2 Imagining Worlds: Does Science Fiction Inform our Technological Reality?

If someone mentions the word *technology* in the same breath as the word *literature*, chances are, most people are going to think of the literary genre of science fiction (SF). Although all literature is concerned with technology, there is, in fact, a long history connecting science and technology to the literary genre of SF. Both those who write SF and read SF are often involved in some way with the study of science and technology in the real world. Furthermore, certain scientific and technological inventions were imagined in SF before they became a reality: Jules Verne wrote about underwater and airborne travel long before submarines and airplanes existed, and Martin Cooper, director of research and development at Motorola, often mentions the *Star Trek* communicator as his inspiration for the design of mobile phones in the early 1970s. According to Cooper, a wireless communication device such as that used in the television series "was not fantasy to us" but rather "an objective."

Scientists to this day look to SF to consider what the writer Michio Kaku describes as "the physics of the impossible." However, there are many reasons beyond the shared interests of scientists and SF writers to explain why SF is a unique lens through which to assess definitions and discussions of science and technology. First, by distancing readers from the realities of the day to day, SF enables them to view technologies not as inevitable, as they sometimes can seem, but as an extension of larger sociocultural issues. Then, by posing "what if" questions not only about the future but also, implicitly, about how we are living today, SF allows readers to think through the consequences of technology in a way writing based solely on facts may not.

Mapping, describing, and understanding the relationships between SF and reality is, of course, complex, often even more so than it may be in other genres of literary fiction. As the SF writer and scientist Gregory Benford explains, "Fiction is (let's be frank) lies—beautiful lies, maybe, intoxicating, uplifting, enormously suggestive—but lies, nonetheless. So 'science fiction' is a contradiction. Is it Lies about the Truth? Or the deeper Truth about Lies?" What Benford is drawing attention to is the fact that while the realism found in SF is—like all literary realism—created through a selective combination of fiction and fact, the equation between these two terms and how they function is quite distinct. SF writers create fictional worlds based on an extrapolation of reality and then represent an altered reality in such a manner that readers experience those worlds as realistic. As a result, SF navigates the line between fiction and reality in a manner distinct from other genres of fictional prose.

All of the writers in this chapter are interested in exploring relationships between technology and SF. However, each approaches the question from a slightly different perspective. Robert J. Sawyer proposes that SF may have more to say about science than, at times, science itself does. Neal Stephenson reflects on the possible relationships between SF and technological innovation. Jon Turney argues that stories and narratives may be as much a part of technological artifacts and processes as they are part of SF. In an essay that considers the characteristics of SF as a genre and the unique place of "hard" SF as a subgenre, Kathryn Cramer reminds us of the unique relationships that exist between the realities of science and the imagined worlds of SF. Damien Broderick looks at today’s and yesterday’s futures and how technology relates to both. Wendy Lesser, in a review of one of Isaac Asimov’s novels, reflects on her own reading of SF and how SF is both part of the age in which it is written and about futures that may come into being much earlier than anyone thought possible. Finally, the physicist Michio Kaku considers not only the relationships between SF and science but the scientific possibilities—and current scientific realities—of the “impossible.”

Robert J. Sawyer
“The Purpose of Science Fiction”

Robert J. Sawyer is a Canadian SF writer who is the author of over two dozen novels. The recipient of numerous awards and fellowships, he has been the recipient of the Hugo, Nebula, and Aurora Awards for best SF novel of the year. His most recent novels include *Red Planet Blues: Murder on the Mean Streets of Mars* (2014), *Triggers* (2012), and *Wonder* (2011), the third volume in his critically acclaimed WWW Trilogy. In this essay, Sawyer reflects on the things that SF can teach us and why, at times, it may be able to do so better than real-world science can.

“Science fiction is the WikiLeaks of science, getting word to the public about what cutting-edge research really means.”

What do you think the purpose of SF is?

Mary Shelley’s 1818 novel *Frankenstein, or the Modern Prometheus*, is generally considered the first work of science fiction. It explores, in scientific terms, the notion of synthetic life: Dr. Victor Frankenstein studies the chemical breakdown that occurs after death so he can reverse it to animate nonliving matter. Like so many other works of science fiction that followed, Shelley’s story is a cautionary tale: It raises profound questions about who should have the right to create living things and what responsibility the creators should have to their creations and to society.

Think about that: Mary Shelley put these questions on the table almost two centuries ago—41 years before Darwin published *The Origin of Species* and 135 years before Crick and Watson figured out the structure of DNA. Is it any wonder that Alvin Toffler, one of the first futurists, called reading science fiction the only preventive medicine for future shock?

Isaac Asimov, the great American science fiction writer, defined the genre thus: "Science fiction is the branch of literature that deals with the responses of human beings to changes in science and technology." The societal impact of what is being cooked up in labs is always foremost in the science fiction writer's mind. H.G. Wells grappled with creating chimera life forms in *The Island of Doctor Moreau* (1896), Aldous Huxley gave us a heads-up on modified humans in *Brave New World* (1932), and Michael Crichton's final science-fiction novel, *Next* (2006), brought the issues of gene splicing and recombinant DNA to a mass audience.

What's valuable about this for societies is that science-fiction writers explore these issues in ways that working scientists simply can't. Some years ago, for a documentary for Discovery Channel Canada, I interviewed neurobiologist Joe Tsien, who had created superintelligent mice in his lab at Princeton—something he freely spoke about when the cameras were off. But as soon as we started rolling, and I asked him about the creation of smarter mice, he made a "cut" gesture. "We can talk about the mice having better memories but not about them being smarter. The public will be all over me if they think we're making animals more intelligent."

5 But science-fiction writers do get to talk about the real meaning of research. We're not beholden to skittish funding bodies and so are free to speculate about the full range of impacts that new technologies might have—not just the upsides but the downsides, too. And we always look at the human impact rather than couching research in vague, nonthreatening terms.

We also aren't bound by nondisclosure agreements, the way so many commercial and government scientists are. Indeed, a year before the first atomic bomb was built, the FBI demanded that the magazine *Astounding Science Fiction* recall its March 1944 issue, which contained a story by Cleve Cartmill detailing how a uranium-fission bomb might be built. Science-fiction writers began the public discourse about the actual effects of nuclear weapons (see for instance Judith Merril's classic 1948 story "That Only a Mother," which deals with gene damage caused by radiation). We also were among the first to weigh in on the dangers of nuclear power (see for example Lester del Rey's 1956 novel *Nerves*). Science fiction is the

WikiLeaks of science, getting word to the public about what cutting-edge research really means.

And we come with the credentials to do this work. Many science-fiction writers, such as Gregory Benford, are working scientists. Many others, such as Joe Haldeman, have advanced degrees in science. Others, like me, have backgrounds in science and technology journalism. Our recent works have tackled such issues as the management of global climate change (Kim Stanley Robinson's *Forty Signs of Rain* and its sequels), biological terrorism (Paolo Bacigalupi's *The Windup Girl*), and the privacy of online information and China's attempts to control its citizens' access to the World Wide Web (my own *WWW:Wake* and its sequels).

Print science-fiction writers often do consulting for government bodies. A group of science fiction writers called SIGMA frequently advises the Department of Homeland Security about technology issues, and Jack McDevitt and I recently were consulted by NASA about the search for intelligence in the cosmos.

At the core of science fiction is the notion of extrapolation, of asking, "If this goes on, where will it lead?" And, unlike most scientists who think in relatively short time frames—getting to the next funding deadline, or readying a product to bring to market—we think on much longer scales: not just months and years, but decades and centuries.

That said, our job is not to predict the future. Rather, it's to suggest all 10
the possible futures—so that society can make informed decisions about where we want to go. George Orwell's science-fiction classic *Nineteen Eighty-Four* wasn't a failure because the future it predicted failed to come to pass. Rather, it was a resounding success because it helped us prevent that future. Those wishing to get in on the ground floor of discussing where technology is leading us would do well to heed Alvin Toffler's advice by cracking open a good science-fiction book and joining the conversation.

Analyze

1. Sawyer mentions Mary Shelley's novel *Frankenstein, or the Modern Prometheus* in the first sentence of his article. Why does he refer to this novel and how does it relate to his larger argument regarding the purpose and importance of SF?
2. How did the writer Isaac Asimov define the genre of SF? How closely does this match Sawyer's definition of the genre?

3. According to Sawyer, what specific constraints do scientists work under that SF writers need not be concerned with?
4. Throughout the article, Sawyer explains the several different ways in which SF writers are involved with science. Make a list of these.

Explore

1. How well does the title of Sawyer's essay represent his essay? In one page, assess the ways in which this title does and does not adequately represent the content of the essay. Afterward, free write about what the article is about and consider some other possible titles that would be appropriate for it.
2. Sawyer makes some very provocative claims in this essay. Briefly summarize his argument and make an outline of the claims he uses to support it. Write a two-page overview of Sawyer's essay explaining how his claims relate to and support his thesis.
3. Look up the myth of Prometheus, making sure to cite your source(s). In your own words, explain the ways in which this myth relates to definitions and discussions of technology in the present day. Then, in one page, reflect on how Sawyer's reference to the myth relates to his argument about the purpose of science fiction.

Neal Stephenson
"Innovation Starvation"

Neal Stephenson is the author of over a dozen novels, which span a range of genres, including SF, historical fiction, and cyberpunk. The recipient of numerous science fiction awards, including the Hugo Prize, the Prometheus Award, the Locus Prize, and the Clarke Award, Stephenson's most recent novel is *Reamde*, a techno-thriller that has been praised by critics both for its readability and its technical sophistication. A former game designer, Stephenson has long been interested in space exploration, a subject that he has explored not only in his fiction, but also by working with contemporary companies and organizations related to the future of space travel. In this essay, Stephenson considers how innovation happens and the place of SF and new technologies in relation to society's ability to "get big things done."

In your vision of the future, what types of large-scale projects could you imagine being developed to "solve age-old problems?"

My lifespan encompasses the era when the United States of America was capable of launching human beings into space. Some of my earliest memories are of sitting on a braided rug before a hulking black-and-white television, watching the early Gemini missions. This summer, at the age of 51—not even old—I watched on a flatscreen as the last Space Shuttle lifted off the pad. I have followed the dwindling of the space program with sadness, even bitterness. Where's my donut-shaped space station? Where's my ticket to Mars? Until recently, though, I have kept my feelings to myself. Space exploration has always had its detractors. To complain about its demise is to expose oneself to attack from those who have no sympathy that an affluent, middle-aged white American has not lived to see his boyhood fantasies fulfilled.

