errors were vitally important to us as a nation. We know, for example, of many forecasts that never proved out, and we know of many significant laser applications that were not anticipated in the first ten years of the laser. Key deficiencies in foresight included weakness in appreciating that small, cheap lasers could be so useful, that so many high-power applications – many of them forecast for military and space applications -- would not prove practical. Contemporary media accounts of the promise of the laser [no serious social downsides were foreseen] gave misleading indications of the laser's role; those who read such accounts should have had little confidence in them. However, it is not at all clear that weak foresight caused significant problems, and it does appear that a form of self-correction was occurring through the decade.

1 Part 1 – The Laser Story in Brief

2

3 The term “laser” is an initialism for “**L**ight **A**mplification by **S**timulated **E**mission of
4 **R**adiation.” Laser technology is an unexpected product of quantum physics, which had
5 revealed that atoms shift from one energy level to another only by a limited number of
6 discrete amounts, called quanta. When an atom is “pumped” to a higher level, it can
7 only absorb particular quanta of energy; and when it loses energy, it emits the same
8 limited quanta of energy in the form of radiation, sometimes as an individual photon. In
9 the late 1950s researchers speculated that if you found the right source atoms, and
10 initially excited them to a higher energy state, they might spontaneously emit light in the
11 form of light of a pure color when the atoms reverted to their lower energy state. Some
12 researchers realized that this could be done in a way that creates a beam of highly
13 coherent [“collimated”] light that does not diffuse significantly after it leaves its source.

14

15 Even before the first practical laser was demonstrated in 1960, government had showed
16 interest in the prospective technology, and had funded research¹. The Air Force was
17 interested in laser research, and offered to support some university work. Then, in
18 1958, a small research company approached the Advanced Research Projects Agency
19 [ARPA] with a proposal to work on the laser concept, and laid out a range of possible
20 practical applications. ARPA made a grant of \$1million, dwarfing the requested sum of

¹ Insert Townes indifference to USAF funding offer here.

1 \$300,000.² Soon many companies, including AT+T, GE, RCA, IBM, and Hughes joined
2 a race to build the first laser.

3
4 The big breakthrough occurred in the California beach community of Malibu, of all
5 places, when Theodore Maiman of Hughes Aircraft, working with a project budget of
6 only \$50,000, used a pink ruby to produce a low-power burst of lased light. In the next
7 several months, others would demonstrate lab lasers using many other materials,
8 including a helium-neon mix, carbon dioxide, and, eventually, semiconducting material.
9 Researchers expressed surprise at how many materials could be made to lase in the
10 lab.

11
12 Developers now attacked the limitations that stood in the way of practical application.
13 They were interested in a source that produced a steady beam, not just pulses, and
14 they wanted a source that operated at room temperature and did not thus require
15 cooling. They looked to get around the fact that any laser only produced light at only
16 one fixed frequency, a problem in some applications. But most of all, they wanted to
17 develop lasers that would produce more power – that were strong enough to deliver
18 significant action at a distance. All these obstacles would be greatly diminished in the
19 1960s.

20

² Nick Taylor, *Laser: The Inventor, the Nobel Laureate, and the Thirty-Year Patent War* (New York: Simon and Schuster, 2000), pp. 85-91.

1 The immediate flood of talent into the field was impressive. It was reported in early
2 1962 that ATT's Bell Labs had 150 people working on laser development³, and that 400
3 US companies had teams working on lasers.⁴ Total research was reported to be about
4 \$30 million a year, with the government supplying about one-half of that sum.⁵ Less
5 than a thousand days after the earth's first laser appeared, 1500 engineers were said to
6 be working on the subject.⁶ At this point, actual laser sales to users were miniscule, but
7 there were already forecasts of a \$1 billion market by 1970.⁷ A large, diverse, and still
8 growing list of potential future applications took form, with laser communications and
9 laser weapons heading the list. Consumer products, however, were not foreseen⁸.

10

11 In about 1964, signs of a letdown became evident as expected applications were slow
12 to prove out. Basic communications application seemed to be a particular
13 disappointment, as the prestigious Bell Labs team was unable to make the needed
14 practical breakthroughs as the 1960s progressed. It was at this point that the idea that
15 the laser was "a solution looking for a problem" took flight. The laser effort slowed, and
16 the community appeared to pause in order to catch its breath. In 1965, it was reported
17 by *Laser Focus* that while laser sales were now up to \$40 million, that was still less than

³ "Light Ray -- Fantastic Weapon of the Future?," *US News and World Report*, April 2 1962, p. 47.

⁴ *Ibid.*, p. 50.

⁵ "The Laser: Special Report," *Business Week*, August 18 1962, p. 62. Defense agencies sponsored the key national scientific conferences on laser in the early days.

⁶ Harlan Manchester, "Light of Hope -- Or Terror?," *Reader's Digest*, February 1963, p. 99.

⁷ Lawrence Lessing, "The Laser's Dazzling Future," *Fortune*, June 1963, p. 139.

⁸ [XXX Add "no consumer impact" report here.]

Laser Implications: How Accurate Were Early Forecasts?

1 the \$60 million still being spent on laser research.⁹ The cautious mood in 1964 was
2 perhaps best caught in the title of a *Popular Mechanics* piece: "Here's Why Those Do-
3 Everything Lasers Don't -- Yet,"¹⁰

4

5 By 1968, however, lasers were taking off, and confidence returned. A *Time* article
6 noted that annual sales were now up to \$300 million, and reported that "the versatile
7 laser is beginning to solve [practical] problems in a manner that more than justifies the
8 early, expansive claims."¹¹ Laser researcher and maser inventor Charles Townes,
9 already a Nobel Laureate, wrote that the business was doubling every three years;¹²
10 This meant that the billion-dollar market milestone was now clearly within sight. At the
11 end of the decade, effective communication technologies finally appeared, and the laser
12 was no longer just a novelty. Its eventual ubiquity, however, was yet to be appreciated.

