1

The Impact of Space Activities Upon Ordinary Citizens and the World

"Let us conquer space!" was the rallying cry of a faction in the US Congress early in the 19th Century. Their strategy was to use federal funds to build a paved road westwards from Maryland through the Cumberland Gap, toward the open spaces of Ohio.

In proportion to modern federal budgets, the project was to be as expensive as the Apollo program a century and a half later.

Opponents argued that it would be a "road to nowhere," that at the far end would be only "empty desolation and howling savages." There were a dozen more worthy and more immediately beneficial projects for the expenditure of public money.

After long debate, the highway—called the "National Road"—was built, and as with later cases of federal investments in new frontiers, it paid off magnificently. Likewise, federal investments in and subsidies of canals, railroads, advanced ocean-going technologies, aircraft, and so forth have opened doors and lowered thresholds for public and commercial traffic to flow through. Federal spending on military forces has protected this flow of commerce as each opportunity and technology came along, both from overt hostilities and from natural dangers.

The arguments in today's "conquest of space" have likewise already been won. After decades of debate on what would be worthwhile to do in space, government (both civil and military) and commercial programs are in full swing, taking advantages of the unique opportunities that space access offers. To the extent that these applications have become invisible mainstays of modern life, most Americans seem to remain unaware of how deeply space assets are woven into the fabric of their daily lives.

But exploitation of space is a two-edged sword. Insofar as space applications have often proved superior to old earthbound ways of doing things, the better ways have come to dominate and push out the former systems. In some areas, such as communications, astronomy, or other scientific research, space remains a specialized supplement to competing or complementary ground systems. In other areas—weather forecasting, navigation, reconnaissance—space systems have so outclassed former competitors that these functions soon (if they're not already) will be nearly impossible to perform without the space systems, as ground-based systems atrophy and wither away.

Exploitation of space is thus also a dependence on space. More specifically, it is a dependence on the security and dependability of space-based assets against all threats, both man made and natural. As these dependencies grow, so too do the vulnerabilities and—for anyone wishing us ill—the temptations. The vulnerabilities can be exploited along a full range of power, from publicity-seeking and thrill-seeking spoofing, to blackmail or terrorist-motivated interference, to national-policy-influencing damage, to intentional crippling assaults coordinated with earthside actions.

Before examining more closely the specifics, we must review the unique characteristics of "space" and their implications on space operations. This is also important because of the time-honored human practice of thinking by analogy, of speculating based on perceived parallels. Because space is quite literally "unearthly," such attempts to extend earthside experience to space often are misleading, sometimes spectacularly and dangerously so.

And while we're at it, it's also important to define certain terms used freely about space, such as "space control," "space power," etc. These common terms often seem to have different meanings and reflect different assumptions from different users. This ambiguity may hide true disagreements or may allow the appearance of a counterfeit consensus. Certainly, poor definitions prevent the construction of reliable theories on top of them.

"Understanding space" is still a challenge today not because people know so little about space, but because they know so much about space that isn't accurate. "It ain't what yuh dunno what'll make yuh look lak a fool," goes the old Appalachian proverb, "It's what yuh DO know, what ain't so." And joking about "rocket scientists" rests on the unspoken assumption that ordinary citizens won't EVER be able to understand space, which is a dangerous abdication of their responsibility as citizens and as customers.

Whether it's the still widespread notion that spacecraft float in space because they are "beyond Earth's gravity," or the still-seen misconception that rockets need something external to push against (as in the notorious *New York Times* put-down of Robert Goddard), or the more subtle misunderstanding that the reason objects heat up when hitting the atmosphere is "air friction,"[1] most of us still are burdened with inaccurate ideas about space. These misunderstandings—this knowledge that isn't so—lies in wait to ambush, deflect, and divert people from adequate understanding of space and from the sound decision making that such understanding enables.

"Space" is disconnected from most of the complexities of "earthly" life, and so its parameters and principles can be listed—it's a short list—and understood relatively quickly. Here are some of the key characteristics of "space" along with a few implications for operating there.

Space really IS "unearthly." It's not LIKE our earthside environment. There are some obvious differences, and some not so obvious ones. The implication is that much ordinary "common sense" doesn't apply. One has to be cautious at making analogies with "everyday life." This implies that while it's true that space is a physical frontier, it's also a mental one.

Space is BIG. Most of the Universe is "space." Solid objects like planets or other globs of matter ("the thick stuff") are tiny dust motes

---

1 Objects heat up when hitting the atmosphere because the shock wave that forms around the object compresses the atmosphere. When a gas is compressed, it gives off heat. That heat is transferred to the object by conduction through the atmosphere, raising the temperature of the object. That's different from the heat that aircraft experience, which is caused by friction in the laminar flow over the aircraft's surfaces, which is also conducted to the aircraft.

in a universe consisting mostly of space. This implies that once you know how to operate in one area of space, you basically can operate anywhere in the Universe that you can get to. Its very size imposes a new form of isolation in terms of communications time delay. This time delay is enough to be noticed and to irritate customers using geosynchronous satellites for two-way telephone conversations.

