

The Spaceflight Revolution Revisited

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There are two models of the future of spaceflight, and there are two theories of how that future might be achieved. The first *model* of spaceflight assumes that we have already achieved most of what is worth achieving in space, whereas the second imagines it will be possible to build a truly interplanetary civilization in which most human beings live elsewhere than on Earth. The first *theory* holds that progress comes incrementally from the inexorable working of free markets and political systems, whereas the second believes that revolutionary transformations must sometimes be accomplished by social movements that transcend the ordinary institutions and motivations of mundane existence.

My 1975 Harvard doctoral dissertation, published in 1976 as *The Spaceflight Revolution*, attributed the early stages of development of space technology in large measure to a social movement that transcended ordinary commercial, military, or scientific motives.[1] First, visionaries like Konstantin Tsiolkovsky, Robert Goddard and Hermann Oberth developed the ideology of spaceflight. Then tiny volunteer groups coalesced around their ideas in Germany, America, Russia, and Britain, becoming the vanguard of a radical social movement aimed at promoting the goal of interplanetary exploration. Shrewd and dynamic entrepreneurs, notably Wernher von Braun and Sergei Korolyov, took the movement on a military detour, gaining the support of the German and Russian governments. Finally, the movement became institutionalized as the space programs of the Soviet Union, United States, and other countries.

After I wrote, some historians gave greater emphasis to the technical needs of the German war machine and the technocratic values of the Soviet Union in the development of spaceflight.[2] Their analyses focus on later phases in space history, and certainly the social movement was crucial at the very beginning. There is room to debate how long it was influential, and when institutional factors took control. The role of a transcendent social movement in the development of spaceflight is an intrinsically interesting question for historians, but it becomes very important if we use the past to try to understand the future. Thus for me the crucial question has always been: Can spaceflight technology develop to the fullest possible extent without the often irrational impetus that a social movement can contribute?

Human beings have not left low Earth orbit since 1972, and for thirty years the emphasis in space has been relatively modest projects that satisfy some of the conventional needs of terrestrial society. The 1986 report of the National Commission on Space argued that the solar system is the future home of humanity, where free societies will be created on new worlds, and great new resources will benefit humanity.[3] However, governments, private enterprise, and the general public have not endorsed solar system colonization as a practical or worthy goal.

This essay will first consider whether technological breakthroughs in space technology and the rational motives of ordinary institutions have the capacity to break out of this relatively static situation. Then we will

survey the roles that social movements of various kinds might play, and conclude with an examination of one particular nascent movement that might possibly build the foundation for a spacefaring civilization.

Progress in Space Technology

When *The Spaceflight Revolution* was written, we had great hopes that the space shuttle would be an economic as well as technical success, but sadly the cost of launching to Earth orbit remains prohibitively high for many applications. The most recent disappointment is the cancellation of the X-33 and the inescapable realization that we are still a long way from the ability to develop a low-cost launch system.[4]

Science fiction writers and other visionaries have suggested a vast array of alternative orbital launch methods.[5] Some, like electric catapults and Jacob's ladders, have some grounding in scientific principles but may present insurmountable engineering difficulties. Others, like anti-gravity and reactionless drives, have no basis in science and thus must be presumed impossible. A third of a century ago, practical nuclear fission rockets were under development, but this approach now seems environmentally unacceptable. It is hard to devise a more environmentally benign propellant than the hydrogen and oxygen used by the main engines of the space shuttle.

There is some hope that nanotechnology will save the day, with materials based on carbon nanotubes that are vastly stronger yet lighter than metals.[6] However, the X-33 failure shows that it is not easy to work with radically new structural materials in demanding aerospace applications, and we may be many decades away from being able to manufacture propellant tanks, wings, and other large structures from carbon nanotubes.

Perhaps Robert Zubrin is right that use of native Martian resources will significantly reduce the cost of a manned expedition.[7] However, the cost may still be more than people are willing to invest. Thus The Mars Society that has been organized around Zubrin's vision may be more important for reviving the spirit of the spaceflight movement than for any particular technical innovation it offers.

Technological breakthroughs in rocketry would certainly help promote space development, but the advances we are likely to see over the next several decades will not be sufficient in themselves. We also need a profound boost in the motivation to invest in an aggressive space program.