Still, I worry that our inability to match the achievements of the 1960s space program might be symptomatic of a general failure of our society to get big things done. My parents and grandparents witnessed the creation of the airplane, the automobile, nuclear energy, and the computer to name only a few. Scientists and engineers who came of age during the first half of the 20th century could look forward to building things that would solve age-old problems, transform the landscape, build the economy, and provide jobs for the burgeoning middle class that was the basis for our stable democracy.

The Deepwater Horizon oil spill of 2010 crystallized my feeling that we have lost our ability to get important things done. The OPEC oil shock was in 1973—almost 40 years ago. It was obvious then that it was crazy for the United States to let itself be held economic hostage to the kinds of countries where oil was being produced. It led to Jimmy Carter's proposal for the development of an enormous synthetic fuels industry on American soil. Whatever one might think of the merits of the Carter presidency or of this particular proposal, it was, at least, a serious effort to come to grips with the problem.

Little has been heard in that vein since. We've been talking about wind farms, tidal power, and solar power for decades. Some progress has been made in those areas, but energy is still all about oil. In my city, Seattle, a 35-year-old plan to run a light rail line across Lake Washington is now being blocked by a citizen initiative. Thwarted or endlessly delayed in its efforts to build things, the city plods ahead with a project to paint bicycle lanes on the pavement of thoroughfares.

5 In early 2011, I participated in a conference called Future Tense, where I lamented the decline of the manned space program, then pivoted to energy, indicating that the real issue isn't about rockets. It's our far broader inability as a society to execute on the big stuff. I had, through some kind of blind luck, struck a nerve. The audience at Future Tense was more confident than I that science fiction [SF] had relevance—even utility—in addressing the problem. I heard two theories as to why:

1. The Inspiration Theory. SF inspires people to choose science and engineering as careers. This much is undoubtedly true, and somewhat obvious.
2. The Hieroglyph Theory. Good SF supplies a plausible, fully thought-out picture of an alternate reality in which some sort of compelling innovation has taken place. A good SF universe has a coherence and internal logic that makes sense to scientists and engineers. Examples include Isaac Asimov's robots, Robert Heinlein's rocket ships, and William Gibson's cyberspace. As Jim Karkanias of Microsoft Research puts it, such icons serve as hieroglyphs—simple, recognizable symbols on whose significance everyone agrees.

Researchers and engineers have found themselves concentrating on more and more narrowly focused topics as science and technology have become more complex. A large technology company or lab might employ hundreds or thousands of persons, each of whom can address only a thin slice of the overall problem. Communication among them can become a mare's nest of email threads and PowerPoints. The fondness that many such people have for SF reflects, in part, the usefulness of an over-arching narrative that supplies them and their colleagues with a shared vision. Coordinating their efforts through a command-and-control management system is a little like trying to run a modern economy out of a Politburo. Letting them work toward an agreed-on goal is something more like a free and largely self-coordinated market of ideas.

Spanning the Ages

SF has changed over the span of time I am talking about—from the 1950s (the era of the development of nuclear power, jet airplanes, the space race, and the computer) to now. Speaking broadly, the techno-optimism of the Golden Age of SF has given way to fiction written in a generally darker, more skeptical and ambiguous tone. I myself have tended to write a lot about hackers—trickster archetypes who exploit the arcane capabilities of complex systems devised by faceless others.

Believing we have all the technology we'll ever need, we seek to draw attention to its destructive side effects. This seems foolish now that we find ourselves saddled with technologies like Japan's ramshackle 1960's-vintage reactors at Fukushima when we have the possibility of clean nuclear fusion on the horizon. The imperative to develop new technologies and implement them on a heroic scale no longer seems like the childish preoccupation of a few nerds with slide rules. It's the only way for the human race to escape from its current predicaments. Too bad we've forgotten how to do it.

"You're the ones who've been slacking off!" proclaims Michael Crow, president of Arizona State University (and one of the other speakers at Future Tense). He refers, of course, to SF writers. The scientists and engineers, he seems to be saying, are ready and looking for things to do. Time for the SF writers to start pulling their weight and supplying big visions that make sense. Hence the Hieroglyph project, an effort to produce an anthology of new SF that will be in some ways a conscious throwback to the practical techno-optimism of the Golden Age.

Spaceborne Civilizations

China is frequently cited as a country now executing on Big Stuff, and there's no doubt they are constructing dams, high-speed rail systems, and rockets at an extraordinary clip. But those are not fundamentally innovative. Their space program, like all other countries' (including our own), is just parroting work that was done 50 years ago by the Soviets and the Americans. A truly innovative program would involve taking risks (and accepting failures) to pioneer some of the alternative space launch technologies that have been advanced by researchers all over the world during the decades dominated by rockets.

Imagine a factory mass-producing small vehicles, about as big and complicated as refrigerators, which roll off the end of an assembly line, are loaded with space-bound cargo, and topped off with non-polluting liquid hydrogen fuel, then exposed to intense concentrated heat from an array of ground-based lasers or microwave antennas. Heated to temperatures beyond what can be achieved through a chemical reaction, the hydrogen erupts from a nozzle on the base of the device and sends it rocketing into the air. Tracked through its flight by the lasers or microwaves, the vehicle soars into orbit, carrying a larger payload for its size than a chemical rocket could ever manage, but the complexity, expense, and jobs remain grounded. For decades, this has been the vision of such researchers as physicists Jordin Kare and Kevin Parkin. A similar idea, using a pulsed ground-based laser to blast propellant from the backside of a space vehicle, was being talked about by Arthur Kantrowitz, Freeman Dyson, and other eminent physicists in the early 1960s.

If that sounds too complicated, then consider the 2003 proposal of Geoff Landis and Vincent Denis to construct a 20-kilometer-high tower using simple steel trusses. Conventional rockets launched from its top would be able to carry twice as much payload as comparable ones launched from ground level. There is even abundant research, dating all the way back to Konstantin Tsiolkovsky, the father of astronautics beginning in the late 19th century, to show that a simple tether—a long rope, tumbling end-over-end while orbiting the earth—could be used to scoop payloads out of the upper atmosphere and haul them up into orbit without the need for engines of any kind. Energy would be pumped into the system using an electrodynamic process with no moving parts.

All are promising ideas—just the sort that used to get an earlier generation of scientists and engineers fired up about actually building something.

But to grasp just how far our current mindset is from being able to attempt innovation on such a scale, consider the fate of the space shuttle's external tanks [ETs]. Dwarfing the vehicle itself, the ET was the largest and most prominent feature of the space shuttle as it stood on the pad. It remained attached to the shuttle—or perhaps it makes as much sense to say that the shuttle remained attached to it—long after the two strap-on boosters had fallen away. The ET and the shuttle remained connected all the way out of the atmosphere and into space. Only after the system had attained orbital velocity was the tank jettisoned and allowed to fall into the atmosphere, where it was destroyed on re-entry.

At a modest marginal cost, the ETs could have been kept in orbit indefinitely. The mass of the ET at separation, including residual propellants, was about twice that of the largest possible Shuttle payload. Not destroying them would have roughly tripled the total mass launched into orbit by the Shuttle. ETs could have been connected to build units that would have humbled today's International Space Station. The residual oxygen and hydrogen sloshing around in them could have been combined to generate electricity and produce tons of water, a commodity that is vastly expensive and desirable in space. But in spite of hard work and passionate advocacy by space experts who wished to see the tanks put to use, NASA—for reasons both technical and political—sent each of them to fiery destruction in the atmosphere. Viewed as a parable, it has much to tell us about the difficulties of innovating in other spheres.

Executing the Big Stuff

Innovation can't happen without accepting the risk that it might fail. The vast and radical innovations of the mid-20th century took place in a world that, in retrospect, looks insanely dangerous and unstable. Possible outcomes that the modern mind identifies as serious risks might not have been taken seriously—supposing they were noticed at all—by people habituated to the Depression, the World Wars, and the Cold War, in times when seat belts, antibiotics, and many vaccines did not exist. Competition between the Western democracies and the communist powers obliged the former to push their scientists and engineers to the limits of what they could imagine and supplied a sort of safety net in the event that their initial efforts did not pay off. A grizzled NASA veteran once told me that the Apollo moon landings were communism's greatest achievement.

In his recent book *Adapt: Why Success Always Starts with Failure*, Tim Harford outlines Charles Darwin's discovery of a vast array of distinct species in the Galapagos Islands—a state of affairs that contrasts with the picture seen on large continents, where evolutionary experiments tend to get pulled back toward a sort of ecological consensus by interbreeding. "Galapagan isolation" vs. the "nervous corporate hierarchy" is the contrast staked out by Harford in assessing the ability of an organization to innovate.

Most people who work in corporations or academia have witnessed some- 20
thing like the following: A number of engineers are sitting together in a room, bouncing ideas off each other. Out of the discussion emerges a new concept that seems promising. Then some laptop-wielding person in the corner, having performed a quick Google search, announces that this "new" idea is, in fact, an old one—or at least vaguely similar—and has already been tried.

Either it failed, or it succeeded. If it failed, then no manager who wants to keep his or her job will approve spending money trying to revive it. If it succeeded, then it's patented and entry to the market is presumed to be unattainable, since the first people who thought of it will have "first-mover advantage" and will have created "barriers to entry." The number of seemingly promising ideas that have been crushed in this way must number in the millions.

What if that person in the corner hadn't been able to do a Google search? It might have required weeks of library research to uncover evidence that the idea wasn't entirely new—and after a long and toilsome slog through many books, tracking down many references, some relevant, some not. When the precedent was finally unearthed, it might not have seemed like such a direct precedent after all. There might be reasons why it would be worth taking a second crack at the idea, perhaps hybridizing it with innovations from other fields. Hence the virtues of Galapagan isolation.