Space is NEARBY. Just a hundred kilometers above us, the physical conditions are those of "outer space." Neglecting air drag, a cannon shell fired vertically at 1,600 m / sec (about one mile per second) will reach "space" in about three minutes. Space is as close as your pager, your mobile telephone, your GPS navigator, and your television remote, and it will soon be as close as your laptop computer. Space used to be a barrier, but like the oceans, it is being transformed into a medium for transportation and a medium for harvesting.

Since space extends "up" forever, so "high above" the rest of Earth, objects in space have a VANTAGE POINT for viewing large areas on the ground, or for being seen by two different areas on the ground so as to relay signals. So it's often the best place from which to view the "big picture" of the Earth's surface and atmosphere, or the "little picture" of specific areas of high interest. Like an antenna on a skyscraper or a mountain, it can serve as a location for communications relay equipment. Furthermore, the global coverage provided by space includes areas of the world that are denied to earthside elements of US national power.

Space is mostly EMPTY of matter. There are random molecules, atoms, and ions flying around, but no "air pressure"—it's a "hard vacuum." This implies that there is no physical "speed limit" since there's nothing to slow down fast objects; also, there's nothing to "push against," so wings and rudders and parachutes and things like that don't work. On the other hand, without crosswinds and currents, future flight paths are simple to predict because there are few forces acting on objects. Also, the emptiness means there's nothing to absorb radiation, either as protection or as veiling of our view of distant objects.

Space is often FULL of energy flow. Usually, there's uninterrupted sunlight (except when in the shadow of a stray piece of matter). Ultraviolet rays can give unprotected skin a sunburn in seconds, and cause severe eye damage in minutes through a too-transparent window. In fact, as Ted Johnson of Boeing puts it, those of us in space are bathed in energy. There is more than enough energy to sustain billions of lives, if we could learn how to efficiently harness it. BUT paradoxically, space can also be very cold since it's an infinite heat sink. The temperature of an inert spacecraft at Earth's distance from the sun will stabilize passively slightly below the freezing point of water. The temperature of the unlit floors of craters at the Moon's north and south poles have cooled far lower and created "cold traps." These "cold traps" catch and accumulate passing water molecules to form the ice layers recently confirmed by space probes (the same logic, and some intriguing radar data, suggests that sun-scorched Mercury also has ice in its polar craters).

Space has physical effects on people who travel there and the hardware that we send there (since it's different from conditions we evolved under). It will quickly kill an unprotected human being and may disable unprotected equipment. The concern for space engineers is how MUCH of Earth's natural environment you need to carry with you to keep you and / or your equipment functional.

Next, after looking at the characteristics of the space environment, what are the characteristics of SPACE FLIGHT?

Spaceflight is NEW. After millennia of dreaming, there's been no more than half a century of human physical access to "space." This means it's still often SURPRISING, both in scientific terms and in unpleasant discoveries of new ways to "crash and burn"—and we should expect it to keep surprising us for a long time to come. And since it's so strange, most earthside analogies are strained at best, and are misleading at worst. Spaceflight is only a few decades younger than powered flight within the atmosphere. This chronological relationship has led to some of the strained or misleading analogies.

Spaceflight is EXPENSIVE and HARD. As a result, new technologies are required which often have later, wider applications in earthside industries. This implies that no known raw material is costly enough to be profitably exported to Earth from space. However, INFORMATION is precious and massless, and there's where the profits are—space often provides information-transfer services much more cheaply than corresponding earthbound alternatives. In the future, high-value low-mass materials such as pharmaceuticals, or high mass objects such as small metallic asteroids, MIGHT prove worthwhile to export back to Earth.

Spaceflight today operates through an extremely narrow series of "choke points," ranging from the handful of operational launch sites to the limitations on communications paths and ground stations. To a much greater degree than any other current human activity (especially those associated with "air power" or "sea power"), spaceflight is disproportionately vulnerable to breakdowns—accidental or deliberate—at these choke points.

Spaceflight is POLITICAL and DIPLOMATIC. The "Show-Off" factor and the symbolism have always been major motivations for government financing of major programs. For example, the goal of Project Apollo, to demonstrate American technological superiority, was fully accomplished. Today, the International Space Station is a diplomatic tool to keep other potential space competitors engaged in a project led by the United States, and especially to keep Russia's aerospace industry tilted westwards.

Spaceflight is INTERNATIONAL in scope. Whatever any one country decides to forego, another country may chose to develop or exploit. Even emerging economies such as Brazil and India recognize the value of having a space industry, and build their own rockets and satellites.