13

14 Part 2 – Anticipating the Laser’s Role; Media Coverage 1960-1970

15

⁹ "The Wonderworld of Lasers," *Changing Times*, February 1967, p. 17.

¹⁰ Theodore Berland, "Here's Why Those Do-Everything Lasers Don't -- Yet," *Popular Mechanics*, March 1964.

¹¹ "The Power and Potential of Pure Light," *Time*, July 12 1968, p. 42.

¹² Charles H. Townes, "The Laser -- What it Can Do," *US News and World Report*, December 23 1968, p.

81. One major factor was that the technical issues in point-to-point optical communication were now quickly being solved.

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1 *The Study Approach* – We selected the laser for early consideration in the MIT PoET
2 program¹³ in part because the recent advent and rapid spread of this technology made
3 its history relatively accessible. We thought that we would be able to retrieve a sense of
4 how the future of the laser was perceived soon after it was thought up. That would give
5 us a way for assessing the reliability of foresight when a emerging technology first
6 emerges, and, ideally, a way to try to identify any systematic sources of error that would
7 be useful to those struggling to foresee the implications of today’s emerging
8 technologies.

9
10 It soon became apparent, however, that the task would not be so easy. Laser forecasts
11 have not been seriously studied. We have found neither a careful *retrospective*
12 examination of foresight about the laser nor a systematic *prospective* professional
13 technology forecast. We thus decided to conduct a routine review of mass media
14 accounts of the laser for the 1960s. This is not, of course, an ideal lens through which
15 to understand how experts themselves – nor their funders -- were perceiving the laser’s
16 future significance. It is, however, a way to form a picture of what the public was being
17 told, and articles aimed at the general public are likely to hit on the social impact of the
18 technology as well as the shapes that the technology will take.

19

¹³ The Institute’s **Program On Emerging Technologies** provides funding for about 15 graduate students under a grant from the National Science Foundation’s Interdisciplinary Graduate Education Research and Training [IGERT] program.

1 We conducted two systematic searches of media accounts from 1960 to 1970. We
2 screened the contents of the *Reader's Guide to Periodical Literature*, selecting and
3 reading all articles that had appeared in general-reader magazines, and second, we
4 conducted an electronic search of articles in *The New York Times* for the same period.
5 Supplemented with the spare handful of books and professional articles on the history
6 of the laser, these media accounts form the basis of inference for this paper.

7
8 *The Data* -- We located 140 mass-reader accounts of the laser and its future. Half
9 were from the *New York Times*, which averaged about six articles per year, and half
10 were from non-daily periodicals appearing in the *Reader's Guide*. *Time* and *Business*
11 *Week* led the periodicals in coverage with about one substantive article per year in the
12 1960s. *Life*, *Reader's Digest*, *Fortune*, *US News*, *National Geographic*, and *The*
13 *Saturday Review* all featured the laser in this decade [most of them covering the subject
14 only once]. Eight more articles were found in *Popular Science* and *Popular Mechanics*.

15
16 Of the total of 140 articles, 45 undertook to survey of current and future laser
17 applications. A few were devoted to particular applications areas, like medical care, but
18 most were broader. Ninety-five articles were primarily standard news stories of a new
19 technological advance, a new product, or the first demonstration of a particular
20 application. By the end of 1963, half of the laser forecasts had appeared, but only
21 about a quarter of the hard-news articles had.

22
23 *Some Balance Issues in the Media Coverage.*

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1
2 This project is not a study of media behavior. However, there is a sense in which media
3 coverage has to mesh with popular attitudes and tastes, and thus it is useful to briefly
4 note three aspects of media treatment of the laser's future that reveal something about
5 the way we think about technology and the change that it brings.

6
7 First, many accounts were dominated by coverage of potential military and space
8 applications. The notion of a death ray – the counterpart, in a literary sense, to the evil
9 eye – had long before taken hold as a possibility in science fiction.¹⁴ In retrospect, the
10 general idea of the laser cannon appears much exaggerated in early coverage. A
11 typical 1962 *Times* headline: "Air Force Seeking Light Rays to Knock Down Foe's
12 ICBM's."¹⁵ A month later, *US News* carried a cover story under the banner, "'Light Ray'
13 -- Fantastic Weapon of the Future?"¹⁶

14
15 Second, dramatic new uses were overemphasized in comparison with important but
16 mundane applications. Novelty was highly valued; a good example was the *Times*
17 story, "Scientists Cut Diamond with New Light Beam."¹⁷ Meanwhile, important everyday
18 applications like laser alignment of underground tunnels and drilling and shaping in

¹⁴ XXX H.G Wells introduced one into his fiction in 18XX.

¹⁵ Jack Raymond, "Air Force Seeking Light Rays to Knock Down Foe's ICBMs," *New York Times*, March 29 1962.

¹⁶ "Light Ray -- Fantastic Weapon of the Future?." *US News and World Report*, April 2, 1962, page 47.

¹⁷ "Scientists Cut Diamond with New Light Beam," *New York Times*, April 18 1962.

1 industry were largely neglected. One must ask whether even professionals do not
 2 share this partiality for the new and the dramatic when they examine newly emerging
 3 technologies. Such astigmatic foresight may well be a human trait, not just a media
 4 bias.