The counterpart to Galapagan isolation is the struggle for survival on a large continent, where firmly established ecosystems tend to blur and swamp new adaptations. Jaron Lanier, a computer scientist, composer, visual artist, and author of the recent book *You are Not a Gadget: A Manifesto*, has some insights about the unintended consequences of the Internet—the informational equivalent of a large continent—on our ability to take risks. In the pre-net era, managers were forced to make decisions based on what they knew to be limited information. Today, by contrast, data flows to managers in real time from countless sources that could not even be imagined a couple of generations ago, and powerful computers process, organize, and display the data in ways that are as far beyond the hand-drawn graph-paper plots of my youth as modern video games are to tic-tac-toe. In a world where decision-makers are so close to being omniscient, it's easy to see risk as a quaint artifact of a primitive and dangerous past.

The illusion of eliminating uncertainty from corporate decision-making is not merely a question of management style or personal preference. In the legal environment that has developed around publicly traded corporations, managers are strongly discouraged from shouldering any risks that they know about—or, in the opinion of some future jury, should have known about—even if they have a hunch that the gamble might pay off in the long run. There is no such thing as "long run" in industries driven by the next quarterly report. The possibility of some innovation making money is just that—a mere possibility that will not have time to materialize before the subpoenas from minority shareholder lawsuits begin to roll in.

Today's belief in ineluctable certainty is the true innovation-killer of our age. In this environment, the best an audacious manager can do is to develop small improvements to existing systems—climbing the hill, as it were, toward a local maximum, trimming fat, eking out the occasional tiny innovation—like city planners painting bicycle lanes on the streets as a gesture toward solving our energy problems. Any strategy that involves crossing a valley—accepting short-term losses to reach a higher hill in the distance—will soon be brought to a halt by the demands of a system that celebrates short-term gains and tolerates stagnation, but condemns anything else as failure. In short, a world where big stuff can never get done.

Analyze

1. Explain why, for Stephenson, "The Deepwater Horizon oil spill of 2010 crystallized [his] feeling that we have lost our ability to get important things done."
2. When and what was the Future Tense conference? How was Stephenson's talk received there?
3. What are the two theories Stephenson mentions to describe the relationships that exist between science and SF?
4. Who was Konstantin Tsiolkovsky? Why does Stephenson mention him in his essay?

Explore

1. In your own words, explain The Inspiration Theory and The Hieroglyph Theory. Although Stephenson distinguishes between the two theories, they share many attributes. Explain how the two theories are related to one another. Then, based on Stephenson's essay, assess whether he appears to be advocating for one theory over another.
2. Neal Stephenson was born in 1960 and, in this essay, he draws attention to the fact that his ideas about technology and its potential applications have been shaped by his generational perspectives. Write a letter to Stephenson explaining how your ideas about technology and its potential applications have been shaped by your generational perspective. Then, explain why you agree or disagree with various propositions he makes in the essay and how your generational perspective may be a factor in your response.

3. Neal Stephenson points to the 2010 Deepwater Horizon oil spill as an event that "crystallized [his] feeling that we have lost our ability to get important things done." Do some research into this oil spill. What happened? What were the consequences? Prepare a presentation for your class explaining why the Deepwater Horizon spill was a significant event and how it relates to Stephenson's comments on the need for greater innovation in technological development in energy production and transportation systems.

Jon Turney
"Imagining Technology"

Jon Turney is a British science writer and editor. He is the author of several books, including *The Rough Guide to the Future* (2010), *Medicine and Health Science Trends* (2001), and *Frankenstein's Footsteps: Science, Genetics and Popular Culture* (1998). He is also the co-author of *Harvey's Heart: The Discovery of Blood Circulation Science* (2001), the co-editor of *Not Art: Ten Scientists' Diaries* (2003), and the author of several reports, including one for the British Heart Foundation's anniversary in 2012. The following essay is excerpted from the report *Imagining Technology* (2013), which was commissioned by Nesta, an innovation charity based in the Britain. In this essay, part of a longer report dedicated to exploring whether "imagining technologies and societies in which they are used make innovation more or less likely," Turney discusses technology's relationships to SF and SF's relationships to technology.

What stories do you tell yourself about technology? What stories do specific technological devices tell you?

Technology's Place in Science Fiction

The brief for this working paper is to appraise science fiction's influence on technological development. Science fiction—henceforth SF—does look like a good place to seek such influence. It is a genre with fuzzy boundaries, so it is fruitless to look for a watertight definition of SF (or even, perhaps, "science" and "fiction"). But one which critics agree is useful is an old formulation by Darko Suvin. He defined SF as "a literary genre whose necessary and sufficient conditions are the presence and interaction of estrangement and cognition, and whose main formal device is *an imaginative framework alternative to the author's empirical environment"* (my emphasis). Another world, a future world, or a different version of this world, in other words.

Suvin goes on to suggest that an SF story has atleast one *"novum"*—a feature which defines a key difference between the reader's everyday world and the world being portrayed. They come in a variety of forms, but in a large portion of SF the novum has a scientific origin. Well, that is not quite right. Despite the label, as critic and SF novelist Adam Roberts observes, "the great majority of SF written in the nineteenth and twentieth centuries is actually 'extrapolated technology fiction'." Hence, the novum is generally technological. Generalisation is hazardous, as Roberts emphasises, but he suggests that "We find tools and machines at the core of most science fiction: such that spaceships, robots, time-machines and virtual technology (computers and virtual realities) are the four most commonly occurring tropes of the field."

There is more to the technology of science fiction than this. And there is more to science fiction than technology. The generalisation is broadly right, though. That means SF as a whole is an important arena for imagining the effects of technologies, existing and yet to come. Its imagined worlds are ones in which life is enabled or constrained by technologies in ways we have not yet seen in our world. Whether we do see them realised may then be influenced by the role technologies play in these alternate realities.

The influence is strengthened by the fact that many SF authors love technology, and many technologists love SF. The latter may be a love that dare not speak its name, though. Science fiction has sometimes been dismissed as a juvenile literature—the Golden Age of SF is always 14, it has been said. And it is still not quite respectable (less so, perhaps, in the UK than in other Anglophone countries). Written SF has always been riven by tensions between an urge to grow beyond its roots in pulp fiction and a wish to celebrate them. While printed SF has been increasingly accepted as sufficiently literary to be worth discussing with literary critical tools, the image of SF in general as crude and not quite grown up has been perpetuated to some extent by its growing cultural presence in films, comic books and computer games.

5 Whether or not this image is justified, crude and not quite grown up fictions can still have great power, and popularity. They provide some of the most readily accessible images of possible technologies and figure continually in public discussion of those technologies. At the same time, their dubious (to some) cultural standing influences the rhetoric of those discussions. What is, or is not, considered science fiction—as opposed to, for example, “serious” speculation, extrapolation, or technological goal-setting—is often the subject of boundary disputes energised by an inferiority, or superiority, complex.

Science Fiction’s Place in Technology

Technology is more than just clever stuff. It is about ways of doing things, as well as the gadgets and devices, the artifacts, that often stand in for technology in public discussion. As with science fiction, definitions abound, and it is more fruitful to consider what they have in common than to try and arrive at a definitive version.

A useful survey by two innovation scholars, James Fleck and John Howells, finds that taking all definitions together suggests considering a “technology complex”, rather than technology per se. Any example includes, in varying combinations, a basic function, an energy source, and artifacts or hardware. But it also extends to such things as layouts, procedures, skills, work organisation, management techniques, capital, industry structures, social relations and culture. They add up to what others have called a socio-technical system. For Fleck and Howells, the main thing about the technology complex is that artifacts always operate as part of human activity in a social context. This suggests that working out what effects a new technology might have, or how it might fit into future ways of life, involves exploring a very large space of possibilities. The kind of space, in fact, that fiction is good at exploring.

This affinity is underlined by another way of putting this notion of the technology complex. Every technology begins in the imagination, and needs a description of what it will achieve. Along with the technical specification of a new invention, there is a built-in narrative. Every patent tells a story. Make this device, or follow this process, and certain things will be possible— things not seen before.

The twinning of technologies with stories is emphasised by historian of technology David Nye. Conceiving a tool entails thinking in time and imagining change, he says. Tools are aids to future action. "A tool always implies at least one small story."

As technological development has become more conscious, and systematic, these stories have grown more elaborate. Every technology, already realised or merely sketched, is always already embedded in stories. They run from the explanation of its basic operation, to its place in a collection of futuristic scenarios, whether those scenarios are business plans, paths to national economic competitiveness, environmental good deeds, effective military strategies, or simply advertisements for aids to domestic comfort.

Just as technologies have always come with stories, there have long been fictional stories about technology. Prometheus, Daedalus and Icarus still symbolise the perils and rewards of innovation. Like technology itself, the stories we tell about it have evolved. As the effects of technological change became more obvious, science fiction was one powerful cultural response. It forms a large subset of the stories about technology we have accumulated, which can be separated conceptually (though not always in practice) from the stories inherent in plans for technological development.

Analyze

1. According to Turney, what are the reasons why SF as a genre, is, in the opinion of some, "still not quite respectable?"
2. What is a "novum" and why is it important to Turney's definition and discussion of SF?
3. Turney writes, "Every patent tells a story." Explain what he means by this and how it relates to his argument about the relationships between technology and science fiction.

Explore

1. Turney proposes that "every technology, already realized or merely sketched, is always embedded in stories." Write a short narrative from the perspective of a tool or technological device that you use on a daily basis, for instance an iPhone, a pen, a bike, or a refrigerator. What might these devices or tools be thinking? What stories could these tools or devices relate with regard to how they are used or what they may know about us based on how we use them?

2. In the first paragraph of his essay, Turney cites the literary critic Darko Suvin's definition of SF as a genre. Rewrite this definition in your own words. Then, looking at how Turney interprets and rephrases this definition, compare and contrast the three: Suvin's, your own, and Turney's.
3. In a two-page response essay, review and reflect on two sections from Turney's essay, "Technology's Place in Science Fiction" and "Science Fiction's Place in Technology." What did you learn from each? Which section do you believe is most persuasive? Why?