Conventional Societal Motivations

Satellites in low-Earth and synchronous orbit are of great importance in the collection and distribution of information, thus essential to the information economy. The wide range of civilian applications includes telephone, data transmission, television, navigation, weather observation, agriculture monitoring, and prospecting for natural resources.[8] The technology is largely perfected, and incremental progress can be achieved by improvement in information systems and simply by investing in more relatively small satellites of the kinds we already have.

Current space technology has proven the capacity to send robot space probes to any location in the solar system and a few billion miles beyond. Orbiting observatories, such as the decade-old Hubble Space Telescope, are effective means for gaining information about the vast realm that lies beyond the reach of space probes.[9] Much can be accomplished over the next century in space science without the need for major new launch technology. Indeed, one could argue that if science were the prime purpose of spaceflight, we would have done well to keep manufacturing the 40-year old Saturn I, rather than developing more sophisticated launch systems.

Many scientists and ordinary citizens believe that the chief justification for the space program is the knowledge of our place in the universe gained by probes and space telescopes. However, if the government really wanted to advance fundamental knowledge that is interesting to the general public as well as to scientists, it would put its money not into spaceflight but into paleontology, archaeology, and anthropology, extremely underfunded fields where rapid advances could be expected to follow quickly from any increased investment.

The search for human origins is a noble and tremendously exciting scientific initiative waiting for the political will to achieve profound discoveries. Very little is currently invested in primary data collection in paleontology and archaeology, and a few million dollars a year could work wonders. In physical anthropology, tools of genetic science already exist that could chart the evolution of the human species and its geographic dispersion. For example, existing techniques are capable of sequencing the DNA of Neanderthal specimens and determining their relationship to modern humans.**[10]** All that is needed is funding.

Military reconnaissance satellites have been essentially perfected, and they are already capable of accomplishing almost any data gathering the defense establishment is willing to invest in.**[11]** For a quarter century, enthusiasts have urged the development of a space-based missile defense system, perhaps employing beam weapons. If it required orbiting many large installations, it would promote the development of efficient launch vehicles which could then be applied to other purposes.**[12]** But currently its advocates emphasize localized theater defense systems and "smart rock" ICBM interception methods that do nothing to advance civilian spaceflight.

Since the 1960s, there has been much talk about commercial exploitation of outer space. For a time, attention was given to the idea of collecting solar energy in space and beaming it to Earth, and there still is hope that some new industrial processes that require weightlessness will prove to be economically profitable. However, space-based solar energy systems would be extremely costly and are not currently part of the world's response to energy needs.**[13]** Today, materials scientists are much more excited about a wide range of terrestrial nanotechnology techniques than about the dubious value of weightless manufacturing.

Like military applications, hypothetical industrial satellites would probably be in low Earth orbit, although some writers have argued that it might be cheaper to build them from lunar materials because of the low velocity required to leave the Moon.**[14]** This would demand some degree of lunar colonization, and it would thereby build a transportation infrastructure that would reduce the cost of deep space missions.

Nonetheless, it is very difficult to develop a scenario in which the Earth itself could ever benefit from importation of raw materials from beyond the Moon. It is more than a cliché that the world is becoming an information society, post-industrial rather than industrial.**[15]** The Earth has ample supplies of almost every useful chemical element, and it is not plausible that we could find energy sources on Mars that would be cost-effective to bring to Earth. Martian resources would be of value if we had already decided to live there, but we would need some motivation other than raw materials to do so. In purely economic terms, beyond synchronous orbit or maybe lunar orbit there may be no bucks, therefore, no Buck Rogers.

Some say that the pressure of population growth on Earth will force humanity to colonize other worlds. Perhaps the most plausible version of this scenario was suggested in Kim Stanley Robinson's series of novels about terraforming Mars: The rich ruling classes might want to develop Mars as a home for themselves when Earth becomes unendurably overpopulated.**[16]**

Unfortunately, examination of actual fertility and mortality trends does not provide a clear demographic justification for space colonization. The population explosion has not yet halted in many poor nations, but they certainly do not have the wealth for spaceflight. Fertility rates have dropped so far in most of the industrial nations, that they are poised for a population collapse that would remove their motivation to expand out into space.