5
 6 Third, there was scant suggestion that lasers would become a part of daily life for
 7 ordinary citizens. Military uses, medical uses and industrial uses dominated the
 8 coverage, and the basic idea that the laser would become ubiquitous in so many
 9 American homes – in music players, printers, etc., is not to be found. There is some
 10 irony in the fact that it was not uncommon to cite the laser as analogous to the transistor
 11 in its eventual importance, but analogies to the common transistor radio were not
 12 pursued.

13
 14 Part 3 – Anticipation vs. Reality – “Myopimetrics” for the Laser

15 Our central purpose in this paper is to see how past foresight compares with actual
 16 events, and a form of truth table helps us do that. A general scheme might sort
 17 applications into a 2-by-3 “myopimetrics” chart:

18

	<u><i>Foreseen and Did Happen</i></u>	<u><i>Foreseen, But Didn't Happen</i></u>	<u><i>Unforeseen, but Happened</i></u>
<u><i>Tech. Boons</i></u>	Cell 1: Good foresight	Cell 2: “False Hopes”	Cell 3: “Bonus Boons”
<u><i>Tech. Banes</i></u>	Cell 4: Good foresight	Cell 5: “False Fears”	Cell 6: “Gotcha Banes”

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1 For the case of the laser forecasts of the 1960's, it turns out, no serious banes were
 2 anticipated in the mass print media, and thus cell 5 is empty. Since the issue of
 3 possible "gotcha banes" [cell 6] is discussed separately below, and "good foresight" [cell
 4 4] entails no social disconnect, only cells 1, 2, and 3 are treated further in this section.

<u>Myopimetric Table – 1960's Foresight for the Laser, as Assessed In 2006</u>	
False Hopes	Laser cannon/death ray, nuclear fusion, underwater searchlight, power transmission to satellites, space communications, rocket ignition, SETI, satellite communications, narrow-beam "radar", space re-entry communication, submarine communication, data processing, television transmission and display, tree-pruning, forest-clearing, electrical bulbs, typewriter eraser, potato peeler, pilot light, spark plugs, enhanced sonar, 3-D television, weather forecasting, astronomy probes, dentistry, cancer treatment.
Bonus Boons	CD/DVD technology, scanners, specialized printing applications, personal printers, speeding detectors, anti-acne treatment, lasik surgery . . . etc.
Good Foresight	Point-to-point communications, spectrometry/interferometers, chemical reactions, light amplifies, materials handling [cutting, vaporizing, drilling], scientific tool [myriad applications], rangefinders, target-illuminators, length and distance measurement, precise construction alignment, holography, optical gyroscope, strobe light, art fraud detection, air turbulence detection, pollution monitoring, ophthalmology, surgery/microsurgery, wound cauterizing,

5

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1 Appendix A contains some detail, application by application, of the vision that appeared
2 in 1960's media. The discussion here is restricted to the major points that emerge from
3 the myopimetric chart above.

4

5 Part 4 – On Errors in Technological Foresight

6

7 The results presented above enumerate fairly large numbers of errors of foresight in the
8 anticipation of the laser's eventual form and role. A main question that now needs to be
9 addressed is what underlying *patterns* might be suggested in these lists of particulars.

10

11 *[A] The Reality That The Forecasters Missed: the Rise of Cheaper, and Usually*
12 *Smaller, Lasers.*

13 When one thinks about the ubiquity of lasers in today's world, it is striking that so many
14 of the common applications employ small and cheap lasers. Compact disc readers and
15 burners come with most new computers, in-home DVD players, the point-of-sale
16 scanners that are now routinely found at checkout counters, and laser printers [including
17 the burgeoning use of lasers for printing on irregular surfaces – shrink-wraps, plastic
18 containers, metal, etc.] are important examples. All depend on small-scale and
19 inexpensive lasing, and none was generally anticipated by 1970.¹⁸ This failure of 1960s

¹⁸ The only two exceptions were for laser printing; in 1962, it was reported that RCA had filed for a patent on a way to use a laser for "non-contact" printing [see "RCA is Granted Patent on Laser Book Printer," *Publisher's Weekly*, December 2 1962, pp. 78-80.], and may have envisioned large-scale machinery. This potential application did not re-appear in general-circulation media until 1968, in Stacy V. Jones,

1 foresight was due to a failure to understand the way that laser technology *itself* was
2 evolving; it was not that the technology was accurately anticipated and the market
3 demand was alone misapprehended.

4

5 The research community was focused mostly on making larger and more powerful
6 lasers in the 1960s; the goal was to deposit more energy at a longer distance.

7 Sometimes, media notice was made that a new milestone was achieved in the laser's
8 output wattage. One might conjecture that early interest was placed on powerful lasers
9 because of the interest in military, space, and communication applications, which
10 inherently required more power, and which may have seemed dominant among laser
11 applications to press and public alike.

12

13 The only class of applications of primary interest in the 1960s that was free of a "bigger
14 is better" flavor was that of medical uses. It was clear from the outset that precision
15 ["knifeless"] surgery had to be a small-scale undertaking; in fact, one of the stated
16 advantages of operating with a laser was that a the laser might be smaller than a
17 scalpel, and thus able to reach areas in the body that scalpels couldn't. And as early as
18 1963, a *Life* article even suggested that scientists would someday use lasers to perform
19 "microsurgery" to destroy particular chromosomes within an animal cell nucleus. It was
20 said that this would allow ingenious genetics experiments.¹⁹ Still, medical applications

"Laser's Beam Is Used in Printing," *New York Times*, November 16 1968. Laser printing did not appear in any of the laser survey articles.

¹⁹ "The Amazing Laser," *Life*, January 4 1963, p. 51.

1 attracted far less coverage that they might now; and those who now reflect on the
2 sentiments of laser developers in the 1960s see the decade as one in which size really
3 did matter.

