In recent years, there has been much debate among pundits and prognosticators about “converging technologies” or “technological singularities.” Simply put, these visions hold that sometime in the twenty-first century human society will arrive at a point when rapidly accelerating technological change will bring changes such as new industrial revolutions, unity between fields of scientific research, and perhaps radical changes in human intelligence and capabilities (Roco & Bainbridge, 2003; Vinge, 1983). Advocates of these “convergence” scenarios say it is not a matter of whether these technologies will come together, but simply when and how (Kurzweil, 2005). Critics, meanwhile, say such predictions are rooted in the selective observations about previous technological trends, with the singularity itself representing a “set of untestable assumptions about our near future” (Hassler, 2008, p. 9).

Utopian beliefs about the transformative effects of technology are not new, of course. They typically reflect a progressive vision of the future rooted in a technologically determinist framework (McCray, 2005; Segal, 1985). In the mid-twentieth century, the technological frontier was, of course, space exploration. Scholars, scientists, and journalists predicted that an expanded human presence in space was inevitable with profound societal and economic changes to follow (Mazlish, 1965; McCurdy, 1997). The first decades of human space exploration generated huge amounts of media attention, inspired schoolchildren to pursue careers in science, and motivated governments to spend billions of dollars in competition with one another. The similarities between imaginations of the space future in the 1960s resonate strongly with those for nanotechnology and singularity-like scenarios circa 2001.

Throughout history, of course, technologies have converged in many creative and surprising ways (Thompson, 2009). In the 1950s and 1960s, for example, the tools for space exploration were the example par excellence of a converging technology. Engineering studies and fictional scenarios for space exploration brought together frontier computing technologies and studies of human physiology in extreme environments with advanced microelectronics and the development of new high-tech
materials. These were all combined with the latest in aerospace and rocket technologies.

Over time, however, the public’s attention and awareness of over-the-horizon technologies shifted as predictions of new technological convergences embraced new frontiers. These included biotechnology, which emerged in the 1970s, cyberspace and the Internet in the late 1980s, and, more recently, nanotechnology which futurists and government officials held out as the preeminent technology of the twenty-first century.2

Over the past 40 years, space and nanotechnology have crossed paths, linked, and gone their separate ways several times (so often, in fact, that we might consider them “reconverging technologies”). At times, connections between the two technologies have been in the realm of engineering design, and at other times, they have resided in science fiction and futuristic scenarios. To help illustrate the ways in which aspirations for both the conquest of outer space and nano-space have converged in detailed engineering studies, laboratory research, and science fiction scenarios, this chapter takes a look at the designs and plans for a hypothetical technological artifact: the space elevator.

The basic idea of a space elevator is straightforward. A tether or cable, made of a super-strong and lightweight material, would be anchored somewhere in the equatorial regions to a platform with facilities similar to a modern airport or rocket launch site. The cable would reach upwards from this base thousands of miles into geostationary orbit. The other end of the cable might be connected to a counterweight in space, perhaps a small asteroid. As the earth rotates, the inertia of the cable’s end keeps it taut and counteracts gravitational pull. Meanwhile, climbers (analogous to elevator cars) powered by solar cells or laser propulsion could ascend the cable and move people and cargo into orbit. Advocates of the concept argue that, once built, the space elevator could provide a cheaper and more environmentally friendly alternative to blasting payloads into orbit via nonreusable rockets. Skeptics say that although such a technology breaks no laws of physics—this is not the realm of warp drives or antigravity machines—a space elevator cannot be built with currently available materials, and even in the future, the political and economic challenges would be considerable (Chang, 2003).

The idea that a cable or tower anchored to earth and stretching out into space could put people and payloads into orbit is more than a century old. Despite numerous thought experiments and technical studies, the feasibility of actually building a space elevator remained purely speculative until the 1990s. The primary obstacle was the lack of any viable material to fashion a cable strong yet light enough to serve as the elevator’s backbone. However, with the discovery of carbon nanotubes in the 1990s, advocates for a space elevator claimed that nanotechnology might offer a possible solution to the designer’s dilemma, perhaps even a path to the stars. As a result, the space elevator, even though it remains a hypothetical technological artifact,
provides a bridge between two vastly different scales of techno-scientific exploration, outer space and nanotechnology.