Spaceflight sprang from MILITARY roots (Chinese, Congreve, V2, ICBM) but is now surprisingly "peaceful"—possibly the most genuine "swords into plowshares" metamorphosis in history. However, those plowshares can also quickly change back into swords. The 1991 Gulf War demonstrated the exceptional military utility of space systems.

Spaceflight is still RARE. Fewer than 400 people have actually traveled into space since 1961. They have accumulated little more than ten full years of presence in space. Only about 600 active satellites and probes are currently in operation. However, this rarity will change in the very near future. Many more satellites will soon be in orbit about our planet as a result of a commercial explosion into the space-based services market. The International Space Station will increase the small number of people in space, but not to the same scale as the change in number of satellites.

Spaceflight is USEFUL in practical terms: applications satellites for communications, navigation, observation (weather, military reconnaissance, mapping, etc.), advertisements, etc., comprise a large fraction of all activities. These applications are returning substantial dividends and there seems to be a much larger market for even more services.

Spaceflight has had an overwhelming cultural and social impact (science fiction, environmental awareness, internationalism, UFOs, etc.), and is probably THE most long-range historical achievement of this century.

Lastly, what are the characteristics of SPACECRAFT, the objects we build to fly into space and perform functions there? And what are the implications of those characteristics?

Spacecraft are EXPENSIVE—most are worth several times their weight in gold to build. Yet they are usually even more expensive to reuse or recycle, because the major cost is not the metal but the human attention to preparing for flight. This latter feature implies that the reusable versus throwaway booster question is not clear-cut. Should the premise of inexpensive spacelift prove true, it may be much smarter to build less reliable, and less expensive, spacecraft.

Spacecraft follow predictable paths because there is only a small number of factors influencing their movement: gravity; air drag (at least in lower orbits); photon pressure from the Sun (if the vehicle is large and lightweight); and artificial impulses, both accidental and deliberate. This implies that you can prepare position predictions days or weeks in advance. Therefore, you can also predict when you will see a satellite days and weeks in advance. If you are a spy satellite, when you get over a target of interest, you can assume that your target knew you were coming and has prepared camouflage and countermeasures—unless you are disguised and they don't recognize you as an observation platform.

Spacecraft require deliberate attitude (orientation, or pointing) control. Although some functions (e.g., an omni antenna, or measurements of radiation fields) don't care which way the vehicle is pointing, others, such as high-gain dish antennas or a telescope, require extremely precise pointing. There is no easy "anchor" or "foundation" in space to maintain spacecraft orientation. There are technological solutions (like jets, momentum wheels, gravity booms, and other devices) and there are various forces that disturb a vehicle's attitude (unintended venting, aerodynamic torque, gravitational torque, etc.). There are even some passive techniques, such as gravity-gradient, which on a small scale mimic the Moon by keeping a vehicle's same side facing the Earth.

Spacecraft are "crewed," although most have their human controllers back on Earth, and only a few carry their controllers along with them. Humans rely on automata to assist controlling spacecraft, but must also instruct the automata on how to react to various situations. Automated and remote-controlled systems are improving all the time while human capabilities and costs (in space and on the ground) are currently at a plateau.

Spacecraft with crews tend to use older, proven, more reliable technology, while unmanned vehicles (more expendable, in theory) can use innovative, advanced technologies. As examples, Mir represents mid-1970's USSR technology; and the shuttle is based on the same era (both have had more advanced components added over the years). Deep space probes and expensive unmanned satellites can take greater technological risk. But the latest unmanned satellites, both commercial and government, are at the very edge of the "state of the art" in structural materials, avionics, etc.

Spacecraft are beyond any national territorial sovereignty, as with the high seas, but they carry "bubbles" of back-home law with them. Besides requiring a whole new set of lawyer jokes, this feature suggests that issues of crime, privacy, property, liability, and other legal issues cannot be left behind. Law seeks precedents, and space law relies largely on maritime law for this otherwise-lacking historical record.

These are all important points about space, about space flight, and about space vehicles. We must get the details right before constructing more complex structures upon them. But we also need to step back from time to time to get the "big picture," which we often miss because of over-concentration on subsets of the issue.

The impact of space exploration on society is so broad as to be almost invisible, because most of us have forgotten, or never knew, what popular consciousness was like prior to the beginning of space exploration. But just as the Age of Maritime Exploration, beginning in the 1500s and 1600s, made Europeans realize that the Earth truly WAS round, and that travelers could leave Europe and reach very different regions. Similarly, the Age of Space has made all earthlings realize that this is but one of many worlds. Along with that realization has come the realization that humans can leave Earth and carry out their activities on a far broader scale.