4
5 We often call our era the Information Age or the Computer Age. It seems possible that
6 later generations will also see our times as the Age of Miniaturization, and the laser has
7 turned out to play a distinct role in making things smaller. That role may be less
8 pervasive than that of microelectronics, nanotechnology, the miniaturization of cameras,
9 modern microsurgery, and cell-level biotechnology, but it is a signal contributor, and it
10 was among the first to arrive on the scene.

11
12 It thus seems ironic, in retrospect, that the future utility of small lasers was largely
13 unappreciated in the 1960s. After all, the transistor was one of the icons of modern
14 innovation at that time, and the new hand-held radio receivers were conspicuous
15 modern marvels.

16
17 Furthermore, the earliest lasers were themselves small. Theodore Maiman's original
18 laser itself used a ruby the size of the tip of a little finger, for example. And a year later a
19 hand-held "PistoLaser" was – for a time -- marketed at a price of \$2950.²⁰ Looking back
20 now, we can find a few acknowledgements that small, cheap lasers were, in fact,
21 proving feasible. A *New York Times* reporter, for example, noted in 1963 that "lasers are
22 now getting smaller and lighter. One model . . . consists of a semiconductor so small

²⁰ "Laser Gun Shoots Light Rays," *Business Week*, December 30 1961, p. 80 ff.

1 that it can hardly be seen without a microscope,"²¹ and that same year *Time* reported a
2 new Tyco Laboratories laser, one powered by flashlight batteries, that the company
3 "could put out in a box the size of a pack of cards, batteries and all."²² By 1970, Bell
4 Labs had announced the development of a new laser "the size of a pen light or cigarette
5 lighter, [which should] cost a few dollars at most and should be capable of giving a
6 lifetime of service."²³ However, except for medical lasers, small-scale *applications*
7 remained vanishingly rare in the forecasts of the 1960s – and even the idea of
8 microsurgery was only appeared in but a handful of the many media surveys. Miniature
9 lasers did not intrigue the imagination.

10

11 *[B] False Hopes in Defense, Space and Energy Applications: Unreasonable Near-term*
12 *Hopes for Telekinetics.*

13 Of the 35 technological projections from the 1960s that remain unfulfilled in 2006,
14 fourteen are found in defense, space, and energy applications. And it is these 14
15 projections that were so conspicuous in early accounts of the laser's future, especially
16 from 1960 to 1963. These False Hopes include the laser cannon [or "Death Ray,"]²⁴

²¹ Maya Pines, "The Laser Lights Up the Future," *New York Times*, September 8 1963, p. 125.

²² "Practical Laser," *Time*, September 13 1963, p. 63.

²³ Jane E. Brody, "Bell Developing a Pocket Laser," *New York Times*, September 1 1970, p. 18.

²⁴ The Pentagon is still at work on the laser cannon. Its High Energy Laser Energy Defense System [HELLADS; know informally as the "HEL weapon"] project is expected to place a 150 kW beam on a fighter jet in 2007, one with the capacity "of knocking down a missile." The cost of this weapon, said to weigh less than a ton, was not reported. "Airborne Laser Brings Star Wars One Step Closer," *Reuters*, August 24 2005. The current DoD budget includes \$51 million for testing "a variety of powerful laser

1 space propulsion, fusion energy, long distance power transmission [including the
2 powering of satellites from ground stations], and effective communications in both space
3 and underwater, among submarines.

4

5 These applications have, at least to date, foundered on their enormous power
6 requirements, and the consequent need for very high energy efficiencies.²⁵

7

8 One can ask why developers failed to appreciate the difficulties in providing the power
9 requirements of these ideas. It may be that overcoming this technological hurdle
10 seemed no more daunting than the notion of getting massively explosive energies out of
11 miniscule atoms had previously. Or the spur may have been that if the USSR were to
12 develop such technologies, US losses could be huge, and they were thus worth a very
13 long gamble – one that the profit-hungry private sector could not itself entertain, but that
14 the government could not afford ignore.

15

16 *[C] Weak Cost-Forecasting: A Hidden Secret Behind The Bad Guesses?*

beams” as anti-satellite weapons: see Bryan Bender, "Pentagon Eyeing Weapons in Space," *Boston Globe*, March 14 2006, p. A9.

²⁵ Energy efficiency is not a common reason for the failure for the other 21 False Hopes, which include such diverse applications as tooth drilling, broadcast transmission, data processing, light bulbs, typewriter erasers, 3D television sets, and potato peelers.

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1 The review of both the False Hopes and the Bonus Boons of laser technology reveals a
2 major obstacle to accuracy in forecasting that has received little attention: projecting
3 costs.

4
5 Virtually all the projections of the laser's future that we found considered only the
6 anticipated *capabilities* of the technology. We found no coverage of future *costs*. In
7 fact, of course, one must understand both a device's capability *and* its cost to accurately
8 foresee the timing and likelihood of future breakthroughs. If hand-held CD players, for
9 example, cost \$5000 each, not many would now be in use, and those who imagined
10 laser-operated potato peelers should have remembered the low cost of the paring knife.

11
12 It is the cost factor that greatly complicates the job of accurate prediction, because of
13 the strong positive feedback seen in cost reductions: that is, if a product's costs can be
14 reduced, more units can be sold, which leads to greater economies of scale and/or
15 product learning curves, which leads to still lower costs. Estimating future production
16 costs is not simply a matter of forecasting the subject technology itself; it takes an
17 understanding of the number of and needs of potential buyers and it takes some
18 understanding of the future costs of competing technologies that may themselves
19 decline. Existing writings on forecasting do not appear to adequately address, either
20 empirically or conceptually, the cost side of technological forecasting. [[[XXX -- Needs
21 further confirmation.]]]