Kathryn Cramer
"On Science and Science Fiction"

Kathryn Cramer is an American SF writer, editor, and literary critic. The author of numerous award-winning SF books and stories, she has also co-edited approximately 30 anthologies related to science fiction and is a founding editor of *The New York Review of Science Fiction*. Currently an editor at Project Hieroglyph, a Web-based space for writers, scientists, artists, and engineers to collaborate on visions of the near future, she is also the editor of the forthcoming book *Hieroglyph: Stories and Blueprints for a Better Future* (2014). In this essay, Cramer reflects on SF as a genre and hard SF as a subgenre, exploring questions related to the relationships between science and SF.

How do you think science relates to SF?

M. C. Escher remarked in his essay "The Impossible" that "Whoever wants to portray something that does not exist has to obey certain rules." The majority of science fiction stories are not plausible extrapolations upon our current situation, using available information; rather they are Escheresque impossible objects which use the principles of science in much the same way that Escher used rules of geometric symmetry—the rules give form to the impossible imaginative content.

Science fiction allows us to understand and experience our past, present, and future, in terms of an imagined future. Like the conventions of perspective in drawing, which allow us to extrapolate railroads from two convergent lines crossed by a lot of parallel line segments, the conventions of science fiction allow us to imagine a physical world beyond the frame of the scenes described. All science fiction about the future, no matter how rigorously constructed, must build its future from fragments of the past and present; the futures we construct are as much a part of the present as we ourselves are; although they will never really be the future, they can represent it.

Physical law tells us that many things are impossible given existing technology, but the ever-expanding frontier of scientific knowledge shows us how to do many things of which we would never have dreamed. Writing stories within the rules of the universe as we know it and yet discovering fantastic possibilities of new ways of life is the central endeavor of the hard science fiction writer. Science fiction writers prefer to give us truth, rather than reality. Science fiction represents what the future could be like, although we know that the future will look nothing like it. Science fiction allows us to know about our future, although when we meet it we may not recognize it.

There has been a persistent view that "hard" science fiction is somehow the core and center of the science fiction field; that all other science fiction orbits around this center; and that the characteristic of this core is a particular attitude toward science and technology. What we habitually call "hard" science fiction is more precisely technophilic science fiction, an attitude which Poul Anderson described in the 1970s: "Science, technology, material achievement and the rest are basically good. In them lies a necessary if not sufficient condition for the improvement of man's lot, even his mental and spiritual lot." He also differentiated the hard science fiction story from other varieties of science fiction: "A hard science story bases itself upon real, present-day science or technology and carries these further with a minimum of imaginary forces, materials or laws of nature." One is more likely to identify a story as "hard" science fiction—regardless of the amount of actual science it contains—if the narrative voice is pragmatic, deterministic, and matter-of-fact about the many high-tech artifacts among which the story takes place, and if the future (or clearly alternate present or past) in which the protagonist lives is primarily the result of significant technological change from the here-and-now. Through repetition we have come to identify this narrative voice as "futuristic."

Like utopian fiction, science fiction grew out of the desire to create and predict the possibility of a better world. In science fiction, this better world will be created and predicted through science and technology: scientific exploration and technological innovation are political acts leading to world salvation. But without the tradition of the folk-tale, science fiction, should it exist at all, would be a literature of didactic tracts, blueprints for "utopia." Fortunately, the enlightened, rationalistic, utopian impulse collided with the irrational, romantic, fanciful folk story-telling tradition.

In addition to its connection to the folk-tale, science fiction has another important connection to pre-literate culture. Before the Reformation, when only the clergy were allowed to read the Bible, the laity looked to religious art not for representations of daily reality, but for revelations of the principles underlying reality—to discover the sacred texts. Science fiction is the religious art of science. While of course anyone who can read today is as entitled to read scientific texts as they are to read the Bible, the habits of "reading" religious art have carried forward to the way we read science fiction. We read science fiction not for representations of our daily lives, but for revelation of the principles behind everyday experience—the cosmic order. As young teenagers we may have read science fiction to learn about science itself. As adults, we probably already know most of the science, perhaps better than many of the authors whose works we read, but science linked to story-telling gives us an emotional experience difficult to replicate while confronting mundane reality alone, without the company of a book.

Since the founding of the science fiction field in the nineteen-twenties, science has been the guiding force of science fiction, and to some extent science fiction has been able to reciprocate. Could there have been a space program without science fiction? While the robots that make cars in Japanese factories bear precious little resemblance to those in *I, Robot*, they might not now exist were it not for Isaac Asimov and company. Several generations of scientists and engineers have grown up reading science fiction, learning that there is such thing as science, and if they work hard in school they can play too—science fiction influenced the career choices of such scientists as Carl Sagan and the late Gerald Feinberg. A number of science fiction readers turned scientist have later in life become science fiction writers: Fred Hoyle, Gene Wolfe, John Cramer, Carl Sagan, Gregory Benford, Robert L. Forward, and Don Kingsbury, just to name a few. Despite this connection between science and science fiction, the nature of this connection remains largely unexplored.

The early defense of science fiction emphasized the wonders of science and the sensation that they arouse in the reader—at its best, science fiction tends to be about the emotional experience of discovering what is true, often represented by scientific discoveries of great consequence. In traditional hard science fiction, the story is to be taken very literally, insisting on it more strongly than any other kind of English-language fiction.

However over the last couple of decades not enough attention has been paid to those virtues that science fiction derives from its unique relationship with science. During this time, the relationship between science and science fiction has been de-emphasized in favor of the relationship between science fiction and literature. By now a significant portion of the field's practitioners prefer to call science fiction "speculative fiction," because the social position of a "futurist" is more desirable than that of a "science fiction writer." From this view, speculative fiction, which addresses not just the past and present, but also the glorious, mysterious future, is a much broader field than "mainstream" (the science fiction world's dismissive term for non-science fiction) set in the currently-known or historically-known world, usually involving only those characters and situations that we conceive of as appropriate to a realistic account. Thus defined, mainstream [science fiction] is a subset of science fiction, and the greats of literature are, intentionally or not, merely speculative fiction writers without much talent for speculation.

Although John W. Campbell promoted this view of science fiction, 10
stripped of Campbell's technologically oriented futurism it takes on a different meaning: science is marginalized in favor of social extrapolation. While the prose style of the average science fiction story has improved, many of the best writers have been distracted from the task of working out their own syntheses of science and fiction, and so it goes: out go the paragraphs giving clear evidence that the writer spent all day calculating the nature and quality of eclipses on a planet with five moons, and in come paragraphs of carefully observed description of the protagonist's moods, signifying the writer's sincere obeisance to the conservative but currently fashionable belief that all good stories are "character driven."

Hard science fiction also interacts with the technologies and accompanying institutions that produce and distribute it. In the twenty years since the death of John W. Campbell, much has happened to obscure his technophilic vision of science fiction. The hard science fiction attitude became a salable commodity on its own, separable from scientific content. Particularly during the Reagan years, "hard science fiction" evolved into right wing power fantasies about military hardware, tales of men killing things with big machines, fantasies that had very little to do with scientific thought or theory.

In that era, the majority of the most talented younger science fiction writers were quite uninterested in writing about science, precisely because what was generally perceived as hard science fiction was rapidly degenerating into political allegory. In the midst of this, many writers were still writing good hard science fiction: Isaac Asimov, Arthur C. Clarke, Charles Sheffield, Joe Haldeman, Donald Kingsbury, Gregory Benford, Greg Bear, Paul Preuss, and Joan Slonsczewski. Simultaneously, certain of the cyberpunk writers, Bruce Sterling, William Gibson, and Rudy Rucker, were bending certain tropes of hard science fiction to their postmodern project. A number of good hard science fiction stories have appeared in the past few years by such writers as Geoffrey Landis, Connie Willis, George Alec Effinger, and Lois McMaster Bujold.

The 1983 Eaton Conference on hard science fiction conference brought together literary critics and "writer/scientists" Robert L. Forward, David Brin, Gregory Benford. They discussed many aspects of the effect of hard science fiction, but judging by the published proceedings of the conference, some basic connections between science and fiction remained obscure.

Having served on panels on hard science fiction at conventions, I had noticed certain rhetorical patterns in the claims hard science fiction writers made for hard science fiction. Whenever possible, they minimize the differences between very hard science fiction and science itself. For example, David Brin, in his essay "Running Out of Speculative Niches: A Crisis for Hard SF?" astutely observes that in a hard science fiction story, "'science" itself . . . is a major character" (8). He goes on to describe how something rather like peer review transpires among hard science fiction writers. While I acknowledge that this sort of interactive reading occurs among hard science fiction writers and among writers in other genres and subgenres, the general drift of Brin's essay in the Eaton Conference Proceedings, and for that matter Forward's, entitled "When Science Writes the Fiction," and Benford's, entitled "Is There a Technological Fix for the Human Condition?", is that science and hard science fiction are very similar. This perception of the similarity of science and hard science fiction is manifest in Benford's definition of hard science fiction in that essay:

> 15 My minimum definition of hard science fiction demands that it highly prize fidelity to the physical facts of the universe, while constructing a new objective "reality" within a fictional matrix. It is not

> enough to merely use science as integral to the narrative . . . Science fiction must use science in a speculative fashion. The physical sciences are the most capable of detailed prediction (and thus falsification by experiment), so they are perceived in fiction as more reliable indicators of future possibilities, or stable grounds for orderly speculation.
>
> But, as mathematician Henri Poincaré pointed out, only a small of minority of the human race experiences mathematics pleasurably. So, while mathematics is the bones holding up the scientific animal, the science must be "de-boned" before it can be used in fiction, because the majority of readers, even hard science fiction readers, will tolerate very few equations in a work of fiction. Even the anthology *Mathenauts*, edited by Rudy Rucker, contains, to my count, only four equations, and of those, none are beyond the ken of a high school freshman.
>
> Although some hard science fiction writers take the same attitude as Leonardo Da Vinci, who claimed in his essay "On Painting and Science" that "No human inquiry can call itself a true science if it is not confirmed by mathematical proofs," and expect that the scientifically literate reader will whip out her calculator and discover that all the math behind appearances works out, as often as not it doesn't. In this sense science and hard science fiction are very different.

Hard science fiction is a lively and diverse literature that attempts to get at the power and wonder of science, to articulate the sensation of discovering the true and the real. Stories like "The Singing Diamond" by Robert Forward and "Surface Tension" by James Blish hit the reader with a shot-gun blast of ideas; at the right moment, under the right circumstances, reading a story like that can capture the feeling of making a major discovery.