In one generation, the phrase “Crying for the Moon” as a metaphor for eternal frustration has been transformed to the cliché, “If we can go to the Moon, why can’t we X,” as a metaphor for easy accomplishment.

Centuries-old scientific puzzles have been answered by this exploration, and many traditional scientific paradigms have been overthrown. For example, the origin of the Earth and Moon is much better understood. Also, the extent of violent processes—mainly collisions, but also unexpected forms of volcanism and “continental drift”—which have formed and shaped the worlds we have explored is also now realized.

And that has led to a consequent realization, still in the process of making its cultural impression around our home planet. Earth is not “immune” to natural processes that go on in space, whether they be solar variations, space dust, meteorites and asteroids, and even radiation outbursts from nearby stars. It’s more than just the tides—everything on Earth from climate to magnetic fields to vast geologic processes seems to be influenced by outside events.

So “space” is not something “elsewhere” that can be dispassionately studied or ignored as the whims of fashion decree. We live precariously on one world which is located IN space, not apart from space, and our survival as a nation, as a species, and as a world may depend on what we discover about natural processes in space —and what we someday choose to try to do about them.

“Space power,” as wielded by instrumentalities of national will such as military forces, then becomes more than merely a convenient tool—or weapon—for the continued struggle for status among Earth’s nations. In the not too distant future, it may become the key to long-term survival.

Space visionary Carl Sagan, commenting on the extinction of the dinosaurs 65 million years ago, remarked that it happened because "the dinosaurs didn't have a space program." While Hollywood-style asteroid impacts correctly stress the kind of danger to Earth's biosphere that can occur naturally, there are many other hazards already known, and doubtless many more to discover.

This book is not about space science or space exploration, although it will touch lightly on those subjects. Instead, it is about policies for the use of space power and strategies to reach the goals defined by such policies. It is also about theories of how and why to use space power. To understand these ideas, more definitions are required for the sake of clarity.

Policy is a goal or aim of a government, society, national group or other organization.

Official policy is a goal or aim consciously chosen by the leadership of an organization. It may be publicly articulated or kept secret. By extension, official policy also includes the identification of what are considered legitimate or illegitimate actions to attain such goals.

Strategy is a plan to use the resources available to achieve a policy.

Military strategy is a plan to use all relevant resources to achieve a policy through the threat or use of armed force.

Space Control is the combination of abilities to enter, to deny entry to, and to exploit the area above the Earth's atmosphere. Air Force Doctrine Document 2-2[2] (23 August 1998) defines Space Control as the means by which space superiority is gained and maintained to assure friendly forces can use the space environment while denying its use to the enemy.

Space power is the combination of technology, demographic, economic, industrial, military, national will, and other factors that contribute to the coercive and persuasive ability of a country to politically influence the actions of other states and other kinds of players, or to otherwise achieve national goals through space activity. The Air Force Doctrine Document 2-2 defines space power as the ability to exploit civil, commercial, intelligence, and national security

---

2 *Space Operations.* Air Force Doctrine Document 2-2, HQ Air Force Doctrine Command, United States, 23 August 1998.

space systems and associated infrastructure to support national security strategy and national objectives from peacetime through combat operations. The 1998 Rand study, SPACE: EMERGING OPTIONS FOR NATIONAL POWER,[3] defines space power as the pursuit of national objectives through the medium of space and the use of space capabilities.

Space power theory is a theoretical concept of how and why space resources work with other factors to contribute to implementation of policy and achieve defined goals. A theory proceeds from facts, makes assumptions, and predicts a result caused by the relationship of factors within the concept.

Air Force Doctrine Document 2-2 further defines a number of military-related "space power" concepts:

THE ROLE OF MILITARY SPACE POWER. As an integral element of national capabilities, space systems influence operations throughout the conflict spectrum. Space supports Service, joint, and multinational operations across the range of military operations, from peacetime engagement to general war. Space forces contribute at all levels of military activity—strategic, operational, and tactical.

OFFENSIVE COUNTERSPACE. Offensive Counterspace operations destroy or neutralize an adversary's space systems through attacks on the space, terrestrial, or link element of space systems.

DEFENSIVE COUNTERSPACE. Defensive Counterspace operations consist of active and passive actions to protect US space-related capabilities from enemy attack or interference.

The Rationale for Human Space Activity

The reasons for groups of mankind to agree to pay for the high cost of space vary by the composition of the group. British spaceflight theorist R. C. Parkinson[4] lists those groups as explorers, adventurers,

---

3 *Space: Emerging Options for National Power.* 1998. Dana J. Johnson, Scott Pace, and C. Bryan Gabbard, RAND, United States.

4 Parkinson, R.C. 1998. "Review of Rationales for Space Activity." Journal of the British Interplanetary Society. Vol. 15, pp. 275–280.

colonizers, technologists, merchants and profiteers (to avoid pejorative connotations I'll refer to the last group as "vendors").