22

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1 Recognition of the role of cost estimation in technology forecasts shows why accurate
2 forecasting is so difficult. In a sense, the forecaster must independently consider both
3 the supply curve and the demand curve for the evolving technology, and for each
4 technology that competes with the laser-based device. Each curve has its own
5 uncertainty range, and so estimating exactly where the two banded curves will intersect
6 is subject to the multiplicative effects of these two uncertainties.

7

8 *[D] Uncertainty in Forecasting Competing and Enabling Technologies; Another Major*
9 *Impediment*

10

11 With the hindsight of over 40 years, it seems clear that there was over-exuberance in
12 the early rush to develop workable lasers. In about 1964, a shakeout was taking place,
13 and it seemed to many participants that earlier expectations had been excessive.²⁶

14 [This is the period in which it seems plausible that a new phrase entered the American
15 lexicon because of the laser, which was seen as “a solution looking for a problem.”²⁷]

16 Looking back, it seems remarkable that significant progress was expected within two or

²⁶ The sentiment was captured in the title for one 1964 article: Berland, "Here's Why Those Do-Everything Lasers Don't -- Yet," p. 102 ff.

²⁷ It was the designer of the first laser, Theodore Maiman, who was given as the source of this *bon mot*; see William M. Freeman, "Developer of the Laser Calls It 'A Solution Looking for a Problem'," *New York Times*, May 6 1964, p. 69. However, it is not clear that he meant to invest the phrase with the sense of skepticism that it now connotes.

1 three years; but within the new laser community, the honeymoon was over. What was
2 holding things up?

3

4 This mid-1960's gloom was, perhaps, felt most deeply for point-to-point
5 telecommunications. Communications had been an application for which early success
6 had been expected, not least, perhaps, because of the sizable concentrated
7 development effort at the prestigious Bell Telephone Laboratories, where laser giants –
8 and eventual Nobel Laureates -- Charles Townes and Arthur Schawlow had done
9 pioneering work. Practical point-to-point communications did not really emerge until the
10 very end of the 1960s, and the reason for this delay offers another general lesson about
11 the hazards of prediction. There had been two major factors for the slow progress.
12 One was that competing transmission technologies – especially microwave – were able
13 themselves to advance as a better and cheaper alternative. The second was that it had
14 become clear that some form of light guides would be needed, rather than open-air
15 transmissions, and that new methods for signal regeneration and routing would be
16 needed. Until “cladded” optical fibers were developed, and signal processing
17 technology appeared, the laser was not competitive. Thus, forecasters had to deal with
18 both the uncertainties of new enabling technologies and of evolving concomitant
19 competing technologies [and, of course, the eventual costs of both] to assess the future
20 of this central laser application.

21

22 Part 5 – On Problems in Foresight about Future Social Impacts

23 *[E] Nobody Really Worried about the Laser's Downsides – But Did it Really Matter?*

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1 Modern society is a contentious one, and it sometimes seems that some group will arise
2 to oppose any new proposal, no matter how innocuous. A new technology necessary
3 produces losers as well as winners, and in a world filled with environmental advocates,
4 health advocates, and the forces of NIMBY,²⁸ one expects to find controversy
5 everywhere, especially when uncertain consequences abound.

6
7 We were thus not prepared to find a total absence of caution and skepticism about laser
8 technologies. Concerns and opposing views were totally missing from the coverage of
9 the laser. No Cassandra appeared. Other than some rare and subdued mentions of
10 the danger to eyesight of exposure to laser light [mostly depicted as a hazard for
11 researchers themselves]²⁹, media coverage seemed to portray the laser as unalloyed
12 boon, and there was no inclination to fear a Faustian bargain in the pursuit of this new
13 technology.

14
15 And, as far as we can see four decades later, they were about right. No shocking
16 downside was missed that we are clearly regretting for today. Lasers are, all in all,
17 good for us.

²⁸ “**Not In My Back Yard**,” or local resistance to placing unwanted public or private facilities nearby.

²⁹ There was one odd exception. In 1965 an article reported on a paper delivered at the American Chemical Society meeting suggesting that, based on animal studies, “laser beams may cause damage to the eyes, brain, and other organs:” see “A Hidden Danger Found in Lasers,” *New York Times*, April 5 1965, p. 21. This suggestion is found nowhere else in our materials. The research had been supported by the Army Surgeon General’s Office.

1
2 Part of the MIT POET Program’s interest in emerging technologies hinges on
3 anticipating and confronting the adverse effects of new technology, and so we
4 redoubled our effort to plumb the real and perceived downsides of the laser. We looked
5 to see if there was controversy over the possible militarization of space if Cold Warriors
6 all lofted “death ray” generators into the skies – and found none. We found some
7 disagreement about the utility of laser cannons [notably, *The New Republic* weighed in
8 on the notion of “bullets of light” laser weapons in 1963,³⁰ warning that it was not
9 feasible], but the debate was over the short-term feasibility of laser weapons, given their
10 enormous power needs, and never about the broader issue of militarization.

11
12 We examined the possible adverse effect of putting laser-sightings on hand guns, on
13 the premise that criminals could be much more threatening if armed with more precise
14 guns.³¹ This issue has never excited much interest in the general population, not least
15 because laser-sighting is actually of limited utility to shooters for technical reasons – for
16 example, the sighting beam itself can, with relentless precision, reveal the shooter’s
17 position to others.³²

³⁰ William Boggs, "Bullets of Light," *The New Republic*, March 16 1963, pp. 5-6.

³¹ Germany, Switzerland, and New York City prohibit the use of laser sights. H.R. 2421 [106th Congress, 1st Session] proposed to add laser-sighted firearms to the list of controlled weapons. Laser sights are easily obtained by gun owners.