Hard science fiction is about the aesthetics of knowledge, even knowledge of the most disturbing, overwhelming kind—that which is bigger than one's loving or hating it. In Philip Latham's "The Xi Effect," Edgar Allen Poe's "Descent in the Maelstrom," and Arthur C. Clarke's "Transit of Earth" this knowledge is deadly, but its revelation is numinous. Hard science fiction is at its core beyond questions of optimism and pessimism, beyond questions of technology and application. Hard science fiction recognizes wonder as the finest human emotion.

20 As most science fiction readers already know, hard science fiction has an identifiable feel, a particular kind of narrative voice, the right attitude. This attitude is respectful of the principles underlying the practice of science, not unlike the reverence one should display when entering the chapel. A rationalist cosmology accompanies this attitude: a cosmology based on the belief that the literal facts of a situation are more important than any interpretation. The anti-mysticism of hard science fiction is a point of pride for science fiction writers (and scientists of similar mindset) who see science as a replacement for religion and superstition.

In his essay on metaphor, entitled "On Truth and Falsity in their Extra-moral Sense," the philosopher Friedrich Nietzsche describes what he feels to be the literal, factual, non-metaphorical situation of humanity, which might easily serve as a description of the hard science fiction cosmography:

> In some remote corner of the universe, effused into innumerable solar-systems, there was once a star upon which clever animals invented cognition. It was the haughtiest, most mendacious moment in the history of this world, but yet only a moment. After Nature had taken breath awhile the star congealed and the clever animals had to die.

The lifespan of our sun is but the briefest moment in the history of the universe; everything we value will vanish soon unless we spread ourselves across the universe, or unless there have been, are, or will be other intelligent life forms out there. Hard science fiction writers try to find a way out of this dilemma. Hard science fiction uses the rules of a deterministic universe to show us that our fate is not yet sealed. As Hal Clement remarked in conversation, in hard science fiction, the universe itself is the antagonist.

Hard science fiction's problem-solving attitude toward our inevitable extinction has three corollaries: (1) no precondition of viable intelligent life is irreplaceable, given enough scientific knowledge, (2) the replacement of things needed to sustain life is necessary, desirable, and promotes the long-term survival of our species, (3) the scientific should replace the unscientific. Nietzsche's pronouncement that "the clever animals had to die" is a depressing thought for the realist; but for the hard science fiction rationalist, it is an exciting challenge! Hard science fiction's strong connection to physics—one of the last systems of classical idealism to retain its intellectual validity—allows hard science fiction to continue to take on the most all-encompassing aspect of the human condition, our survival as a species. The technophilic wing of the science fiction community treasures the thought that because of our interest in and enthusiasm for technological innovation, we may just be the next stage of human evolution. This notion leads to one of hard science fiction's paradoxes: if our faith in science replaces religious faith, science is coopted into becoming a religion, which, of course, would be unscientific. The work of Arthur C. Clarke best shows the tension between science and religion within hard science fiction: some editions of his novel Childhood's End carried the disclaimer that the opinions in the book were "not those of the author." His Christmas hard science fiction story "The Star" also shows this tension: the story "explains" the Star of Bethlehem in hard science fiction terms, a scientific and technological notion replaces a religious one; yet, were it not for Christianity, this replacement would lack meaning.

The primacy of the sense of wonder in science fiction poses a direct challenge to religion: does the wonder of science and the natural world as experienced through science fiction replace religious awe? It is perhaps no coincidence that a similar controversy has emerged in the New Age movement over whether or not true enlightenment can be attained through the use of meditation machines—are electric revelations authentic? If not, how can we tell the difference?

The idea that in the future better and more scientific things will replace all the things we currently need and use—a cosmic belief in an ever-improving standard of living—constitute what I call the replacement principle of science fiction. Robert Heinlein's "It's Great to Be Back" expresses this idea in strong terms: a family returning to Earth after years on of living on the Moon discovers that their nostalgia for the lushness of Earth and the richness of its societies was misguided sentimentality. Frederick Pohl's "Day Million" describes a society in which most of what we know has been replaced by something more futuristic, but he makes less attempt at salesmanship. While atomic light bulbs no longer seem like such a good idea, the notion of living in an L5 colony, traveling to another planet, and communicating with an extraterrestrial intelligence still enchant us. If "slow glass" as described in Bob Shaw's "Light of Other Days" were commercially available, many of us would buy it. And we remain fascinated by such technologies as cloning (see Ursula K. Le Guin's "Nine Lives") and time travel (see Ian Watson's "Very Slow Time Machine"). The big ideas of hard science fiction are more ambitious than the creation of any single device.

Hard science fiction shows us many alternate places to live: space stations, other planets, undersea communities, and so on: hard science fiction takes the position that we should have the knowledge and technology to create, from the building blocks of the universe, everything we need to have rich and happy lives, so as to end our child-like dependence on the Earth and what nature gives us.

Though some hard science fiction writers claim that their future worlds and situations never violate physical law, and therefore just might happen, most science fiction scenarios are at least implausible, often wildly so, and many are outright impossible. The long-standing controversy over whether science fiction writers should use faster-than-light travel in their stories exposes the various conflicting demands upon the writer: because of science fiction's utopian goal of saving humanity from extinction, it is a game that must be played by the rules; it will do no good to beg for favors from the uncaring universe. Eliminating faster-than-light travel from possibility does rather limit our options: we're all dressed up with no place to go. And yet, we must become a self-made species, become the fittest, so we can survive the inevitable death of our sun.

Analyze

1. How does Cramer define "hard science fiction?" How does "hard science fiction" differ from what she calls "science fiction?"
2. What are the differences between SF and speculative fiction, according to Cramer?
3. For what reasons, according to Cramer, were younger SF writers uninterested in writing about science during the Reagan era?
4. What is the "replacement theory" in SF?

Explore

1. Cramer begins her essay with a quote from an essay by the artist M. C. Escher. If you are not familiar with Escher's work, find an image of one of his works on the Web. After you have done so, and based on what you have learned about Escher's work from looking at this image, write one page reflecting on how Escher's work relates to the point Cramer is making in her first paragraph about the relationships between science and SF.

2. Cramer writes, "all science fiction about the future, no matter how rigorously constructed, must build its future from fragments of the past and present". In your own words, explain the point Cramer is making. Then, reflecting on Cramer's sentence and your rewording of this sentence, write a two-page essay explaining why this is a particularly important point to consider when thinking about SF and its relationships to science and technology in the real world.
3. Although Cramer does not choose to use section headings in her essay, the essay clearly falls into distinct sections. As you reread this essay, consider where you would place section breaks. Once you have finished rereading the essay, go back and give a subtitle to each section based on what it is about. Finally, in one or two pages explain your rationale for choosing these section breaks and section titles.

Damien Broderick
"Stranger Than You Can Imagine"

Damien Broderick is an Australian SF and science writer. The author of more than a dozen books, Broderick has also edited over 50 books and was the founding SF editor of the Australian popular-science magazine *Cosmos*. A graduate of the Ph.D. program in Literary Studies at Deakin University, Australia, Broderick completed a dissertation studying relationships among SF, literature, and science. Before moving to San Antonio, Texas, where he now resides, Broderick was for several years a Senior Fellow in the School of Culture and Communication at the University of Melbourne. In this essay, Broderick considers the ways in which technology has and has not allowed us to realize the future predicted in various SF novels and how the future of our present may be very different from the future of the past.

What do you think the future will be like? Why?

Personal jet packs! Weekend trips to Mars! Domed cities beneath the sea! No more time-consuming food, just neat nutrition pills!

That was the future, or part of it, expected by the popular imagination; fuelled by science-fiction comics, movies, and lurid pulp stories reaching back to the 1930s. So when the 21st century began, and we were still stuck here in suburban gridlock, watching attractive airheads getting kicked off the island and bored nobodies doing nothing for hours a day on *Big Brother*, everyone became very cynical about the future. How dull it was! Meanwhile, the new future, the real future, looked like a nightmare of greenhouse scorchers and drought, or shocking, unexpected flooding. Space shuttles fell out of the sky in blazing ruin. Clones were expected any day, but many pious people feared they would have no souls. Darwin had gone out of fashion in the heartland of Western power, the United States. And astrologers now outnumbered astronomers.

It is not so surprising that the future has not turned out like the comic books. After all, nobody expects 21st century law enforcement to be run by masked avengers wearing capes and driving in jet-propelled Batmobiles. Real astronauts don't do their work repairing the Hubble space telescope in satin tights and brass bikinis, with glass bubbles over their heads, despite decades of comics portraying them this way.

The real future crept up on us, in the form of mobile phones (a surprise technology actually predicted in comics such as *Dick Tracy* and the 1960s television program *Star Trek*); portable laptops at affordable prices with vastly more grunt than the computers used to send men to the moon; and computer-generated movies that portray wild 1940s science-fiction horror and space soap-opera scenes in exceptional, believable detail thanks to just such computers. And of course, DVDs, commuter cars built around microelectronics, café lattes, Pilates exercises, and airport bookstores clogged with vapid self-help manuals.

5 In other words, yesterday's future—our present day—is a blend of the predictable and the only slightly surprising. Still, a hundred and fifty years ago, the claim that people would do away with horses in the street, and spend their holidays flying through the air while packed like hens would have seemed mad. The real future of 50 years hence is likely to be just that wrenchingly strange.

And the reason for that strangeness—strictly unpredictable in detail from where we sit here and now—is an accelerating rate of change. It's driving certain key technologies forward in a wild rush, especially computing power.

Taking this insight literally leads to a very perplexing forecast: the singularity, as it's been called, or the spike. It's an ever-soaring curve on the graph of change, dragging us upward through a series of drastic dislocations in work and play; the very shape of our minds and bodies; the world we inhabit.

Here's a jolting change greater than anything we've seen so far in history: by the middle of this century it's possible, even probable, that the relentless ageing of our bodies will be halted by advances in biological understanding plus remarkable new medical interventions. However slowly these health improvements start out, they will carry their beneficiaries forward, step-by-step, year after year, to an era where everyone who chooses has the option of rejuvenation and indefinitely extended youth.