MERGING OUTER SPACE WITH NANOSPACE

For more than three decades, technological enthusiasts have linked a fascination with space exploration to a whole host of future-looking technologies, including nanotechnology, artificial intelligence, and robotics. The word “cyborg,” for example, has its origins in the work of Manfred Clynes and Nathan Kline, two researchers interested in altering the human body via drugs and biological modification in order to allow astronauts to survive the extreme environs of outer space (Kline, 2009; Kline & Clynes, 1961). Proposed even before Yuri Gagarin orbited the earth, Clynes’ and Kline’s “cybernetic organisms” presaged scenarios for converging technologies that advocates of transhumanism described years later (Boström, 2005).

The links between nanotechnology and space exploration go back, not surprisingly, to the activities and writing of K. Eric Drexler, the most visible popularizer of nanotechnology starting in the mid-1980s and continuing well into the 1990s. Before this, however, Drexler was a devoted supporter of space-based settlements and manufacturing, ideas promulgated largely through the technical studies and writings of Princeton physicist Gerard O’Neill. Drexler first encountered O’Neill’s ideas about the “humanization of space” as an undergraduate student at MIT in the 1970s. As an active member of the L5 Society, a citizens’ pro-space group from that era, Drexler wrote technically sound articles about the future possibilities of asteroid mining, space-based closed ecological systems, and solar sails (even receiving patents for his ideas in the process).

After moving to Silicon Valley in 1985, Drexler published a book that summarized his vision of the technological future. Titled *Engines of Creation*, Drexler’s book was written for broad, nonspecialized readers interested in the future of technology and its implications. With an introduction by Marvin Minsky, MIT’s guru of artificial intelligence and one of Drexler’s mentors, *Engines* became the canonical text for the specific form of nanotechnology Drexler popularized (Drexler, 1986). A major theme of *Engines*, one promoted by other early pro-nanotech enthusiasts of whom many had been involved in the pro-space movement, was that nanotechnology offered solutions to a whole host of problems, including the need for cheaper and easier ways to access space.

In the mid-1990s, one of the first government agencies in the United States to support an in-house effort to explore the possibilities of nanotechnology was the National Aeronautics and Space Administration (NASA). At its Ames Research Center, located in the heart of Silicon Valley (where futuristic technologies of all sorts are the coin of the realm), a small group of chemists and computer experts started a research program in computational
nanotechnology. Besides its access to Silicon Valley’s computer communities, Ames hosted NASA’s supercomputing center. Originally developed to do simulations of airflow and other fluid dynamics problems, the center’s high-speed parallel computing resources could also be directed to molecular nanotechnology simulations.

The group’s initial goal, according to an early member, was to explore some of the more radical Drexlerian ideas for nanotechnology and see how they might be applied to space-related technologies (Johnson, 2006; A. Globus, personal communication, September 24, 2009). The new forms of carbon discovered recently, buckyballs (or fullerenes) and nanotubes, received a great deal of the group’s attention. They discussed the possibility that “in the distant future,” one could design and build “atomically precise programmable machines” made of fullerenes. To back this up, the group did extensive design and simulations of nanoscale gears, sensors, and other devices “built and tested” via computer. Some 65 people were part of the Ames nanotechnology team at its peak, making it one of the world’s largest groups focused on nanoscale research. But, as the group continued to expand, its research shifted away from computer modeling of nanoscale gears and machines with Ames’s supercomputers to the lab-based fabrication and study of actual materials and devices, including, eventually, carbon nanotubes.

NASA’s initial work reflected what Drexler called “exploratory engineering.” By this, he meant the practice of “designing things we can’t yet build” (1988, p. 132); although perhaps anathema to some scientists, engineers have often designed objects which are possible but not within the reach of current manufacturing. Although their designs were sound, they called for new materials and other technologies that, although imaginable, did not exist yet. It is often through this process that engineers develop a better understanding of the weaknesses of current designs and work out paths to achieve improvements. Indeed, all engineering is heavily oriented toward the future—asking about what could be built, designing plans for what might be built (Constant, 1980; Johnson, 2010; Vincenti, 1990).