³² Laser sights are effective only in certain lighting conditions, and cannot cope with the need to “lead” a moving target. It is reported that militaries now do not use laser sights, and police rarely do.

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1

2 One adverse effect of lasers – one that did not trouble 1960s forecasters – has
3 surfaced, and that is the willful or negligent blinding of individuals by laser beams.³³

4

5 The potential of eye damage from lasers was obvious from the beginning – in fact,
6 Maiman himself may have experienced serious eye irritation in the hours before he
7 coaxed the world's first laser to life.³⁴ Eventually FDA regulatory issued standards for
8 lasers of different power levels, and to universities and other research establishments
9 have safety guidelines for laser users.

10

11 Nonetheless, eye damage does occur outside the lab. Several temporary blindings
12 occur each year;³⁵ typical cases involve misuse of low-power laser pointers as
13 playthings by young people.

14

15 There is contemporary concern about a newly-reported danger; malicious attempts to
16 blind airborne pilots with laser light. It is reported that over 400 such incidents have
17 occurred since 1990,³⁶ with dramatic recent increases reportedly stimulated by the

³³ Laser inventor Gordon Gould's 1959 grant proposal to ARPA raised the possibility of blinding of enemy troops with lasers. The Geneva Convention prohibits military use of lasers to blind enemy soldiers.

³⁴ <<XXX find that Maiman account>>

³⁵ Estimates of the number of accidents from 1964 to 2003 range from 400 to 4000. See R. Timothy Hitchcock, "Walking the Knife Edge -- Myths in Laser Safety," *The Laser Institute of America Today*, July 2003. Malaysia has banned laser pointers.

³⁶ Bart Elias, "Lasers Aimed at Aircraft Cockpits," ed. Congressional Research Service (January 2005).

1 reduction in the prices of green lasers. In February 2006 a man in New Jersey was
2 convicted of aiming a laser at aircraft from his back yard, momentarily blinding both
3 pilots in a twin-engine charter plane.³⁷ Such effects are now feared as a potential
4 terrorist tactic, and sanctions and countermeasures are being explored.³⁸

5
6 So here is one clearly adverse effect of the laser that might have been anticipated, but
7 wasn't. If it had been – if a prescient seer in 1966 had known that this problem would
8 arise 40 years later – what might have been done that wasn't? An aggressive response
9 might have been to license users of industrial lasers capable of distant blindings. Would
10 such an action have been wise? Would its benefits in risk reduction have been greater
11 than the costs in retarding full use of industrial lasers? That seems doubtful – not least
12 because it would have been difficult to believe, in the 1960s, how distressing terrorism
13 could become to Americans – and such measures even now are not being considered.

14
15 Our general conclusion has to be that the apparent absence of caution in the early
16 assessment of the future of the laser has caused little known social harm.

17

Few of these have apparently made the news.

³⁷ John Holl, "Man is Sentenced to Probation for Shining a Laser Beam at a Passing Plane," *New York Times*, February 18 2006, p. A13. The plane was at an altitude of 3000 feet and was 11 miles from its destination at Teterboro Airport. The laser had been purchased via the internet.

³⁸ Federal law prohibits the intentional aiming of lasers at commercial flights.

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1 Still, it is worth trying to understand why the laser story was so uncontroversial – why it
2 is that *false* fears, at least, were not raised. One possibility is that there were many
3 cautious people who were initially worried about adverse effects, but all of them soon
4 satisfied themselves that there was no conceivable downside, and they remained quiet.
5 I doubt this conjecture; the great majority of media accounts simply lack any coverage
6 of downsides against the potential upsides of lasers, even though such controversies
7 might have added color to contemporary articles.

8

9 A simpler and fairly persuasive explanation is that the 1960s were simply technology-
10 friendly, especially for technologies with plausible national security implications. The
11 Cold War was at its height, and the public perceived clearly that technical might
12 translated to military might; atomic weapons and radar were seen as two keys to victory
13 in the World War II [which then lay just 15 years in the past]. The Soviet Union had
14 developed a hydrogen bomb much sooner than we thought it could, appeared to have a
15 startling edge in space flight . . . and if a small Sputnik could wing its way directly over
16 the US heartland now, who knew what fearful capabilities could come along in its wake?
17 President Kennedy took office in 1961 after raising a campaign warning that there was a
18 US/USSR missile gap, and the US was playing catch-up. In fact, there are slight but
19 positive traces in media accounts that the Soviets were working hard to take a lead in
20 laser development itself. Readers of the Sunday magazine of the *New York Times*
21 were told in 1963:

22

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1 “While many of the latest developments in laser techniques are secret, reports
2 from scientific meetings indicate that the Russians have known the principles of
3 lasers for several years. During an interview with an American industrialist last
4 winter, Premier Khrushchev picked up a steel ruler from his desk, pointed to tiny
5 holes in it which he said were drilled by laser light, and boasted that Soviet
6 scientists were well ahead of ours in this field.”³⁹

7
8 Similarly, General Curtis LeMay, chief of staff for the US Air Force, asserted that laser
9 weaponry would mean a “new era in warfare,” and darkly reminded his audience of
10 Russian laser research and Khrushchev’s mention of a new “fantastic weapon.”⁴⁰

11
12 In addition, the 1960s was a period in which civilian technology was still generally seen
13 as benign at worst, and labor-saving on average. Attitudes would change before long –

³⁹ Pines, "The Laser Lights Up the Future," p, 124. In November 1963, the Soviets were reported to have bounced a laser beam off the moon, duplicating an American feat conducted only a year earlier: see "Soviet Bounces Light Beam off Moon in a Laser Test," *New York Times*, November 5 1963, p. 5. In 1965, long before American researchers had mastered the practical difficulties in point-to-point communications, a Soviet newspaper announced that a laser link would soon be introduced into the Moscow telephone system: see "Moscow to Open Laser Phone Link," *New York Times*, October 31 1965, p. 20.