Recent United Nations estimates predict that nineteen nations of the world will each lose more than a million in population by the year 2050: Russia (loss of 41 million people), Ukraine (20 million), Japan (18), Italy (15), Germany (11), Spain (9), Poland (5), Romania (4), Bulgaria (3), Hungary (2), Georgia (2), Belarus (2), Czech Republic (2), Austria (2), Greece (2), Switzerland (2), Yugoslavia (2), Sweden (1), and Portugal (1).**[17]** Fertility rates are also already below the replacement level in Australia, Canada, France, New Zealand, and the United Kingdom.

Fertility rates are still above replacement in the United States, and the US Census projects population

growth throughout the next century.[18] In part, growth is assured by immigration, and by the fact that fertility rates are still high in some minority groups. Major uncertainties are the roles of religion and politics. The collapse in European fertility rates may partly be explained by secularization and by indirect effects of the welfare state.[19] America is far more religious than almost any European nation today, other than Ireland and Poland, and its political environment is quite different from that of Europe or Japan. If the United States eventually follows the other industrial nations in abandoning religion and adopting the welfare state, then American fertility rates could collapse just as those in most of Europe have already done. If that happens, then there is no nation both rich enough and demographically motivated to colonize the solar system.

Finally, one might hope simply that the passage of time will allow a steadily increasing portion of the population to become interested in space. Spaceflight accomplishes a little more each year, and the growing status of science fiction in popular culture should also contribute to increased enthusiasm.

However, opinion polls reveal only modest growth in support for the space program. Perhaps the best data source is the General Social Survey, a repeated scientific study of a random sample of Americans that has included a question about the space program for twenty-five years. In 1973, just 7.8 percent of the American public wanted funding for the space program increased. By 1998, this fraction had grown just to 10.8 percent. A pessimistic way to look at this is to note that this increase of 3 percentage points over a quarter century would mean 12 percentage points every century. Linear extrapolation would predict a majority of the population will support increased space funding in about the year 2325.

Of course, a crude projection like that is scientifically indefensible. Support has moved up and down over the years, apparently in response to events. The highest level of support was in 1988, responding to the nation's return to space after the Challenger disaster, when 18.9 percent wanted funding increased. The biggest trend over the twenty-five years was actually a shift from feeling funding should be reduced to feeling it was about right. In 1973, 61.4 percent wanted the space program reduced, compared with only 42.2 percent in 1998. Those who felt about the right amount was being invested rose from 30.8 percent in 1973 to 43.8 percent in 1998. But a projection based on the fifteen years 1983-1998 shows no growth in those who want space funding increased, and no decline in the proportion of the population who want it reduced, so projections are very sensitive to the assumptions on which they are based.

While opinion polls give some reason for slight optimism, they certainly do not reveal the kind of rapid growth in support that would be required to break out of the current doldrums. Hope springs eternal, but there is little reason to expect that either a breakthrough in space technology or a surge in conventional motivation will transform spaceflight in our lifetimes. Thus we need to consider the possible impact of another spaceflight social movement.

The Problem of Social Movements

The regularities of human interaction can be classified in terms of four levels of social coordination: parallel behavior, collective behavior, social movements, and societal institutions.[20] *Parallel behavior* is when individuals do roughly the same thing for similar reasons, but without influencing each other directly. An example is the isolated pioneers who developed the intellectual basis of spaceflight, including Tsiolkovsky, Goddard, and the early work of Oberth. On the basis of their ideas, an international network of informal communication developed, chiefly through publications, in which the ideas were disseminated and spaceflight enthusiasts came into contact with others of like mind. The sociological term for informally coordinated mass activity is *collective behavior*, including such phenomena as panics, riots, fads, and crazes.

It often happens that collective behavior can develop a degree of formal organization and become a *social movement*. For spaceflight the watershed was the founding of pro-space voluntary organizations, notably in Germany, the United States, the Soviet Union and Britain. A successful social movement often becomes incorporated in or co-opted by a *societal institution*, such as government space programs. Then, the early enthusiasms of the typical institutionalized movement become mired in bureaucratic inertia, and it is very difficult to transform well-established institutions.[21]

Much of the traditional social-scientific literature on social movements focuses on the movements of deprived groups within society.[22] These often take the form of protests, and they typically challenge the comfortable status of societal elites. To many influential people, the evolutionary processes of conventional societal institutions feel safer and more reasonable than revolutionary movements.