"Explorers" go to space to learn the answers to big, nonmaterial questions. They are interested in learning the history of the solar system, trying to discover if there is life somewhere other than Earth, to measure unusual processes which occur in new environments, etc. The underlying motivation of this group is human curiosity. Because this group is often comprised of noted scientists, they have political influence beyond their small numbers.

The "Adventurers" are a related group who want to go where no one else has ever been. They want to participate in great adventures of humankind, like going to the Moon and exploring Mars. Adventurers are bored by space activities that can be construed as routine, such as shuttle flights and satellite launches. Of course, Adventurers would be excited to actually attend a routine space launch. They do believe that spaceflight is a good thing in its own right.

In Parkinson's definition, those who believe that the future of mankind includes manned spaceflight are "Colonizers." Colonizers are sure that the cumulative benefits of manned space flight will provide the resources necessary for human survival in the future. They also tend to believe that humankind will have to perfect manned spaceflight to ensure the survival of the species against some unknown disaster in the future. Colonizers place a priority on human spaceflight, the development of an economic superstructure to reduce the cost and encourage the growth of space activities, and finally, to increase public participation in space activities. Often those in the "Colonizer" class are so far ahead of everyone else they deserve to be called "Dreamers," in both the positive and negative sense of that term.

Parkinson would consider three of his groups more practical and realistic than the others. The "Technologist" supports the growth of technology, particularly sophisticated hardware. They are most impressed by the "spin-offs" of high technology into other uses. Technologists believe in the intrinsic value of the newest, most expensive, most sophisticated solution to a current challenge. They believe technology can solve any problem.

"Merchants" are concerned with the useful application of space activity to life on Earth. In the long term, they are very similar to the "Colonists," but the short term and what is immediately useful is most important to them. Merchants assume that market forces will eventually make other space applications useful.

The "Vendors" are merchants who market to the combined space community. Their focus is on the short term and making a profit immediately. They make the instruments of space operations, rockets, satellites and the like. Vendors have the best understanding of the near-term motivations of government and commercial decision makers and seek to accomplish the immediately achievable. They furnish part of the market forces that make space profitable for the merchants.

Since most space programs today sprang from government programs, it is obvious that government rationales are some combination of the foregoing groups of the space community. But governments have their own rationales for space operations. Parkinson lists them as defense, internal order, taxation, education, welfare, and economic activity.

Defense is an obvious space activity. However, the details of what space provides to national defense are probably not well understood even by most educated people. Many assume, for example, that some sort of missile defense system is already in place, while not appreciating the critical needs of systems of navigation and communications. Internal order, achieved using both space and non-space means, includes a sense of well-being by the ordinary citizen, an essential trust in the government's ability to provide services, to resolve disputes, and to provide justice. It is closely related to Economic Activity and Education.

Economic Activity is the role of the government in providing the infrastructure of national life and business activity. It includes roads, sewers, bus lines, electrical power, and many other things in addition to space-related services. Included in this category is the encouragement of exports. An example of economic activity is the commercial GPS industry in the United States, with more manufacturers of GPS receivers than any other country, supported by both a large internal market and a large export market for the services of a government space activity.

Qualified people to develop this activity are provided by Education. Most nations understand that a well-educated workforce is an invaluable national resource. Besides providing the skill to develop the high-tech systems to expand modern lifestyles and modern markets, well-educated citizens generate high income and pay high taxes. Space is part of this lifestyle and provides a sense of adventure and glamour to the study of science and mathematics.

Welfare is the expenditure of government funds on the citizens of the state. It includes expenditures on health care, support to dependent children and support of industries vital to the economic and national security health of the nation. Space expenditures provide the job creation support to well-educated, hardworking, technically-knowledgeable experts, while the medical and technological “spin-offs” of space technology has greatly assisted the government to provide assistance to less well-off citizens as well.

Governments and private groups are now operating in space for essentially the same purposes they operate on Earth. Governments are mostly motivated by issues related to national security, economy, and status. National Security as defined includes the gaining of information, the development of industries to provide an industrial base, and advertising a nation’s high-tech capabilities. Private groups—ranging from international corporations to universities to amateur radio clubs—have a much wider range of motivations.

In terms of national security, there are both military and non-military applications. For both applications, there are concerns: short-range, long-range, and in between.