Until now, as the playwright Tom Stoppard has noted wryly, "age is a very high price to pay for maturity." The end result of the Human Genome Project and its successors will see the abolition of that terrible and once inevitable price. After all, the egg cells from which each of us grew were as old as our mother, yet those comparatively old cells later matured and built brand spanking new babies. Is there any reason why we can't learn the secrets of the egg cells that ensure healthy youngsters, and then apply those lessons to keep all our adult cells, and the tissues they comprise, healthy and youthful?

There might be moral objections to eternal youth. Just as blustering at- 10
tempts were once made to prohibit anaesthetics during childbirth, since its pain was imagined to be a punishment imposed by God, so the debilities of age and the finality of death could be considered a necessary part of life, imposed by the deity's wisdom. It's illuminating to recall how many other natural conditions we duck by using technology such as glasses, central heating, dental anaesthetics and tampons. It seems that the changes we're told God wants us to avoid are often those that haven't happened yet. Once we get used to them, once they become part of our lives, moralists discover belatedly that God really doesn't mind after all.

But the singularity will not stop at physical immortality (if that convergence of technologies isn't blocked by war, political caution, or the ruination of the planet by unsustainable industrial and agricultural approaches).

As machines get smarter, they won't just take over the burdens of toil, they will enhance us as well . . . literally. The promise of virtual reality may have stalled as we wait for computer power to double and redouble every year or so—a proliferation that gives us a thousand times as much power every decade, and a million times after two decades, a billion after three. Two or three decades hence, a benign version of the world of *The Matrix* is feasible. Augmented by billions of nanomachines smaller than brain cells, we could have the opportunity to link our thoughts and emotions directly, one person to another, in a kind of machine telepathy. We might roam through rich imaginary spaces and landscapes that make today's supposedly awesome special-effects movies seem as convincing as a child's crayon drawings.

Some might choose to upload their personalities into a totally constructed reality, perhaps even migrate there, adventurous denizens of a wholly new frontier. Living that way, we might be able to copy ourselves numerous times, our variant selves remaining linked in an electronic version of the way nature now links our twin brain hemispheres. One copy, or more, might remain safely archived for back-up, others might roam the depths of space in cheap, tiny starships designed to carry our nano-selves at nearly the speed of light into the deep night—even at the cost of losing their connection to the core self, at least until they return home.

But these are merely my projections beyond the opaque wall of the singularity, a place we can go only in imagination—for now. Even so, what we dream today will be the merest shadow of tomorrow's reality. Let's hope the under-funded research programs working toward extended youthful lifespan succeed in time for us, personally, to share in that great adventure.

Analyze

1. Why, according to Broderick, are most people "cynical about the future" in the twenty-first century?
2. According to Broderick, why has today's reality not turned out to be "like the comic books?"
3. How does Broderick describe and define "the singularity?"

Explore

1. Using an online search engine, locate an image that visually represents the future Broderick describes as being part of the "popular imagination." Then, locate an image that visually represents the reality of the twenty-first century as depicted in Broderick's essay. Finally, locate an image that visually represents the "real future" described by

Broderick. Could one of the three images be used to visually represent Broderick's description of the future after the singularity? If not, locate an image that would visually represent the future Broderick describes after the singularity. Write a well-developed paragraph explaining how each image you have located relates to the passage in Broderick's essay it is illustrating.

2. In a short essay, explain how the title of Broderick's essay fits well with both the reality of the twenty-first century and Broderick's vision for the future after the singularity.
3. While Broderick admits that people have become "very cynical about the future" based on the realities of the twenty-first century, he also speculates in his essay that the future of today will be quite different from yesterday's future. In a two- or three-page essay, explain his reasons for being more optimistic about the future of the present compared with the future of the past. Then, explain why you agree or disagree with his assessment.

Wendy Lesser
"Unearthly Powers"

Wendy Lesser is an American writer and editor. The author of several fiction and nonfiction books, she is also the founding editor of *The Threepenny Review*, a quarterly review of arts and society published out of San Francisco. A cultural critic and frequent book reviewer, her most recent book, *Why I Read: The Serious Pleasure of Books* (2014), recounts her experiences as a reader and what she has learned as a result. In the following essay, first published in *The Threepenny Review*, Lesser reviews one of Isaac Asimov's novels, *Endless Eternity*, reflecting on her own reading of SF as a youth and the ways in which the present may be turning out to be very much like the one Asimov depicted in his novel.

Is there a technology that you use regularly today that reminds you of a technology you may have once read about in an SF story, or seen in a film or on TV?

The world we inhabit is one in which weekly newsmagazines, printed on paper in columns of type, are considered primitive and profoundly obsolescent; in which an entire bookshelf of bound volumes can be stored in a gadget the size of a fingertip; in which a mechanical device that is only about four inches long and a fraction of an inch thick can record whatever we like, play it back to us through a tiny earpiece, and rest comfortably in a pocket when not in use; in which space flight has been invented but is rarely used by humans, who have lost interest in it after the initial decades of excitement; in which hand-held or easily portable computers are a commonplace item; in which literature can hardly be distinguished from film in the public mind; and in which some members of society long fruitlessly for a past era when all such developments were unknown and almost inconceivable.

We *do*, in fact, live in such a world, but I mean something else. The above description, detail by detail, exactly characterizes the world of Isaac Asimov's *The End of Eternity,* a science-fiction novel set mainly in the 482nd, 575th, and 2456th centuries. What is remarkable is that Asimov's book first appeared in print in 1955.

For those of you who were not around then (and I barely was—I was three at the time), let me assure you that none of the present-day realities mentioned in my first paragraph was even a mote in a scientist's eye. In 1955, the year my family moved to Palo Alto, my father had just started working for IBM, where he helped develop the huge mainframe computer that would eventually become the great-great-great-grandfather of Macs and PCs alike. By 1966 or 1967, when I began reading Isaac Asimov novels, a version of that mainframe had recently become available for use in a few high-school computing classes, so that some of us in the Palo Alto school system were taught how to inscribe the punch-cards that fed into the mechanical maw—a process so inhuman and alienating and difficult, so resolutely *digital* in its outlook, that I was determined never to have anything to do with computers again. This resolve disintegrated in about 1983, when I purchased my first "personal computer," a boxy Kaypro whose 64-kilobyte RAM was laughably minute by today's standards, but whose CPU was nonetheless more powerful (or so the salesman told me) than the massive computer that first flew a man to the moon in 1969.

And this is not to speak of laptops, cell phones, flashdrives, iPods, DVDs, Kindles, and all the other devices which only came into widespread use in the last decade or two. Asimov thought all this would take many centuries; instead, it took less than two generations. Yet if he was wrong about the timing, he was fantastically right about not only the inventions themselves, but the effect they would have on society.

Part of the pleasure of reading old science fiction is precisely this: with the special powers vested in you by historical hindsight, you can compare the playfully visionary forecasts with what actually took place. This puts you rather in the position of Asimov's "Eternals," the characters in *The End of Eternity* who stand outside of time, observing and controlling the vast majority who still live within it. The Eternals, contrary to what their name suggests, do not live forever; they age and die just as normal people do. But they have such extensive powers of technical analysis (their highest-ranked functionaries are called Computers, who are superior to Sociologists, who are above Technicians) that they are capable of predicting what will happen to any individual human or group of humans. And because they also have at their beck-and-call an easy form of time travel—consisting of "kettles" that whizz along preset pathways in the fourth dimension, taking them many centuries "upwhen" or "downwhen"—they can actually enter into history at specific points in time and repeatedly change it. These so-called Reality Changes might involve something as small as moving a container from one shelf to another, or as large as engineering the deaths of a dozen people in a crash. The aim is always to produce the Maximum Desired Response (M.D.R.) with the Minimum Necessary Change (M.N.C.): to insure, in short, that the unpleasant or anti-social or generally disruptive event does not occur, and thus to keep mankind in a state of comfortable if slightly dull equilibrium.

Though technology is what makes this kind of reality-control possible, only a human being is capable of finding exactly the right moment and method of change. "Mechanical computing would not do," Asimov's typically invisible, intangible narrator tells us. "The largest Computaplex ever built, manned by the cleverest and most experienced Senior Computer ever born, could do no better than to indicate the ranges in which the M.N.C. might be found. It was then the Technician, glancing over the data, who decided on an exact point in that range. A good Technician was rarely wrong. A top Technician was never wrong." And then, in the kind of portentous single-sentence paragraph in which science fiction delights, Asimov adds: "Harlan was never wrong."

Harlan is our hero, a man whose "homewhen," or time of origin, is the 95th century, but who as a teenager was lifted out of Time to become one of the Eternals. (Forgive me—the capitals are all Asimov's.) Like all

Eternals, he can never go back to his own century, not only because the rules forbid it, but because if he went back he would, like Jimmy Stewart in *It's a Wonderful Life,* find everything horribly changed; he would learn that he had never had a home or a mother or an existence of any kind, because the ongoing series of Reality Changes (some, perhaps, implemented by himself) would have wiped him off the record. So instead he travels light, moving from one century to another, putting in the fix as needed, obeying his superiors, and only occasionally wondering why life is structured the way it is and whether Eternity really lasts forever. (Apparently it doesn't: even the Eternals cannot get into the "hidden" centuries between the 70,000th and the 150,000th, and when they enter the system after that, all they find is a dead, uninhabited, featureless world.)

I won't go any further into the plot of this novel. If you have never been a science-fiction fan, I will long since have lost you anyway. But if you ever were a fan—as I was, quite obsessively, in my teens—you cannot do better than to return to the works of Isaac Asimov. Cheesy as the love story inevitably is, and inconsistent as some of the time-related logic turns out to be (why, for instance, does Harlan have to cancel an appointment in the 575th century in order to go to the 3000th and see a man who is "free this afternoon," when normal logic tells us he could have gone and returned in a matter of minutes, or even seconds?), the essential storyline has a deeply compelling quality that is—to me, at least—irresistible. As I approached the end of this novel, I found myself agitatedly turning pages in the way I always do in the last hundred pages of a Henry James novel (even, I'll confess, a Henry James novel I have read before). And, as in a James novel, the propulsive force is a desire to find out how things turn out for these deeply knowing but finally helpless characters, who are up against moral dilemmas they can't easily solve, and who are impeded in their attempted solutions by people who are socially and economically more powerful than they are.