Since the end of the Apollo program, a number of moderate social movement organizations have supported increased efforts in space.[23] In the main, these are respectable groups and their contributions have been worthwhile. However, as Michael Michaud noted in his study of these groups, they have not achieved significant breakthroughs.[24]

A really new spaceflight movement might upset the delicate relationship between the established space program and the branches of government that provide the money for it, and it might alienate many opinion leaders in the general public, even if it energized the enthusiasm of others. At the very least, a fresh social movement would demand fresh thinking that shatters conventional notions about what science, technology and the human spirit could accomplish in space.

Religious movements are especially suspect in the modern era, yet they have the capacity to break through ordinary routines and to experiment with utopian alternatives such as extraterrestrial society.[25] Few people already involved in the space program, and few members of the general public, are prepared to embrace a radically new religion. Some of them are faithful believers in the traditional religions. Most of the rest are probably secularists with neither religious faith nor much trust in religious enthusiasts.

Most people seem horrified by the few highly-publicized religions oriented toward contact with extraterrestrial beings. Both Heaven's Gate[26] and The Solar Temple[27] tried to travel to other worlds by committing suicide, and the latter also committed a number of murders. A theologically similar space-oriented group called The Raelian Movement has not resorted to violence but has hurled a powerful religious challenge at conventional society by setting out to clone human beings as part of its radical method for transcending the limitations of terrestrial life.[28]

Religious movements have a tendency to pursue goals by supernatural rather than natural means. An example is the little book published by the Hare Krishna movement, *Easy Journey to Other Planets*, advocating chanting rather than rocketry as the best means to experience other worlds.[29] Thus, it is possible that space-oriented cults will seek to explore the galaxy, but they will probably attempt to do so through supernatural rituals rather than through spaceflight.[30]

This brief survey of research on social and religious movements is not very encouraging. However, the examples of the Civil Rights, Women's Liberation, and Environmentalist movements remind us that social movements are often very effective in changing society's priorities. Perhaps a totally new kind of movement could emerge in the next few years, employing technology to serve fundamental human needs that in earlier centuries would have motivated religious or political movements.

The Starbase Movement

Let us imagine a successful social movement of the future that could actually build an interplanetary and even interstellar civilization. I will present one idea here, but perhaps others are possible. The idea relies upon plausible developments in fields of science and technology that seem remote from astronautics, namely: cognitive neuroscience, genetic engineering, nanotechnology, and information systems. But the fundamental key is a transcendental movement that would provide the motivation to apply these developments to the foundation of cosmic civilization.

The chief impediment to rapid development of spaceflight is the problem of returning a profit to the people who must invest in it. The most obvious way to motivate people to invest in interstellar exploration is to invite them to travel personally to the stars and create new lives for themselves on distant worlds. But we are decades and perhaps centuries away from having the technological capability and infrastructural base to accomplish this in the conventional manner we have always imagined, by flying living human bodies and all the necessities of life to other planets. There is, however, another possible way.

Visionaries in a number of cutting-edge disciplines have begun to develop the diverse toolkit of technologies that will be required to overcome death. A prominent example is Ray Kurzweil, a pioneer of computer speech recognition, who argues that human beings will gradually merge with their computers over the next century, thereby becoming immortal.[31] The idea dates back at least to Arthur C. Clarke's 1953 novel, *The City and the Stars*. In 1966, Roger MacGowan and Frederick Ordway speculated that successful spacefaring species might evolve past the state of being biological organisms, becoming "intelligent synthetic automata." [32] We have in fact advanced some distance in that direction over the past thirty-five years, and we now see the real possibility of achieving that dream in a manner that preserves unique human personalities, and blends natural with synthetic modalities.