Even outside the world of futuristic technology prognosticators and small groups of NASA researchers, links—rhetorically, at least—between space and nanotech existed. In 1999, policymakers in the U.S. government were laying the groundwork for a major new research initiative that promoted nanotechnology as the next technological revolution. In advance of announcing the National Nanotechnology Initiative (NNI), advocates produced a glossy brochure that highlighted the research bonanza that nanotechnology promised. The brochure’s cover juxtaposed an image of a crystalline surface made with a scanning tunneling microscope, nanotech’s counterpart to the rocket in terms of iconic exploratory technology, with “cosmic imagery” (Nordmann, 2004) that “evokes the vastness of nanoscience’s potential” (Interagency Working Group, 1999). That same year, as scientists and engineers lobbied Congress for the NNI, Nobel laureate

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Richard E. Smalley invoked the spirit of the Apollo program. What was needed, Smalley said, was someone bold enough to “put a flag in the ground and say: ‘Nanotechnology, this is where we are going to go’” (House of Representatives Committee on Science, 1999, p. 12).

Rhetorical flourishes and symbolism aside, when federal science managers organized the NNI they ignored its direct historical ties to futurism and exploratory engineering—what my colleagues and I have termed hidden or camouflaged history—and focused instead on more immediate needs, for instance, of the electronics industry and other sectors connected to economic competitiveness (McCray, 2005). Whether motivated by embarrassment or expediency, the futuristic aspects of nanotechnology’s history were detached, at least officially, from federal policy initiatives. An examination of the space elevator’s history helps us reconnect some of these severed threads.

THE SPACE ELEVATOR, INVENTED OVER AND OVER

The Russian space visionary Konstantin Tsiolkovsky once wrote, “First, inevitably, the idea, the fantasy, the fairy tale. Then, scientific calculation. Ultimately, fulfillment crowns the dream” (Crouch, 1999, p. 30). This path from imagination to reality is a condensed history of a whole host of radical technological ideas that have yet to be realized, including the space elevator.

The idea that one could anchor a cable, stretch it out into space, and use it to transport people and payloads in and out of earth’s gravity well is more than a century old. In 1895, Tsiolkovsky published a series of thought experiments that elevator advocates cite as a starting point for later detailed studies (Rynin, 1971). One idea Tsiolkovsky proposed was a hypothetical tower extending into space, a place he used to imagine a gravity-free environment (Pearson, 1997). Tsiolkovsky soon turned his attention to developing designs and theories for rocket motors—exploratory engineering that space pioneers like Robert Goddard, Frank Malina, and Wernher von Braun later proved right—and his earlier idea of a tower reaching to the heavens was mostly forgotten until the 1960s.

During the Space Race, Soviet and American scientists and engineers proposed general concepts, incorporating space-to-earth cables several times in the technical literature (Artsutanov, 1960; Lvov, 1967; Pearson, 1975). However, rockets, not “heavenly funiculars,” as one Russian writer called them, were the ascendant technology during the Apollo era. All other options remained engineering curiosities. For example, Isaacs, Vine, Bradner, and Bachus (1966) described a space-elevator-like concept in 1966, 3 years before Neil Armstrong and Buzz Aldrin walked on the moon. However, the authors of this peer-reviewed article in Science were researchers at oceanographic research laboratories, not NASA. Hans Moravec, who
became a robotics guru and major proponent of transhumanist technologies, proposed a similar idea for a “sky hook” in the 1970s while he was studying artificial intelligence at Stanford (Moravec, 1977). The point here is that many of people promoting alternatives to the traditional rockets were relatively obscure in the broader space community or situated outside of it entirely.6

In 1979, science fiction author and futurist Arthur C. Clarke published his novel *The Fountains of Paradise* and thus ended the space elevator’s relative invisibility. The plot of *Fountains* revolves around a visionary engineer (Vannevar Morgan, a certain nod to Vannevar Bush, the doyen of U.S. science policy), who designs a bridge to space that is located on a fictional version of Sri Lanka. In Clarke’s story, engineers built the elevator’s cable from “pseudo-one-dimensional diamond crystals” he called “hyperfilament” (p. 39). *Fountains of Paradise* introduced the space elevator to thousands of sci-fi readers, and Clarke promoted the idea via interviews and appearances at technical meetings. Clarke’s enthusiasm helped establish credibility for the idea. He had, after all, predicted telecommunications satellites long before *Sputnik*, co-authored the screenplay for *2001: A Space Odyssey*, and sat next to Walter Cronkite during the first Apollo landings.