⁴⁰ Raymond, "Air Force Seeking Light Rays to Knock Down Foe's ICBMs," p. 2. One magazine also speculated that the Russians were at work on the gamma-ray emitting “graser,” which would present known risks to living tissue and penetrate water. See Wallace Cloud, "Science Newsfront: More Coherent Rays," *Popular Science* 1965, p. 29.

1 Earth Day was coming ever closer, the consumerist movement was developing steam,
2 environmental activism was rousing, and broad concerns about the stratospheric ozone
3 hole and global warming were going to appear before long. But the 1960s remained a
4 largely pro-technology era, and the nature of technological forecasts reflected that
5 essential fact.

6

7 [F] Truth-Testing Some Theories Against the Laser Case

8

9 Members of our research team have suggested two generalizations concerning the
10 uptake of emerging technologies, and it is useful at this point to test each of them
11 against the case of the early evolution of the laser.

12

13 [1] The “Plug-in Fallacy.” The first premise is that foresight about emerging
14 technologies tends to be accurate when applied to *plug-in* applications, and to be
15 inaccurate for revolutionary applications and second-order social implications. A “plug-
16 in” application simply replaces a component of an existing system with a newly-
17 emerging component. For example, if a transistor can be plugged into a circuit to
18 replace a vacuum tube, that application will be most clearly seen and forecast. The
19 automobile would be thought of simply as a carriage that needed no horse – a matter of
20 plugging in a new source of motive power into the current transportation system, rather
21 than as a device that could help transform western culture.

22

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1 There are senses in which the plug-in fallacy is found in the laser case, but they are
2 neither pervasive nor significant. It is true that the earliest applications included
3 ophthalmic procedures for which strong carbon-arc light sources had already been
4 used. However, some of the most widely discussed possible applications, most
5 trenchantly the “death ray,” were not plug-ins at all, as the imagined function was not
6 being performed by any existing technology, and the idea itself was born of science
7 fiction.

8
9 One factor that seems to militate against the plug-in fallacy is that media authors
10 evidently find plug-in applications less newsworthy than more imaginative,
11 unprecedented applications. That is not to say that, in the 1960s, they routinely
12 encourage introspection about either the wisdom or the second-order effects of those
13 non-routine applications, but they did tend to highlight them for their readers as
14 arresting possibilities.

15
16 [2] “The Disconnect Theorem.” This hypothesis holds that the larger the “disconnect”
17 between how a technology actually works and how people *think* it works, the more
18 social disruption that the technology causes.

19
20 This notion receives no support from the laser case. There were, in the early years,
21 many examples of the disconnect, some described below. However, none was
22 associated with social disruption; in fact the only application that even suggests social

1 disruption – reported attempts to maliciously blind pilots and others with laser beams –
2 displays no disconnect at all.

3

4 A typical stark examples include the idea that [because lasers emit light rather than
5 invisible electromagnetic frequencies], future broadcasting could involve local TV
6 transmitters from which lights of a variety of colors are sent to homes with receivers.⁴¹

7 Other writers reasoned that, because laser light is so highly collimated, lasers would be
8 excellent searchlights, perhaps for use under the seas or in earth-observing satellites
9 uses.⁴² An early *Reader's Digest* piece called the laser “a new type of electric torch.”⁴³

10 Magazine illustrators drew earnest cartoons showing a beam breaking an incoming
11 missile in half. None of these cases [although the case of the death ray is, of course a
12 much more complicated and long-lived story] persisted long in laser forecasts, however,
13 and most such oversimplifying misconceptions disappeared quickly and quietly. These
14 ill-informed “disconnects” are not found in late-1960s accounts.

15

16 [3] Christensen’s Notion of “Disruptive Technology.” In 2000, Clayton Christensen
17 suggested that to understand technological innovation, one must distinguish between

⁴¹ Martin Mann, "Ruby That Amplifies Light," *Popular Science*, October 1960, p. 25.

⁴² "Light Ray -- Fantastic Weapon of the Future?," p. 47 ff. Mann, "Ruby That Amplifies Light.", Thomas Meloy, "The Laser's Bright Magic," *National Geographic*, December 1966, p. 858 ff.

⁴³ Manchester, "Light of Hope -- Or Terror?," p. 97.

1 “established technology” and “disruptive technology.”⁴⁴ Christensen’s own interest is in
2 business strategy, but we asked ourselves whether the distinction he is making helps us
3 understand how emerging technologies are understood, and thus how their social
4 implications are perceived.

5
6 At this point, we are unable to apply Christensen’s distinction, for lack of a definition that
7 can be applied in real time. His book contains a long illustrative list of the two classes of
8 innovative technology – for instance, mobile telephony and nurse practitioners are
9 “disruptive,” while wireline telephony and medical doctors are “established.”⁴⁵ But he
10 does not provide an operational definition that allows a contemporary observer to
11 determine whether an emerging technology belongs in one class or the other. At this
12 point, it appears, the distinction is only observable retrospectively. And for our
13 purposes, that is not enough.

14
15 *[G] The Pace of Error Correction in Laser Foresight Was, Arguably, Socially Acceptable.*
16 To say that foresight was frequently in error is not to say that it caused great harm. We
17 must ask whether the many mistakes in foresight were actually damaging; whether, for
18 example, the False Hopes actually amounted to serious diversions of resources and
19 national attention from more important uses, and whether the failure to identify Bonus
20 Boons materially impeded their development and thus their social contributions.