For military uses, space offers an unmatched vantage point for observation of potentially hostile activity anywhere in the world. Appropriately, the first President to so much as mention space reconnaissance in public was Lyndon Johnson, the early space program’s biggest booster. “I wouldn’t want to be quoted on this,” LBJ told a small group of educators in Nashville in March 1967, “but we’ve spent thirty-five or forty billion dollars on the space program. And if nothing else had come out of it except the knowledge we’ve gained from space photography, it would be worth ten times what the whole program has cost. Because tonight, we know how many missiles the enemy has and, it turned out, our guesses were way off. We were doing things we didn't need to do. We were building things we didn't need to build. We were harboring fears we didn't need to harbor."[5]

Space is also a medium through which physical force or electromagnetic energy can be projected. This can be by missiles launched from Earth against other Earth targets or against targets already in space, or it could be in the form of radar pulses or laser beams. Space also offers a deployment area for stationing weapons for use both against in-space targets and against surface targets.

National security is also served by enhancing national technological levels, and the development of space projects often serves to elevate the technical competence of industrial teams, and accelerate the acquisition of advanced capabilities. As a result, new solutions become available to other pressing technological challenges.

National diplomatic ends are also served by using space activities to advertise national competence in technologies related to military capabilities, and to bind other nations into joint ventures. Because of its still-potent symbolism, space can often bestow on the associated negotiations a futuristic aura that works to the advantage of those perceived as dominant.

The American public very inadequately appreciates the dollar value of commercial space activities. In 1996, world space technology industries made profits of about $75 billion. In 2000, such profits are expected to reach about $125 billion.[6] Figure 1-1 shows these significant trends.

In non-government arenas, small private groups experiment with unusual applications, while would-be profit-making corporations seek to convert the unique characteristics of space and space vehicles into moneymaking activities. By the end of 1997, about $100 billion had been spent on commercial space activities since their inception.

---

5 "Satellite Spying Cited by Johnson." *The New York Times*. March 17, 1967. Internet source: (http://webster.hibo.no/asf/Cold_War/report1/williame.html) found by Rusty Barton, San Jose, California.

6 The State of the Space Industry—Annual Outlook for 1997. May 1997. SpaceVest, Space Publications, KPMG Peat Marwick, Virginia Tech Center for Wireless Communications.

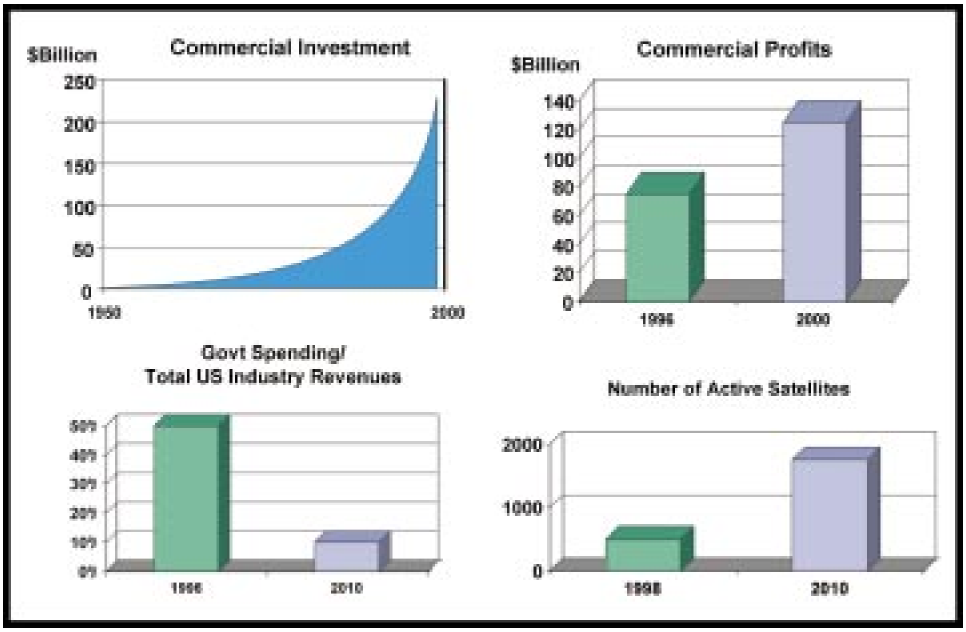

FIGURE 1-1. The Growth of Commercial Space Activities.

An estimated $125–$150 billion more will be invested over the next three to five years. During the first decade of the 21st Century, continuing high levels of profit are expected to bring a torrent of both American and foreign funds—in the area of $650–$800 billion—to the global space industry. By 2010, cumulative American investments in space alone will reach $500–$600 billion or about as much as the value of present American investments in Europe. That same year, revenues from global commercial space activities are projected at $500–$600 billion. By 2020, the national space industry should be producing 10%–15% of American Gross Domestic Product (GDP).

It is conservatively estimated that since the beginning of the US space program in the late 1950s, derived technology has added about $2 trillion in present dollars to the American economy. As much as double that figure could be added to the US GDP in the next quarter century. For the past quarter century, government investments in space science and technology have led to far greater returns than has money put into any other ventures. This ratio of investment to profit seems almost certain to continue for the next half-century or so.