Although Clarke’s ideas were firmly grounded in scientific and engineering fact, at least one major obstacle remained. As one space elevator advocate recalled, all of these early designs assumed a large supply of “unobtainium” (B. C. Edwards, personal communication, June 4, 2007).7 The lack of a viable material from which to make a cable presented what engineers sometimes call a “tall tent pole”—a technical problem so critical that solving it can hold up the entire project, with all other problems lost beneath the canvas. The people who speculated on how to build a space elevator all agreed that the cable would have to be extraordinarily light and strong, and various studies considered Kevlar and materials containing graphite whiskers. Diamond, a material whose artificial manufacture received a great deal of attention from materials scientists in the 1980s, was also a candidate. All of these high-tech materials, however, were dismissed by space elevator advocates as impractical or impossible. Without a real material—one that actually existed and which might be manufactured in large amounts—further design work on a space elevator was beside the point.

**SMALLEY’S SPACE**

This situation changed after November 1991 when Sumio Iijima, a Japanese physicist, announced that he had made “helical microtubules of graphitic carbon.” These long, thin cylinders, later christened carbon nanotubes, became another key icon of nanoscience (Iijima, 1991; Kroto, Heath, O’Brien, Curl, & Smalley, 1985). The ensuing flood of research on carbon nanotubes moved the concept of the space elevator into the realm of the
theoretically possible. It also brought new players and institutions to the space–nanotechnology nexus.

Rice University professor Richard Smalley was one of these new arrivals. In 1985, *Nature* carried an article co-authored by Smalley, Curl, and Kroto that announced the discovery of carbon-60, christened “Buckminsterfullerene.” This discovery set off an avalanche of research and publications on this new allotrope of carbon. Iijima’s 1991 discovery was one of the outcomes of this work, and as Mody (2010) has shown, it catalyzed Smalley’s interest in both carbon nanotubes as well as nanotechnology.

Smalley was willing to use Drexler’s popular writings as a vehicle to raise research funds for his own work at Rice University. For example, in 1993, when Smalley wanted to generate support for a new nano-research center at Rice University, he mailed copies of Drexler’s books to the school’s trustees (Smalley, 1993a, 1993b). At the same time, Smalley had extensive correspondence with people about how NASA might support his research on carbon nanotubes. As he put it in an e-mail message to a Rice colleague, “I have some thoughts that will seem crazy at first blush . . . I’m talking with some people at NASA JSC [Johnson Space Center, located near the Rice campus] next week to see what they think about all this fantasizing. Maybe we can suck off a bit of their >$10,000,000,000/yr budget and actually do something worthwhile” (Smalley, 1996).

Smalley’s main interest, of course, was to secure stable funding. This would enable his growing research network to better understand carbon nanotubes and eventually produce them in large amounts. Nonetheless, space also beckoned to Smalley who, as he stated in interviews, chose his career because of the Space Race. In public talks and private meetings with potential patrons, Smalley placed the space elevator between fact and fiction, suggesting that with the right support and funding it might be possible. If nothing else, it could serve to stimulate nanoscale research on more near-term goals and bring attention to the burgeoning new field.

For example, the colorful cover of the July–August 1997 issue of *American Scientist* depicted a nanotube-enabled elevator extending out into space. The feature article inside, coauthored by Smalley, detailed the science behind these new allotropes of carbon (Yakobson & Smalley, 1997). But when he wanted to illustrate the extraordinary theoretical strength of carbon nanotubes, Smalley, who was initially supportive of Drexler’s visions for nanotechnology, turned to the possibility of using carbon nanotubes for a future space elevator. Smalley’s overall strategy of blending futuristic and technologically revolutionary possibilities with near-term “normal science” worked. By 1999, NASA supported his Carbon Nanotechnology Laboratory at Rice with a multimillion-dollar award.

The road between science fact and fiction went both ways after the discovery of carbon nanotubes. Kim Stanley Robinson’s 1993 novel *Red Mars* placed a space elevator at the center of a conflict between groups with competing goals for settling the Red Planet. Robinson’s book, which won
the Nebula Award in 1993, described a cable made from robotically processed carbon mined from asteroids. What form it is in is not clear—later in the book, he refers to a cable made from “graphite whisker with diamond sponge-mesh gel double-helixed into it” (p. 499). But, in homage to earlier sci-fi writers who used the elevator concept, Robinson named the two stations for the transport system “Clarke” and “Sheffield.”