For a number of years, I have studied the techniques for archiving aspects of human personality in computerized information systems, along the way publishing computer-assisted textbooks on some of the methodologies.[33] In May 1997, I launched a web-based project, called *The Question Factory*, to create a very large number of questionnaire measures to archive aspects of personality that were generally missed by standard psychological tests.[34] In addition to placing a number of item-generation open-ended surveys on my own website, I joined the team creating *Survey2000* and *Survey2001*, two major online questionnaire projects sponsored by the National Geographic Society. My initial result was a set of eight personality-archiving software modules incorporating 15,600 items and 31,200 measurements.[35] Anyone can begin to archive his or her personality using these Windows-based programs today.

A complementary approach involves making digital audio-visual recordings of a person's perceptions, speech, and behavior. For example, Carnegie-Mellon University's Experience on Demand project is developing "tools, techniques and systems allowing people to capture a record of their experiences unobtrusively." [36] Steven Spielberg's Survivors of the Shoah Visual History Foundation has videotaped the reminiscences of more than 52,000 survivors of the European holocaust, a 180-terabyte dataset that cost \$175,000,000 to assemble.[37] The same effort could have captured much of the personality of a single individual. A combination of real-time computer graphics and artificial intelligence based on an individual's full personality record could even today produce a realistic dynamic simulation of that individual.

Many people today carry personal digital assistants (PDAs), and some of these are already connected to Internet. Over the next few years, these will evolve into multi-media gateways to the world of information, serving as advisors, coaches, agents, brokers, guides, and all-purpose servants. At the same time they perform all these functions, they can unobtrusively record the user's wishes, thoughts, actions, and words. Advanced devices of this type will adapt to the user's needs and personality, so they will have to learn many of the facets of the person anyway. They will also be companions that converse and play games with the user. Many forms of personality archiving methods can be blended seamlessly with these activities.

A combination of foreseeable advances in several fields of science and technology will permit vast improvements in our ability to capture and reanimate a human personality. In time, cognitive neuroscience, perhaps drawing upon molecule-size sensor developments in nanotechnology, will be able to chart the structure and function of a living human brain. "Gene on a chip" bio-electronic devices will permit cost-effective sequencing and analysis of those aspects of a person's genetic code that influence his or her personality. Information science, especially in the very active field of digital libraries, will develop the necessary techniques for efficient storage and access of petabyte records of the individual. Finally, advances in genetic engineering, information systems, and robotics will allow archived human beings to live again, even in transformed bodies suitable for life on other planets and moons of the solar system.

New lives must be lived on new worlds.[38] Overpopulation from a zero death rate would soon fill any one planet, and humanity would lose its finest treasure if there were no more children. In the past, several religions imagined that the afterlife was located in Heaven. Once reanimation of archived human personalities becomes possible, it will be necessary to enact a world-wide constitutional law that resurrection must not be done on Earth, but only in the heavens.

We see the beginnings of this prohibition against terrestrial resurrection in the remarkably powerful world-

wide movement to ban human reproductive cloning. Other technologies are likely to be banned on Earth in later decades, such as advanced forms of artificial intelligence and android robots. Genetic engineering is already under concerted attack, and there are the beginnings of a movement to ban some forms of nanotechnology.[39] Scientists in these fields may have to do their work beyond the reach of terrestrial religions and governments, but that will be costly. Only a goal as valuable as eternal life could motivate investment in substantial scientific infrastructure on the Moon or Mars.

Calculation of the geometric realities facing colonization of the universe suggests that there might not be enough room in the galaxy for endless copies of absolutely everybody. The population of an expanding sphere of inhabited worlds increases according to the cube of its radius, while the surface area from which colonization ships can directly reach new solar systems increases only as the square of the radius.[40] To some extent this problem can be dealt with by gradually increasing the time between lives. But unless a means of instantaneous interstellar travel is devised, the rate of expansion of the human population is limited.[41]

The answer is a simple one. A person must earn a new life by contributing in some way, direct or indirect, to the development and maintenance of the entire system that explores and colonizes space. Thus, each generation has a moral contract with the ones that follow. Every person who contributes substantially has a right to expect at least one more life. Future generations must honor that promise, if they are to have any hope that the generations after them will grant them a second life as well.