There are now (1998) about 600 active satellites orbiting the Earth. Perhaps another 1,500–2,000 will be placed in orbit by 2010. A majority will perform telecommunications functions, and probably two thirds will be American-built.

The US Government or American corporations own nearly half of current satellites. Ten years from now, when their total number has tripled or quadrupled, that fraction may decline somewhat due to the growth of foreign space technology firms, but it should still be roughly in the 35%–45% range.

Another trend is the ratio of government to private satellite ownership. While more or less holding its own in absolute terms, the scale of government space activities is declining rapidly relative to that of commercial enterprises, measured by total number of spacecraft and by the total investment in spacecraft. In 1996, global civil and military government space expenditures were roughly $58 billion, about 70% of which was American. As noted above, the revenues of American space technology firms alone were roughly one and a half of that.

Barring the unexpected, NASA's annual budget should remain indefinitely in the $13–$14 billion range in present dollars. Estimating future military space spending is more difficult. American defense spending may rise slightly from present levels over the next decade but it will likely remain in the area of $260–$270 billion a year. Meanwhile, the proportion devoted to military space activities will probably rise from its present 10% to as much as 15%, or perhaps $40 billion.

But this means that, at most, all US Government spending on space would be about $50 to 60 billion during the 2010 fiscal year. That would amount to only about 10% of the expected revenues of the American space industry that same year.

Furthermore, much of government spending on space will be purchases of commercially available equipment. These figures help explain why continuation of the present course of national space policy will lead to its domination by commercial considerations in a decade's time, if not sooner.

We now use near-Earth space for communications, navigation, terrestrial monitoring, deep-space observation, timekeeping, and direct broadcast activities. We will soon be able to utilize near-Earth space for imaging across different portions of the electromagnetic spectrum with less than one-meter Earth-surface resolution, for the emplacement of large space laboratories for bioengineering and other experimentation, and for carrying out worldwide mobile telephone and data transmissions, etc. In the next generation beyond that, we are likely to construct platforms for gravity-free materials production, for the exploitation of solar power, for large-scale hypersonic transportation and space tourism,[7] as well as the expansion and improvement of previous uses of orbital space and the introduction of applications not even yet imagined. Consider a few examples of space-related solutions that are increasingly important to key global markets:

- Telecommunications was the first real commercial moneymaker in space, and it represents the largest sector of commercial space activities. Hundreds of public and private concerns worldwide own, operate, and utilize satellite systems for a variety of services. Satellites, as an integral part of the world's telecommunications infrastructure, provide critical support for services such as long-distance data transmission, television broadcasting, and cable TV. In the developing world, satellites are delivering basic telephone service to millions of people for the first time. Emerging economies are using satellite technology to support rapid growth. In the United States and Europe, satellite technology is enabling new services such as personal communications systems, distance learning, telemedicine, and private networks. Piggyback radio relays on low-orbit satellites detect air and sea distress beacons ("SARsat") and have saved thousands of lives. A space-based "Global Air Traffic Control System" is being discussed. Growth rates of 20 to 30 percent

7 Koelle, H. H. 1998. "Spaceflight in the 21st Century: Projections, Plans, Chances, and Challenges." *Journal of the British Interplanetary Society*. Vol. 51, pp. 251–266.

annually are expected to continue in many segments of this sector.

- Satellite-based telecommunications systems have vast market potential. Demand for personal communications services is booming worldwide. The rapidly expanding economies of Europe, South America, and Asia face the task of implementing telecommunications systems to meet growing societal and business demands. For the developing world, satisfying the demand for basic telephone service remains a challenge. In all of these markets, satellite-related wireless systems provide a cost-effective and technologically robust solution to fulfill market demand. Further, space industry solutions are also meeting other critical market needs such as direct-broadcast satellite television, satellite broadcasting for cable distribution, fixed wireless telecommunications, global mobile communications, and integrated content services.

Over the past two decades, data from Earth-sensing satellites have become important in helping to predict the weather, improve public safety, map the Earth's features and infrastructure, manage natural resources, and study environmental change. In the future, the United States and other countries are likely to increase their reliance on these systems to gather useful data about the Earth. By the early 21st Century, satellite remote sensing systems will generate prodigious quantities of data about Earth's atmosphere, land, oceans, and ice cover. The value of these data will depend on how effectively they can be used. Turning remotely sensed data into useful information will require adequate storage and computer systems capable of managing, organizing, sorting, distributing, and manipulating the data at exceptional speeds.