The interest of Nobel laureate Smalley and sci-fi writers like Robinson shows where space exploration and nanotechnology converged again in the guise of a hypothetical space elevator. More importantly, it points to the willingness of “mainstream” scientists to embrace exploratory engineering in their approaches to the public and patrons. By the late 1990s, university scientists, business leaders, and policymakers had marginalized Drexlerian ideas, if not Drexler himself. Nonetheless, Smalley adopted the same rhetorical strategy Drexler often used of blending science fiction scenarios with scientific descriptions and engineering projections. By this point in the space elevator’s history, the vision, and possibly the materials for fulfilling it, were imagined to be there. The next stage was to carry out more robust and thorough design studies.

“ONCE YOU HAD CARBON NANOTUBES . . .”

At about the time that Smalley’s article in *American Scientist* appeared (Yakobson & Smalley, 1997), Bradley C. Edwards, a scientist at Los Alamos National Laboratory, was beginning to mull over the space elevator idea. Edwards, a physicist who helped build hardware for space missions, read that a space elevator could not be built for at least 300 years. The outright dismissal of the concept bothered Edwards, and he began to seriously explore the concept. As he explained, “Once you had carbon nanotubes, the rest of it could be done” (B. C. Edwards, personal communication, June 4, 2007). As he studied the existing technical literature, Edwards also read science fiction treatments by Clarke, Kim Stanley Robinson, and other authors. Edwards recalled, “While you can’t actually build the cable that is in *Red Mars*, Robinson did enough careful thought and planning on it so that it wasn’t too far off base. That was very interesting to me” (B. C. Edwards, personal communication, June 4, 2007).

For decades, even as the bulk of NASA’s budget went to more traditional rocket and space science programs, the space agency maintained a modicum of support for advanced concepts so long as they were sufficiently far in the future to not endanger existing programs. One such operation was the NASA Institute for Advanced Concepts (NIAC). Created in 1998, the NIAC—a small operation that had an annual budget around $4.5 million—sought to “inspire, select, and fund revolutionary ideas and concepts” (R. Cassnova, personal communication, June 29,
In 1999, Edwards requested funding from NASA to explore the idea further. After passing peer review, Edwards received some $570,000 over the next 3 years from NIAC and raised several million more from other sources (NIAC, 2007). Between 2000 and 2003, Edwards thoroughly analyzed the entire space elevator idea, including safety factors, economic implications, and legal issues (see Edwards, 2003). His previous experience at Los Alamos designing spacecraft systems was an asset, and he divided his space elevator design into dozens of separate yet manageable technical problems. Whereas, for example, previous concepts for a space elevator imagined thick cables weighing hundreds of thousands of tons, the potential of carbon nanotubes allowed Edwards to design his hypothetical system around an “initial ribbon, 8 inches wide and thinner than paper” and based, of course, on carbon nanotubes (Edwards & Westling, 2003, p. 43).

Edwards’ research reinvigorated the space elevator concept and helped generate a flood of media attention and public interest. Edwards, who retired from Los Alamos to pursue the idea full time, gave scores of invited talks, including audiences at the Air Force, DARPA, and Congress. Meanwhile, articles in major newspapers started to carry stories about the space elevator. With predictable titles like “Stairway to Heaven,” these helped create a flood of interest. Web-based magazines and blogs stimulated more interest. To give one example of the situating of the space elevator between fiction and reality, the PBS science show *Nova* ran a segment on the space elevator. As the show’s host, astrophysicist Neil deGrasse Tyson, said, “Fueled by the promise of these tiny tubes, people are already working to turn the Space Elevator into a reality . . . Perhaps someday technology will catch up with our imaginations and take the Space Elevator out of the realm of science fiction once and for all” (McMaster, 2007). Humorist Dave Barry (2003) was less respectful: Government scientists, Barry wrote, had an idea “so radical . . . you wonder if they’ve been smoking reefers the size of Yule logs.”