As noted above, many human populations are failing to reproduce even at the replacement level and are destined to vanish gradually from the earth through an insidious form of genetic suicide.[42] In particular, highly educated nations and groups whose religion or philosophy does not encourage childbirth are failing, whereas uneducated populations and fundamentalist groups are growing. Well educated people can ensure the demographic growth of their population through interstellar immortality. By "arrival of the fittest," those with the most advanced minds and cultures will spread across the galaxy.

Even a very low birthrate per lifetime can cause population growth when an individual has many lifetimes in which to reproduce. Additionally, some individuals who make extraordinary contributions to human progress may thereby earn the right to live out several lives simultaneously in different solar systems, reproducing themselves as well as giving birth to children who are distinct personalities.

We have the technology, already today, to begin archiving human personalities at low fidelity within what I call *Starbase*, a database destined eventually to be transported to the stars. To gain entry to *Starbase*, a person must contribute significantly in some way to the creation of interstellar civilization. One way is to help develop technologies for archiving and reanimating human personalities at ever higher fidelity. Another is to work toward the establishment of small human colonies, first on the Moon and Mars, where *Starbase* can be headquartered and where serious work on reanimation can begin.

When the time comes for the first interstellar expeditions, they will be carried out not by biologically-based humans in their first brief lifetimes, but by eternal *Starbase* modules incorporating the archived but active personalities of the crew and colonists. At the destination, the crew will not waste its time terraforming planets, but will adapt the colonist into whatever form (biological, robot, cyborg) can thrive in the alien environment. Subsequent waves of colonists can be sent as radioed datafiles, in a technically feasible version of the old science fiction dream of teleportation.

A *Starbase* movement could offer the stars to people living today, and this realistic hope would motivate us to create first an interplanetary then an interstellar civilization. It draws upon advanced technology from fields other than rocketry, and it promises to serve the instinctive desire for survival. By conceptualizing human beings as dynamic systems of information, it harmonizes with the fundamental principles of post-industrial society. Such a movement could provide powerful new motivations for a second spaceflight revolution.

Conclusion

Ancient Greek scientists knew that the Earth was a sphere, and they understood roughly how large it is. However, the classical civilization of Greece and Rome failed to exploit that knowledge, send expeditions to the Americas, and colonize the New World. Similarly, our more technically advanced civilization understands the fundamental scope of the galaxy, yet we seem to lack the cultural dynamics and social organization required for interplanetary let alone interstellar travel and settlement.

Pessimists might conclude that we should tear down our present civilization quickly to hasten the next dark age, so that the successor spacefaring civilization will get an earlier start. But the seeds of each new civilization need to be securely planted within the old, just as Christianity took root within classical society and later helped shape industrial society. Two thousand years ago, Christianity was but one of many cults vying for attention within the Roman Empire, but it rose to become the most influential movement of all human history. Thus, optimists would attempt to launch many space-related social movements, in the hopes that one of them would eventually take humanity to the stars.

At the extreme, optimists and pessimists might agree that the human species, as it is currently defined, simply is inferior to the task. With a life span generally under a century, we require quick returns on our investments, and our instincts are too easily satisfied by modest lives on our home planet. But extreme optimists differ from pessimists in that they imagine we can evolve into something higher, a truly cosmic species for whom all the universe is home.

Count me among the optimists. Probably, many intellectual leaders and policy makers in the standard aerospace agencies and corporations will find the Starbase idea too radical for their tastes. Yet business as usual is not going to create interplanetary civilization. In time, the standard institutions of Western Civilization will disintegrate, like those of the Roman Empire sixteen hundred years earlier. Already we see demographic trends that are extremely worrying: unchecked population growth in the poor countries, and impending collapse in most advanced nations. Human exploration of the universe through an aggressive space program has nearly stalled. The future demands a new spaceflight social movement to get us moving again.