⁴⁴ Clayton Christensen *The Innovator’s Dilemma; the Revolutionary Book that Will Change the Way to Do Business* (HarperBusiness Essentials, 2002). First published in 2000.

⁴⁵ *Ibid.*, page xxix.

1
 2 More generally, and much more significantly, we note that very few of the False Hopes
 3 were sustained over time; in fact, most of them were mentioned only a few times over a
 4 relatively short period, and then slipped from view [see accompanying Table]. One
 5

<u>Learning and False Hopes – The Laser Case, 1960-1970</u>			
<u>Foreseen Use</u>	<u>No. Mentions</u>	<u>First Mention</u>	<u>Last Mention</u>
Laser Cannon/Death Ray	XXX	'59	'70
Nuclear Fusion		'57	'70
Ocean Searchlight		'60	'66
Earth-to-Satellite Power		'61	'66
Rocket Ignition		'63	'63
Space Communications		'60	'62
SETI		'61	'62
Satellite Communications		'60	'62
Narrow-beam "radar"		'58	'60
Spacecraft Re-entry Comm.		'62	'65
Submarine Communications		'62	'62
Data Processing		'62	'67
TV Transmission		XXX	
TV Display		XXX	
Tree-Pruning		'63	'63
Forest-Clearing		'64	'64
Light-bulbs		'63	'63
Typewriter Eraser		'67	'67

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Potato Peeler		'68	'68
Pilot Light - Ranges		'68	'68
Spark Plugs		'63	'63
Sonar Analog		'62	'62
3-D TV		'67	'67
Weather Forecasting		'67	'67
Astronomy Probes		'61	'62
Dental Drill		'65	'65
Cancer Treatment		'64	'65

1

2 notable example of this was the General Motors "Futurama" exhibit at the 1964 World's
3 Fair in New York. A model of a future road-building machine showed a gargantuan
4 contraption proceeding through a forested jungle, leaving a new paved road behind it.
5 The forest was to be cleared, it was explained, by lasers.⁴⁶ This appears to be the first
6 and last suggestion of laser lumberjacking.

7

8 By some mechanism, forecasting errors were identified and removed over time for the
9 large majority of False Hopes. A fair number of them [typewriter eraser, rocket igniter,
10 pilot light, suburban tree pruners] appeared only once. And several of the early
11 dramatic applications [astronomy probes, radio/TV broadcasting, satellite
12 communications, large-scale power transmission] passed from the prognosticators'
13 crystal balls by about 1963, never to recur in the decade. [Interestingly, a number of

⁴⁶ John M. Lee, "Mechanical 'Brains,' Lasers, and 2-Way Picture Phones are Shown by Industry," *New York Times*, April 22 1964, p. 25.

1 False-Hope consumer applications appeared, each only briefly, in the later 1960s, after
2 several years in which consumer applications were ignored altogether. Examples
3 include 3D television sets, TV displays, electrical bulbs, movie-sized TV screens, and
4 the lowly potato peeler.] For the most part, weak ideas were raised, found wanting, and
5 abandoned.

6
7 In fact, only three False-Hope applications persisted on laser forecasts through great
8 parts of the decade [remember, however, that long-distance point-to-point
9 communications remained unrealized until the very end of the decade]. They are the
10 military death ray, [which would be debated as the Reagan SDI initiative long after the
11 1960s closed], nuclear fusion⁴⁷, and space communications. . . and, if DoD plans are
12 realized, of course the newly-operational anti-satellite lasers will, in 2007, at last remove
13 the “Death Ray” from this short list of False Hopes.

14

15 Conclusion

16 Although much has be written about technological innovations, and many attempts have
17 been made to provide foresight about newly-emerging technology, little has be written
18 that characterizes or – more to the point – that assesses that foresight. The PoET
19 program is undertaking to begin to fill that gap.

20

⁴⁷ Work continued on using lasers to trigger fusion, but eventually another technology was found to be superior.

1 A review of media coverage of the future of the laser when the laser was an emerging
2 technology indicates that we should have only limited confidence in the accuracy of any
3 particular forecast. The writers of contemporary articles, and the expert sources they
4 consulted with, often guessed wrong about the laser's later form and its later social
5 meaning. The preoccupation with military and space applications that infused the
6 1960s press – and, evidently the research community itself – gives too much emphasis
7 on prospective higher-energy applications, and there was little inkling that the evolution
8 of smaller, cheaper lasers would make it ubiquitous in today's homes, stores, and
9 industrial facilities. If this is demonstrably true for the laser, one must presume that it is
10 demonstrably true for other emerging technologies, including those for which – unlike
11 the laser – adverse social implications are both feared and experienced.⁴⁸

12
13 But this finding does not really get to the important point of assessing past competence
14 at technological foresight. Our study takes us to a larger and much more significant
15 question. Given that errors are perhaps unavoidable, is it generally true that self-
16 correction mechanisms are in place that moderate the social costs of the mistakes? Are
17 there institutional ways to make such mechanisms more reliable and immediate? Can
18 we find ways to more quickly expose the false fears and false hopes in new

⁴⁸ As noted at the outset, the cost of harm from unforeseen banes is only one of two major issues. The other is the opportunity cost of failing to appreciate [eventual] boons early. For the laser, the failure to see in the 1960s that small, cheap lasers were important may have delayed their development and delivery. Evaluating the cost of that delay seems very complicated, but it must still be counted as a problem of technological foresight.

1 technologies, to react to the "Gotcha Banes" when they reveal themselves, and to more
2 quickly capitalize on the "Bonus Boons" when they appear on the horizon?

3

4

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