The End of Eternity may be one of Asimov's better novels, but it follows the same essential pattern as all his others, as I discovered when I went back recently to reread *Foundation's Edge* and *The Robots of Dawn*. Like all obsessive writers, Isaac Asimov is a victim of the repetition compulsion, reproducing a single novel over and over again in all its myriad forms. His goes something like this: An individual with good powers of analysis and logic, as well as a great deal of modestly worn courage, confronts a gigantic system that is out to thwart him because he threatens, wittingly or unwittingly, to bring about its downfall. In the course of his efforts, he has to rely on other people without knowing for sure which ones are his friends or lovers and which his enemies or betrayers. He is good at crossing cultural boundaries and even interacting with other life forms (some of Asimov's most touching relationships are those between human and robot), but he retains a stubborn, almost curmudgeonly affection for the values and sensations of his own home place. Generally this place is Earth, and even when it is not, he and his entire culture have a kind of residual nostalgia—though also a civilized man's anti-primitive aversion, or an adult's anti-infantile one—for that long-lost homeland, that long-gone birthplace of the human race.

One of the advantages of looking back on Asimov's work from the remove of several decades, not to mention the turn of a century, is that one can see how deeply enmeshed he was in the history of his own time. He was the child of Russian emigrants who left the Soviet Union for America in 1923, just three years after their son Isaac was born; and one can, if one chooses, view his whole science-fiction oeuvre as a recapitulation of the Soviet experiment and the Cold War reaction to it. Yet these novels, although they wear their anti-totalitarian garb as prominently as Orwell's ever did, are unlikely ever to be kidnapped by the right, for the simple reason that all the individualistic, novelty-mongering American virtues are countered in Asimov's work—and sometimes outweighed—by their opposites: that is, a belief in collective effort, a passion for history, and an ineradicable pessimism about the prospects for human progress. For Asimov, super-civilization and technological achievement always go hand-in-hand with a general softening or attenuation of the human spirit, and it is only by getting back to basics (or intuition, or felt sensation) that people can continue to move ahead. It is an essentially nostalgic view, and as such it is profoundly Russian, however much Asimov may have felt himself to be a fully fledged citizen of his new country.

The author's note attached to the 2010 reissue of *The End of Eternity* tells us that Isaac Asimov, in addition to writing vast quantities of science fiction, "taught biochemistry at Boston University School of Medicine and wrote detective stories and nonfiction books on Shakespeare, the Gilbert and Sullivan operettas, biochemistry, and the environment. He died in 1992." But if we go back a mere quarter of a century or so, to the 1984 Ballantine paperback of *The Robots of Dawn,* we can locate ourselves at a moment when the author himself (not to mention Ballantine Books) was still with us. In the author's note to that book, we learn that "at the present time, he has published over 260 books, distributed through every major division of the Dewey system of library classification, and shows no signs of slowing up. He remains as youthful, as lively, and as lovable as ever, and grows more handsome with each year. You can be sure that this is so since he has written this little essay himself and his devotion to absolute objectivity is notorious." If you are one of those people who, like myself, remains committed to the primitive, cellulose-based habits of reading, the pages on which you read this will be yellowed and flaking; but the voice will be as strong and as vitally alive as ever. Now, *that's* what I call time travel.

Analyze

1. Make a list of the inventions mentioned by Lesser in the first paragraph and explain how each has been realized, either by pointing to a specific technology or some historical event enabled by a specific technology.
2. According to Lesser, what does the term "homewhen" refer to in Asimov's novel?
3. List some of the reasons why Lesser assesses Asimov's *The End of Eternity* as one of the author's "better novels."

Explore

1. Do a rhetorical analysis of Lesser's essay in order to respond to the following questions: Who may be the intended audience for this essay? What is Lesser's purpose in writing this essay? Cite specific evidence from the essay to support your reasons for assessing the intended audience, or audiences, and purpose, or purposes.
2. Although primarily a review essay, Lesser also seems to be writing a personal essay or memoir. Examine how Lesser's essay combines elements of both genres—the review essay and the memoir—in her essay. As a class, discuss the ways in which her incorporation of elements of a personal essay help her readers better understand the points she makes about Asimov's novel.
3. Lesser writes, "One of the advantages of looking back on Asimov's work from the remove of several decades, not to mention the turn of a century, is that one can see how deeply enmeshed he was in the history

of his own time." In a short essay, describe how the technologies and cultural issues being discussed in Lesser's own essay reflect the concerns of someone writing in 2010.

4. Write a review of Lesser's review, making sure to choose a specific audience and publication for your essay. Would you recommend that people read Lesser's essay? Why or why not?

Michio Kaku
"Physics of the Impossible"

Michio Kaku is the Henry Semat Professor of Theoretical Physics at the City University of New York's Graduate Center. A leader in the field of theoretical physics, he is the author of several popular science books, including *Parallel Worlds*, *Visions*, *Beyond Einstein*, *Hyperspace*, and *Physics of the Impossible*—the basis for his Science Channel TV show, *Sci Fi Science: Physics of the Impossible*. His most recent book, published in 2012, is *Physics of the Future: How Science Will Shape Human Destiny and Our Daily Lives by the Year 2100*. A co-founder of string field theory, Kaku is a working scientist who has expressed his interest in continuing the work of Albert Einstein to "unite the four fundamental forces of nature into a single grand unified theory of everything." In this essay, excerpted from his book *Physics of the Impossible*, Kaku reflects on his early fascination with SF, how this interest related to his pursuit of a career as a scientist, and the relationships between science and SF.

What is something that is today, from a scientific perspective, considered impossible that you would like to study in order to understand whether the impossible might someday be possible?

One day, would it be possible to walk through walls? To build starships that can travel faster than the speed of light? To read other people's minds? To become invisible? To move objects with the power of our minds? To transport our bodies instantly through outer space?

Since I was a child, I've always been fascinated by these questions. Like many physicists, when I was growing up, I was mesmerized by the possibility of time travel, ray guns, force fields, parallel universes, and the like. Magic, fantasy, science fiction were all a gigantic playground for my imagination. They began my lifelong love affair with the impossible.

I remember watching the old *Flash Gordon* reruns on TV. Every Saturday, I was glued to the TV set, marveling at the adventures of Flash, Dr. Zarkov, and Dale Arden and their dazzling array of futuristic technology: the rocket ships, invisibility shields, ray guns, and cities in the sky. I never missed a week. The program opened up an entirely new world for me. I was thrilled by the thought of one day rocketing to an alien planet and exploring its strange terrain. Being pulled into the orbit of these fantastic inventions I knew that my own destiny was somehow wrapped up with the marvels of the science that the show promised.

As it turns out, I was not alone. Many highly accomplished scientists originally became interested in science through exposure to science fiction. The great astronomer Edwin Hubble was fascinated by the works of Jules Verne. As a result of reading Verne's work, Hubble abandoned a promising career in law, and, disobeying his father's wishes, set off on a career in science. He eventually became the greatest astronomer of the twentieth century. Carl Sagan, noted astronomer and bestselling author, found his imagination set afire by reading Edgar Rice Burroughs's John Carter of Mars novels. Like John Carter, he dreamed of one day exploring the sands of Mars.

I was just a child the day when Albert Einstein died, but I remember people talking about his life, and death, in hushed tones. The next day I saw in the newspapers a picture of his desk, with the unfinished manuscript of his greatest, unfinished work. I asked myself, What could be so important that the greatest scientist of our time could not finish it? The article claimed that Einstein had an impossible dream, a problem so difficult that it was not possible for a mortal to finish it. It took me years to find out what that manuscript was about: a grand, unifying "theory of everything." His dream—which consumed the last three decades of his life—helped me to focus my own imagination. I wanted, in some small way, to be part of the effort to complete Einstein's work, to unify the laws of physics into a single theory.

As I grew older I began to realize that although Flash Gordon was the hero and always got the girl, it was the scientist who actually made the TV series work. Without Dr. Zarkov, there would be no rocket ship, no trips to Mongo, no saving Earth. Heroics aside, without science there is no science fiction.

I came to realize that these tales were simply impossible in terms of the science involved, just flights of the imagination. Growing up meant putting away such fantasy. In real life, I was told, one had to abandon the impossible and embrace the practical.

However, I concluded that if I was to continue my fascination with the impossible, the key was through the realm of physics. Without a solid background in advanced physics, I would be forever speculating about futuristic technologies without understanding whether or not they were possible. I realized I needed to immerse myself in advanced mathematics and learn theoretical physics. So that is what I did.

In high school for my science fair project I assembled an atom smasher in my mom's garage. I went to the Westinghouse company and gathered 400 pounds of scrap transformer steel. Over Christmas I wound 22 miles of copper wire on the high school football field. Eventually I built a 2.3-million-electron-volt betatron particle accelerator, which consumed 6 kilowatts of power (the entire output of my house) and generated a magnetic field of 20,000 times the Earth's magnetic field. The goal was to generate a beam of gamma rays powerful enough to create antimatter.

My science fair project took me to the National Science Fair and eventu- 10
ally fulfilled my dream, winning a scholarship to Harvard, where I could finally pursue my goal of becoming a theoretical physicist and follow in the footsteps of my role model, Albert Einstein.

Today I receive e-mails from science fiction writers and screen-writers asking me to help them sharpen their own tales by exploring the limits of the laws of physics.

The "Impossible" Is Relative

As a physicist, I have learned that the "impossible" is often a relative term. Growing up, I remember my teacher one day walking up to the map of the Earth on the wall and pointing out the coastlines of South America and Africa. Wasn't it an odd coincidence, she said, that the two coastlines fit together, almost like a jigsaw puzzle? Some scientists, she said, speculated that perhaps they were once part of the same, vast continent. But that was silly. No force could possibly push two gigantic continents apart. Such thinking was impossible, she concluded.

Later that year we studied the dinosaurs. Wasn't it strange, our teacher told us, that the dinosaurs dominated the Earth for millions of years, and then one day they all vanished? No one knew why they had all died off. Some paleontologists thought that maybe a meteor from space had killed them, but that was impossible, more in the realm of science fiction.