New groups, motivated by Edwards’ exploratory engineering, began to get in on the action. In 2005, contributions from the Spaceward Foundation, a nonprofit organization “dedicated to furthering space science and technology,” helped NASA add space-elevator related contests to its Centennial Challenges program. NASA’s initiative, sought to encourage innovation by awarding cash prizes to teams meeting specific technical challenges. These contests stimulated the space elevator community and broadened its base of support. For several years, scores of garage tinkerers and students met to compete for large prizes in contests to develop hardware for a future space elevator. In 2009, the *New York Times*, CNN, and dozens of web-based news sources reported on the Space Elevator Games (Chang, 2009). Held in Mojave, California, where several private spaceflight startups are based, the Games featured LaserMotive, a small Seattle company, which won $900,000 for demonstrating a prototype of a machine that might one
day scale a space elevator’s cable. The space elevator, at least as an incentive for innovation and experimentation, had left the ground floor.

SPECULATION AND EXPERIMENTATION

Engineering, as I have noted earlier, is rooted simultaneously in present-day designs—be they for a bridge, a road, or a spaceship—but done with future goals and projects in mind. Artifacts of the future, such as a space elevator or Drexlerian nano-assemblers, have existed in a similar state. Marked by the subjunctive—what might or could be, as opposed to what is or will be—they inhabit a liminal arena of possibility (Squier, 2004; Turner, 1977). Similarly, a diverse collection of people—from Nobel prize–winning scientists to basement mechanics—visited the same liminal space where they took advantage of the opportunity to “fantasize and play with new objects and possibilities—to dream, to model, and to tinker in new ways” (Pinch, 2007). Seen in this fashion, liminality can help us understand some key aspects of the space elevator, and indeed, it could well be used to describe other less visible aspects of nanotechnology’s history.

An analogy drawn from the history of technology can also help us better apprehend the present/future existence of a nano-enabled space elevator. In the interwar period, space exploration was the primary “futurist technology” as researchers proposed theories of rocket propulsion and design on paper (Winter, 1983). Until the proper materials and institutional support became available, however, the rocket existed largely in a speculative state. This changed when amateur groups such as the Verein für Raumschifahrt and the American Rocket Society helped propel the rocket from ridicule to reality. And for rocket gurus like Malina and von Braun, who were building actual hardware, science fiction remained an important inspiration.

Like the early rocket tinkerers, today’s grassroots space elevator groups are typically situated outside of the mainstream of patronage for science and engineering, that is, they are not operating with multimillion-dollar NASA or NSF grants. Their activities reflect the myth of the lone inventor winning fortune and fame with technologies developed in garages or dorm rooms—think of Philo Farnsworth, Steve Jobs and Steve Wozniak, or Larry Page and Sergey Brin. No doubt, this linkage to a mythical part of America’s technological past accounted for the favorable and widespread coverage given by the media to events like the Space Elevator Games. And, like the early rocket pioneers, space elevator advocates take inspiration from fiction and imagine that their work will pay off someday, perhaps with far-reaching societal consequences. The contributions of amateur scientists to the production of new knowledge have been well established by historians of science (McCray, 2008). Space elevator–themed contests are another example of how people outside the mainstream academic-corporate
research community can help foster new innovations today just as they did for the personal computer in the 1970s.

Finally, the space elevator, situated at the confluence of nanotech and space aspirations, raises some questions about the imagined unity of converging technologies at some future point (Roco & Bainbridge, 2003). Although we can speak of it as a single entity, the reality is that nanotechnology—like space exploration before it—is a fragmented field. It encompasses a diverse range of activities, practices, goals, institutions, pedagogies, and instrumental techniques, making it more of a sociological than an epistemological phenomenon. The idea that nanotechnology will somehow fuse with biotechnology, information technology, and cognitive science and become a universal discipline does not reflect the messiness of actual technological innovation (see Bowker, 1993). What history shows is that technologies, even hypothetical ones, rarely converge into a single über-technology but are constantly converging, splitting, mutating, and reconverging as new ideas are proposed, tried, and adopted or discarded. Along the way, a host of diverse institutions and individuals, from a major NASA lab to groups of independent tinkerers to Nobel prize winners to futurists, used the space elevator concept in various ways to advance particular agendas.