Once dominated by the governments of the United States and the Soviet Union, Earth remote sensing is now a broad-based international activity. This development has transformed the ground rules for intergovernmental cooperation and offers new opportunities to reduce the costs and improve the effectiveness of overlapping national remote sensing programs. In conjunction with this trend, the emergence of the private sector is likely to play a crucial role in the future of satellite remote sensing. Firms have already taken the lead in linking data sources to data users by turning raw data into productive information. In addition, several private firms have begun to market raw data from privately financed remote sensing systems.

Space-based Geographic Information Systems (GIS) provide detailed and precise terrestrial data needed by a variety of markets. For example, farmers use GIS tools to analyze and manage their crops thereby improving crop yields and enhancing competitiveness in an increasingly global marketplace. Insurance companies utilize GIS data to assess claims following a flood or fire disaster. Timber companies, government agencies, and environmental groups use GIS data to monitor forests.

Space-based systems provide crucial data for environmental monitoring, both in real-time weather forecasts and in long-term trend assessments. Killer hurricanes and typhoons don't catch people by surprise anymore, and less violent and much slower climatic trends, such as El Niño, can be detected more easily from space. In the debate over "global warming" and the disputed role of human industrial and agricultural activities in the process, space-based sensors are providing the critical raw data to measure and characterize the process.

Today's space-based Global Positioning System (GPS) technology enables tracking of objects with pinpoint precision—a critical capability with many applications. Transportation companies can monitor their fleets more closely to adhere to tight delivery schedules. Construction companies use GPS to streamline the process of surveying complex building sites. Automobile manufacturers are using GPS to offer consumers value-added services such as location and direction finding, trip tracking, and emergency response assistance.

Space Industry Macro-Trends

After more than 40 years of space activity, there have recently been some noticeable new trends in the world's space industry infrastructure. SpaceVest, a privately owned space industry research company,[8] lists them as globalization; deregulation / privatization; capital market acceptance; technology convergence; government funding stability; and emergence of new industry leaders. SpaceVest goes on to define them as follows:[9]

Globalization. The space industry is inherently global by nature. More than 20 countries have active national programs related to the development of space infrastructure, with the United States, Europe, Russia, China, and Japan leading the way. In addition, many developing nations have become significant purchasers of space-related products and services such as satellite-based telecommunications systems and remotely-sensed data. Emerging markets in Central Europe, Russia, Africa, South America, and the Pacific Rim represent significant opportunities for the space industry, particularly the telecommunications sector. These opportunities have led to a number of firms expanding internationally through mergers, acquisitions, and strategic partner arrangements.

Deregulation/Privatization. The global trend toward deregulation of telecommunications has given rise to a multitude of new competitors, services, and markets serviceable by the space industry. Additional space-related commercial opportunities are being created by the privatization of many traditional government space activities. For example, Europe has established private marketing organizations for launch vehicles (Arianespace, Starsem, etc.) and remote sensing satellite data (Spot Image). In the United States, government-owned national launch ranges are now licensed to private concerns, and many suppliers of defense-related space infrastructure who formerly sold exclusively to the government are now permitted to compete commercially.

Capital Market Acceptance. The financial community is increasingly recognizing the emergence of the space industry as a mainstream industrial activity with powerful growth characteristics. Successful financial performance should continue to attract capital to

---

8 *The State of the Space Industry—Annual Outlook for 1997.* May 1997. SpaceVest, Space Publications, KPMG Peat Marwick, Virginia Tech Center for Wireless Communications.

9 Definitions reprinted with the permission of SpaceVest.

the industry, thereby institutionalizing the space industry in the capital markets. While capital market acceptance is still not as widespread as for information technology ventures, the financial community has begun to recognize that many ventures with a space component are not as risky as previously thought. Nevertheless, satellite telecommunications projects still remain the preferred space industry investment.

Technology Convergence. The convergence of telecommunications and information technologies will continue to fuel commercial growth for advanced "infocom" products and services for a global mobile community. The inherent "look-down" advantages of space-based capabilities will continue to provide an effective means for delivering services and gathering information on a regional or global basis.

Government Funding Stability. Space-based capabilities have become integral to the defense community. Continued stability of research and development expenditures for both civil and defense initiatives is expected. Expenditures related to deploying space infrastructure are expected to continue, with a higher utilization of commercially-developed capabilities. This increasing reliance on space assets for defense operations will provide a revenue base for continued space technology development.

Emergence of New Industry Leaders. The small-to-medium-sized firms in the space industry generally have been on the forefront of commercial innovation. They often possess the low-cost structures and commercially oriented market behavior necessary to capitalize quickly on market opportunities and to compete effectively. Given the substantial size of the worldwide space industry and the emergence of numerous commercially viable niches, many of these companies can experience ample growth without inviting significant competitive response.

This chapter has introduced features of "space power" as it relates to the real world, and has provided a foundation upon which we can venture higher to consider how space power is formed, how it is wielded, and how it can be preserved and enhanced. These are the themes to turn to next.