References

1. William Sims Bainbridge, *The Spaceflight Revolution* (New York: Wiley Interscience, 1976).
2. Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (New York: Free Press, 1995); Walter A. McDougall, *The Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985).
3. National Commission on Space, *Pioneering the Space Frontier* (New York: Bantam Books, 1986).
4. Frank Moring, Jr., "NASA Kills X-33, X-34, Trims Space Station," *Aviation Week and Space Technology*, March 5, 2001, pp. 24-25.
5. William Sims Bainbridge, *Dimensions of Science Fiction* (Cambridge: Harvard University Press, 1986).
6. Richard W. Siegel, Evelyn Hu, and M. C. Roco, *Nanostructure Science and Technology* (Dordrecht, Netherlands: Kluwer, 1999); M. C. Roco, R. S. Williams and P. Alivisatos, *Nanotechnology Research Directions* (Dordrecht, Netherlands: Kluwer, 2000); M. C. Roco and William Sims Bainbridge, *Societal Implications of Nanoscience and Nanotechnology* (Dordrecht, Netherlands: Kluwer, 2001).
7. Robert Zubrin and Richard Wagner, *The Case for Mars* (New York: Free Press, 1996).
8. For example, see the National Research Council report, *People and Pixels: Linking Remote Sensing and Social Science*, edited by Dianna Liverman, Emilio F. Moran, Ronald R. Rindfuss, and Paul C. Stern (Washington, DC: National Academy Press, 1998).
9. Robert W. Smith, *The Space Telescope* (New York: Cambridge University Press, 1989).
10. Matthias Krings, Anne Stone, Ralf W. Schmitz, Heike Krainitzki, Mark Stoneking, and Svante Pääbo, "Neandertal DNA Sequences and the Origin of Modern Humans," *Cell*, (1997) 90: 19-30; see also Dennis H. O'Rourke, S. W. Carlyle, and R. L. Parr, "Ancient DNA: Methods, Progress, and Perspectives," *American Journal of Human Biology*, 1996, 8: 557-571.
11. Jeffrey T. Richelson, *America's Space Sentinels: DSP Satellites and National Security* (Lawrence: University of Kansas Press, 1999).
12. William Sims Bainbridge, *The Spaceflight Revolution* (New York: Wiley Interscience, 1976), pp. 241-243.
13. *Electric Power from Orbit: A Critique of a Satellite Power System* (Washington, D.C.: National Academy of Sciences, 1981).
14. Gerard K. O'Neill, *The High Frontier* (New York: Bantam Books, 1977); Richard D. Johnson and Charles Holbrow, editors, *Space Settlements: A Design Study* (Washington, DC: National Aeronautics and Space Administration, 1977).
15. Daniel Bell, *The Coming of Post-Industrial Society* (New York: Basic Books, 1973).
16. Kim Stanley Robinson, *Red Mars* (New York: Bantam, 1993); *Green Mars* (New York: Bantam, 1995); *Blue Mars* (New York: Bantam, 1997).
17. Population Division, Department of Economic and Social Affairs, United Nations, *World Population Prospects: The 2000 Revision* (New York: United Nations, 2001), p. 58.
18. Frederick W. Hollmann, Tammany J. Mulder, and Jeffrey E. Kallan, "Methodology and Assumptions for the Population Projections of the United States: 1999 to 2100," Population Division Working Paper No. 38, United States Census Bureau, 2000.