Today we now know that through plate tectonics the continents do move, and that 65 million years ago a gigantic meteor measuring six miles across most likely did obliterate the dinosaurs and much of life on Earth. In my own short lifetime I have seen the seemingly impossible become established scientific fact over and over again. So is it impossible to think we might one day be able to teleport ourselves from one place to another, or build a spaceship that will one day take us light-years away to the stars?

Normally such feats would be considered impossible by today's physicists. Might they become possible within a few centuries? Or in ten thousand years, when our technology is more advanced? Or in a million years? To put it another way, if we were to somehow encounter a civilization a million years more advanced than ours, would their everyday technology appear to be "magic" to us? That, at its heart, is one of the central questions running through this book; just because something is "impossible" today, will it remain impossible centuries or millions of years into the future?

Given the remarkable advances in science in the past century, especially the creation of the quantum theory and general relativity, it is now possible to give rough estimates of when, if ever, some of these fantastic technologies may be realized. With the coming of even more advanced theories, such as string theory, even concepts bordering on science fiction, such as time travel and parallel universes, are now being re-evaluated by physicists. Think back 150 years to those technological advances that were declared "impossible" by scientists at the time and that have now become part of our everyday lives. Jules Verne wrote a novel in 1863, *Paris in the Twentieth Century,* which was locked away and forgotten for over a century until it was accidentally discovered by his great-grandson and published for the first time in 1994. In it Verne predicted what Paris might look like in the year 1960. His novel was filled with technology that was clearly considered impossible in the nineteenth century, including fax machines, a world-wide communications network, glass skyscrapers, gas-powered automobiles, and high-speed elevated trains.

Not surprisingly, Verne could make such stunningly accurate predictions because he was immersed in the world of science, picking the brains of scientists around him. A deep appreciation for the fundamentals of science allowed him to make such startling predictions.

Sadly, some of the greatest scientists of the nineteenth century took the opposite position and declared any number of technologies to be hopelessly impossible. Lord Kelvin, perhaps the most prominent physicist of the Victorian era (he is buried next to Isaac Newton in Westminster Abbey), declared that "heavier than air" devices such as the airplane were impossible. He thought X-rays were a hoax and that radio had no future. Lord Rutherford, who discovered the nucleus of the atom, dismissed the possibility of building an atomic bomb, comparing it to "moonshine." Chemists of the nineteenth century declared the search for the philosopher's stone, a fabled substance that can turn lead into gold, a scientific dead end. Nineteenth-century chemistry was based on the fundamental immutability of the elements, like lead. Yet with today's atom smashers, we can, in principle, turn lead atoms into gold. Think how fantastic today's televisions, computers, and Internet would have seemed at the turn of the twentieth century.

More recently, black holes were once considered to be science fiction. Einstein himself wrote a paper in 1939 that "proved" that black holes could never form. Yet today the Hubble Space Telescope and the Chandra X-ray telescope have revealed thousands of black holes in space.

The reason that these technologies were deemed "impossibilities" is that 20
the basic laws of physics and science were not known in the nineteenth century and the early part of the twentieth. Given the huge gaps in the understanding of science at the time, especially at the atomic level, it's no wonder such advances were considered impossible.

Studying the Impossible

Ironically, the serious study of the impossible has frequently opened up rich and entirely unexpected domains of science. For example, over the centuries the frustrating and futile search for a "perpetual motion machine" led physicists to conclude that such a machine was impossible, forcing them to postulate the conservation of energy and the three laws of thermodynamics. Thus the futile search to build perpetual motion machines helped to open up the entirely new field of thermodynamics, which in part laid the foundation of the steam engine, the machine age, and modern industrial society.

At the end of the nineteenth century, scientists decided that it was "impossible" for the Earth to be billions of years old. Lord Kelvin declared flatly that a molten Earth would cool down in 20 to 40 million years, contradicting the geologists and Darwinian biologists who claimed that the Earth might be billions of years old. The impossible was finally proven to be possible with the discovery of the nuclear force by Madame Curie and others, showing how the center of the Earth, heated by radioactive decay, could indeed be kept molten for billions of years.

We ignore the impossible at our peril. In the 1920s and 1930s Robert Goddard, the founder of modern rocketry, was the subject of intense criticism by those who thought that rockets could never travel in outer space. They sarcastically called his pursuit Goddard's Folly. In 1921 the editors of the *New York Times* railed against Dr. Goddard's work: "Professor Goddard does not know the relation between action and reaction and the need to have something better than a vacuum against which to react He seems to lack the basic knowledge ladled out daily in high schools." Rockets were impossible, the editors huffed, because there was no air to push against in outer space. Sadly, one head of state did understand the implications of Goddard's "impossible" rockets—Adolf Hitler. During World War II, Germany's barrage of impossibly advanced V-2 rockets rained death and destruction on London, almost bringing it to its knees.

Studying the impossible may have also changed the course of world history. In the 1950s it was widely believed, even by Einstein, that an atomic bomb was "impossible." Physicists knew that there was a tremendous amount of energy locked deep inside the atom's nucleus, according to Einstein's equation $E = mc^2$, but the energy released by a single nucleus was too insignificant to consider. But atomic physicist Leó Szilárd remembered reading the 1914 H. G. Wells novel, *The World Set Free,* in which Wells predicted the development of the atomic bomb. In the book he stated that the secret of the atomic bomb would be solved by a physicist in 1933. By chance Szilárd stumbled upon this book in 1932. Spurred on by the novel, in 1933, precisely as predicted by Wells some two decades earlier, he hit upon the idea of magnifying the power of a single atom via a chain reaction, so that the energy of splitting a single uranium nucleus could be magnified by many trillions. Szilárd then set into motion a series of key experiments and secret negotiations between Einstein and President Franklin Roosevelt that would lead to the Manhattan Project, which built the atomic bomb.

Time and again we see that the study of the impossible has opened up entirely new vistas, pushing the boundaries of physics and chemistry and forcing scientists to redefine what they mean by “impossible.” As Sir William Osier once said, “The philosophies of one age have become the absurdities of the next, and the foolishness of yesterday has become the wisdom of tomorrow.”

Many physicists subscribe to the famous dictum of T. H. White, who wrote in *The Once and Future King,* “Anything that is not forbidden, is mandatory!” In physics we find evidence of this all the time. Unless there is a law of physics explicitly preventing a new phenomenon, we eventually find that it exists. (This has happened several times in the search for new subatomic particles. By probing the limits of what is forbidden, physicists have often unexpectedly discovered new laws of physics.) A corollary to T. H. White’s statement might well be, “Anything that is not impossible, is mandatory!”

For example, cosmologist Stephen Hawking tried to prove that time travel was impossible by finding a new law of physics that would forbid it, which he called the “chronology protection conjecture.” Unfortunately, after many years of hard work he was unable to prove this principle. In fact, to the contrary, physicists have now demonstrated that a law that prevents time travel is beyond our present-day mathematics. Today, because there is no law of physics preventing the existence of time machines, physicists have had to take their possibility very seriously.

Already one “impossible” technology is now proving to be possible: the notion of teleportation (at least at the level of atoms). Even a few years ago physicists would have said that sending or beaming an object from one point to another violated the laws of quantum physics. The writers of the original *Star Trek* television series, in fact, were so stung by the criticism from physicists that they added “Heisenberg compensators” to explain their teleporters in order to address this flaw. Today, because of a recent breakthrough, physicists can teleport atoms across a room or photons under the Danube River.

Analyze

1. Who is Flash Gordon, and why does Kaku mention the television show based on his character in the introduction to his essay?
2. Explain the point Kaku is making by discussing the example of plate tectonics.
3. Why does Kaku end his essay with a paragraph about teleportation? How does this paragraph relate to several key points he makes throughout the essay?

Explore

1. Watch an episode of *Star Trek*, making a note of every technological tool that is used in the episode and its functions. Make a list of technologies that appear in the television episode and explain how each is related to, or reflected in, technologies that we use today. Review and discuss these lists as a class, paying particular attention to the different ways in which technologies from the television show relate to the technologies we use today.
2. Watch the first episode of Kaku's television show *Physics of the Impossible* on YouTube. As you watch the episode, write a description of what you are watching, keeping track of what happens in the episode and the themes and issues presented. After watching the episode, write a three- to five-page essay comparing and contrasting the experience of reading the essay and watching the video. In the essay, explain some of the similar themes and issues discussed. Describe some of the differences in how similar themes and issues were presented in the video and in the essay. Reflect on your response to the video and to the essay, as well as on the similarities and differences between what you learned from each.
3. Quantum Mechanics and the Theory of Relativity appear to both be very important in Kaku's discussion of the possibility of realizing in reality technologies that were once thought to be "impossible." Do some research on Quantum Mechanics and the Theory of Relativity. Explain briefly what each is, and in a short essay explain how these theories and Kaku's discussions of them relate to time travel.

Forging Connections

1. Each author in this chapter takes some position with regard to how SF relates to the future, the present, and the past. In a three- to five-page essay, compare and contrast the ways in which two of the authors in this chapter discuss SF's relationship to the future, present, and past. Based on this comparison, explain how your understanding of SF and its purposes may have changed.
2. In his essay, Neal Stephenson lays out two broad theories, The Inspiration Theory and The Hieroglyph Theory, which can be used to describe the complex relationships between science and SF. Choose two essays in this chapter and explain why each seems to be characterized more by The Inspiration Theory, The Hieroglyph Theory, or some combination of both.

Looking Further

1. Several authors in this anthology refer to the relationships between technology and myth, both in terms of how "mythical" contemporary thinking about technology can be, as well as in terms of the ways in which classical myths about technology as recounted in the myths of Prometheus, Daedalus, and Icarus help us better understand how technologies function. Look up the myths of Prometheus, Daedalus, and Icarus. Compare and contrast these. Then, consider how the themes and issues raised by one relate to one or more of the essays in this collection.
2. In discussing the relationships between technologies and stories, Jon Turney quotes the historian of technology David Nye, who wrote, "a tool always implies at least one small story." Such stories, Turney explains, are found both in "the explanation of [the tool's] basic operation" and in "its place in a collection of futuristic scenarios." Choose a specific tool, either mechanical or digital. Then, write a short story (three to five pages) about the tool in which you incorporate a description of its current day-to-day uses and imagine and describe its possible applications. Afterwards, reflect on how your short fiction may have changed your understanding of the real-world functions of this tool and its social significance.