Nonetheless, nanotechnology (specifically, the discovery of carbon nanotubes) was central to moving the space elevator to a stage somewhere between speculation, detailed design, and garage tinkering. Seen more broadly, the attention of science writers and other journalists on these new allotropes of carbon material stimulated huge amounts of attention as to what their possible applications might be. Smalley, a scientist predisposed to futurist imagining yet deeply rooted in mainstream lab-based research, helped make a space elevator, along with nanotechnology itself, seem credible. However, the discovery of carbon nanotubes would have had far less impact if nano-advocates like Drexler had not already promoted nanotechnology as the most promising technology of the twenty-first century. Together, the advocacy of nanotechnology, the invention of a new material with promising properties, detailed engineering studies by Edwards and others, and modest NASA support brought credibility to the idea. To top it all off, the interest and activity shown by amateurs and weekend engineers created a compelling frame for the media—that of David, with his “space elevator sling,” taking on the corporate aerospace Goliaths—which, along with science-fiction narratives, brought the space elevator publicity and a global audience.

Technologies are the tools people use to make their future. Accompanying nuts-and-bolts hardware are less tangible tools such as ideas and plans for what the future should or could be like. Situated between fiction and reality for over a century, prize-winning science fiction, mainstream media attention, serious technology studies, commercial investment, and enthusiasm of amateur technologists have all nurtured the space elevator for decades. In order to understand the social life of emerging technologies, we
must appreciate that histories of the technological future are of importance regardless of whether the technologies themselves ever become reality, let alone converge.

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NOTES

1. Vinge (1983) later acknowledged that the term originated, so far as he knew, in a tribute Stanislaw Ulam gave in 1958 for his colleague, mathematician John von Neumann.

2. At least this was the case a decade ago. More recently, discussions among science journalists and activists, who often act as bellwethers of change, have been discussing synthetic biology with increasing frequency; ex: http://www.synbioproject.org/about/

3. The book was originally published with a different subtitle—Challenges and Choices of the Last Technological Revolution—which hews closer to Drexler's original vision that his book be about technology in general rather than a treatise on nanotechnology per se.

4. In some ways, this is reminiscent of nanotech advocates citing Richard Feynman's 1959 "There's Plenty of Room at the Bottom" speech as the origin of their field.

5. Pearson (1997) concludes that although Tsiolkovsky anticipated the space elevator idea the actual credit for the invention should go to him and Yuri Artsutanov who independently published on the idea.

6. A case in point is the work done on a nuclear powered spacecraft. For example, Project Orion was a well-funded effort that attracted serious interest from physicists Ted Taylor and Freeman Dyson; it was disbanded in 1965 (Dyson, 1965).

7. "Unobtanium" is a colloquial term used in the aerospace industry to denote, as the name suggests, something which is too expensive or exists only in theory. More recently, corporate lust for the hypothetical material was a plot device used in the 2009 Oscar-winning movie Avatar.


9. One reviewer of Edwards' proposal was Gentry Lee, a chief engineer at the Jet Propulsion Laboratory who co-authored several science fiction books with Arthur C. Clarke and was also a member of NIAC's Science, Exploration,
and Technology Council. According to Edwards, Gentry Lee “caught the proposal half way to the garbage can and got people to look at it more closely” (B. C. Edwards, personal communication, June 4, 2007). Edwards, according to NIAC’s last report in 2007, also raised some $8.5 million in non-NASA funding.

10. According to the Executive Summary in Edwards’ (2003) final report, the space elevator concept resulted in “hundreds of television, radio, and newspaper spots around the world,” making it arguably the most visible project that NIAC funded (p. 2).

11. The idea of prizes for technological accomplishments has a long history going back to the celebrated eighteenth-century prize for determining longitude. In aerospace history, prizes have been particularly noteworthy. The Orteig Prize (for the first trans-Atlantic flight) and, more recently, the million-dollar Ansari X Prize (for the first nongovernment launch of a reusable, manned spacecraft, which the SpaceShipOne team won in 2004) are examples. Recently, there has been increased interest on the part of government agencies such as NASA, the Department of Energy, and DARPA to sponsor technology prizes (for one perspective see Kalil, 2006).

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When Space Travel and Nanotechnology Met


Nanotechnology plays an important role in space missions such as nanosensors for satellites, dramatically improved high-performance materials, or highly efficient propulsion systems. Radiation shielding is an area where nanotechnology could make a major contribution to human space flight. NASA says that the risks of exposure to space radiation are the most significant factor limiting humans’ ability to participate in long-duration space missions. A lot of research therefore focuses on developing countermeasures to protect astronauts from those risks. To meet the needs for radiation protection as well as other requirements such as low weight and structural stability, spacecraft designers are looking for materials that help them develop multifunctional spacecraft hulls.