19. Ronald Inglehart and Wayne E. Baker, "Modernization, Cultural Change, and the Persistence of Traditional Values," *American Sociological Review*, 2000, vol. 65 (February), pp. 19-51.
20. William Sims Bainbridge, "Collective Behavior and Social Movements," in *Sociology* by Rodney Stark (Belmont, California: Wadsworth, 1985), pp. 492-523, reprinted in second edition (1987) and third edition (1989).
21. William Sims Bainbridge, "Beyond Bureaucratic Policy: The Space Flight Movement," pp. 153-163 in *People in Space*, edited by James Everett Katz (New Brunswick, New Jersey: Transaction, 1985).
22. Neil J. Smelser, *Theory of Collective Behavior* (New York: Free Press, 1962); Hans Toch, *The Social Psychology of Social Movements* (Indianapolis: Bobbs-Merrill, 1965); Ted Robert Gurr, *Why Men Rebel* (Princeton: Princeton University Press, 1970).
23. Trudy E. Bell, "American Space-Interest Groups," *Star and Sky* (September 1980), pp. 53-60;
24. Michael A. G. Michaud, *Reaching for the High Frontier: The American Pro-Space Movement, 1972-84* (New York: Praeger, 1986), p. 308.
25. William Sims Bainbridge, "Religions for a Galactic Civilization," pp. 187-201 in *Science Fiction and Space Futures*, edited by Eugene M. Emme (San Diego: American Astronautical Society, 1982).
26. Robert W. Balch, "When the Light Goes Out, Darkness Comes," in *Religious Movements*, edited by Rodney Stark (New York: Paragon House, 1985), pp. 11-63; "Waiting for the Ships: Disillusionment and the Revitalization of Faith in Bo and Peep's UFO Cult," in Lewis, James R. (ed.), *The Gods Have Landed: New Religions From Other Worlds*. Albany: State University of New York Press, 1995), pp. 137-166; Ryan J. Cook, "Heaven's Gate," in *Encyclopedia of Millennialism and Millennial Movements*, edited by Richard Landes (New York: Routledge, 2000), pp. 177-179; Winston Davis, "Heaven's Gate: A Study of Religious Obedience," *Nova Religio*, (2000) 3 www.novareligio.com/davis.html.
27. Susan J. Palmer, "Purity and Danger in the Solar Temple," *Journal of Contemporary Religion* (1996) 11, pp. 303-318; "The Solar Temple." Pp. 394-398 in *Encyclopedia of Millennialism and Millennial Movements*, edited by Richard Landes (New York: Routledge, 2000), pp. 394-398.
28. Susan J. Palmer, "The Raëlian Movement International" in *New Religions and the New Europe*, edited by Robert Towler (Aarhus, Denmark: Aarhus University Press, 1995), pp. 194-210; Phillip Charles Lucas, "Raelians" in *Encyclopedia of Millennialism and Millennial Movements*, edited by Richard Landes. New York: Routledge, 2000), pp. 342-344.
29. Bhaktivedanta Swami, A. C., *Easy Journey to Other Planets* (Boston: ISKCON Press, 1970).
30. Rodney Stark and William Sims Bainbridge, *The Future of Religion* (Berkeley: University of California Press, 1985); *A Theory of Religion* (New Brunswick, New Jersey: Rutgers University Press, 1996); William Sims Bainbridge, *The Sociology of Religious Movements* (New York: Routledge, 1997).
31. Ray Kurzweil, *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (New York: Viking, 1999).
32. Roger A. MacGowan and Frederick I. Ordway, III, *Intelligence in the Universe* (Englewood Cliffs, New Jersey: Prentice-Hall, 1966).
33. William Sims Bainbridge, *Survey Research: A Computer-Assisted Introduction* (Belmont, California: Wadsworth, 1989) this textbook includes 9 software programs and datasets; *Social Research Methods and Statistics* (Belmont, California: Wadsworth, 1992) this textbook includes 11 software programs and datasets.

34. William Sims Bainbridge, "Religious Ethnography on the World Wide Web," in *Religion on the Internet*, edited by Jeffrey K. Hadden and Douglas W. Cowan, volume 8 of the annual *Religion and the Social Order* (New York: JAI/Elsevier, 2000), pp. 55-80 especially pp. 66-75.
35. The Question Factory, www.erols.com/bainbri/qf.htm [obsolete URL]
36. www.informedia.cs.cmu.edu/eod/
37. www.vhf.org/
38. William Sims Bainbridge, *Goals in Space* (Albany, New York: State University of New York Press, 1991).
39. Bill Joy, "Why the Future Doesn't Need Us," *Wired*, April 2000.
40. William Sims Bainbridge, "Computer Simulation of Cultural Drift: Limitations on Interstellar Colonization." *Journal of the British Interplanetary Society* (1984) 37:420-429.
41. Sebastian von Hoerner, "Population Explosion and Interstellar Expansion." *Journal of the British Interplanetary Society* (1975) 28:691-712.
42. Nathan Keyfitz, "The Family that Does not Reproduce Itself." In *Below Replacement Fertility in Industrial Societies*, edited by Kingsley Davis, Mikhail Bernstam and Rita Ricardo-Campbell. (Cambridge, England: Cambridge University Press, 1987), pp. 139-154; Ben J. Wattenberg, *The Birth Dearth* (New York: Ballantine Books, 1987).