Strategic Planning Study:

Government Roles in Creating Markets for New Technologies

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Congress held to the principle that private entrepreneurs and not federal agencies ought to construct the transcontinental line. Law-makers proposed "to do enough, and only enough, to induce capitalists to build the Pacific railway."

The central challenge facing NASA and its supporters in the 21st century will be finding ways to leverage government space activities, including direct spending, in such ways as to maximize aggregate space contributions from the government and commercial sectors combined.

The Congress declares that the general welfare of the United States requires that the National Aeronautics and Space Administration (as established by title II of this Act) seek and encourage, to the maximum extent possible, the fullest commercial use of space.

Preface and Summary

Money for space exploration no longer flows readily from the national treasury. In 1965, shortly after the space race began, Congress lavished 19 percent of all federally tax-supported outlays for discretionary programs of a civil nature on the National Aeronautics and Space Administration (NASA). By the year 2000, NASA's share of the civil discretionary budget had fallen to just 4 percent. NASA's budget is currently flat, stuck in the $13 billion range, with little opportunity for growth. Government funding for civil space activities, which currently amounts to about $4 monthly for every resident of the United States, is no longer sufficient to support the overall vision of space exploration.

For $13 billion or so annually in tax-supported funds, NASA is not going to fulfill the space exploration dream. It is not going back to the Moon – not the way it went thirty years ago, with astronauts in expensive spacecraft. The agency is certainly not going to send humans to Mars, an expedition that could require the federal government to appropriate as much as $50 billion annually during the years necessary to organize the voyage.

Still, Americans continue to spend substantial amounts of money on space-based activities. Estimates for the year 2000 suggest that the average U.S. resident spent about $10 monthly on goods and services produced by the commercial space sector – an amount estimated to total about $31 billion that year. The sum has been growing at rates approaching 18 percent annually. During the years immediately following the launch of the first earth-orbiting satellite, government tax revenues for civil space activities were easier to attain than private capital. Recently, the reverse has been true.

Imagine if government officials, through cleverly designed policies, could encourage space revenues based on private purchases to increase by 12 percent annually. By 2010, commercial space revenues in the U.S. would increase to $96 billion. Aggregate national space spending would reach $125 billion – the sum of commercial revenues plus government spending on civil and military space. Worldwide, if the trend continued overseas, the sum would be far larger, topping $300 billion per year. More expansion could occur in the decades that followed.

At those rates – with worldwide private and public space expenditures surpassing $300 billion per year – many of the visions associated with the extraterrestrial realm become possible. Expenditures would spread beyond current space applications such as satellite communication. Commercial involvement could extend to the full range of space activities, including human migration and expeditions of discovery. This study suggests the manner by which government activity might encourage commercial growth in a number of space activities. The activities are arranged into five scenarios. The scenarios are not meant to be exclusive (more than one could be pursued), but attaining all five simultaneously might prove difficult.

- Scenario #1: Expand existing Earth applications, particularly those associated with satellite technology.
- Scenario #2: Invest in space transportation, so as to achieve the long-sought goal of cheaper and safer access to space.
- Scenario #3: Develop extraterrestrial resources, particular those that might be

used to relieve dependence on terrestrial sources of energy.

- Scenario #4: Expand the presence of humans in space, largely through devices that reduce the cost of space operations.
- Scenario #5: Commercialize science and discovery, even to the point of generating privately sponsored expeditions.

The challenge, of course, is how to excite commercial involvement in these areas using government incentives that in the U.S. civil sector are not likely to exceed a few billion dollars per year. This is a formable task. However, it has been done before and it can be done again.

The most striking feature of past government support for other commercially viable technologies is the degree to which public officials have been able to generate economic growth using mechanisms other than direct cash subsidies. Yet NASA officials continue to depend almost entirely upon annual government appropriations. Year by year, agency heads and lobbyists march to Capitol Hill in search of elusive tax dollars. Congress appropriates money derived from tax receipts in response to these claims. As anyone who frequents the national capital knows, this activity represents the tip of the fiscal iceberg. Most of the means by which the federal government supports the commercial development of new technologies do not depend upon annual discretionary appropriations. In some ways, they are analogous to the manner in which nature may have created the universe, fashioning substance out of practically nothing at all.

These devices take numerous forms. They appear as government regulations, tax credits, loan guarantees, land grants, price supports, purchase guarantees, secondary markets, bonding authority, certificates of convenience and necessity, and insurance pools. They have been used to promote shipping, railroad construction, mining, commercial aviation, agricultural productivity, higher education, alternative energy sources, housing development, and overseas investment. In the sections that follow, this study will review the manner in which such devices have been used to support commercial development of past technologies and suggest ways by which they might be used in conjunction with cash appropriations to excite commercial development in space.

Properly employed, such devices could be utilized to overcome many of the barriers that restrain the rapid expansion of commercial activities in space. A combination of financial incentives, research support, business competition, and public-private partnerships could be used to reduce the high cost of space operations. Government subsidies of a non-cash sort could be used to expand private demand for goods and services produced in space. Regulatory reform could provide a more favorable environment for private investment in space.

NASA will continue to play a central role in these developments. The shape of the organization may change as commercial activities supplant government control. The vision that motivates space activities may be transformed as commercial products replace tax-financed expeditions. Most certainly, public officials will face challenges significantly different than those that launched the space program many years ago. The central problem confronting people searching for the resources to do more in space is no longer one of squeezing tax revenues out of reluctant legislators, although that is still important. The central challenge facing NASA and its supporters in the 21st century will be finding ways to leverage government space activities, including direct spending, in such ways as to maximize aggregate space contributions from the government and

commercial sectors combined.

In the chapters that follow, readers will encounter the government roles that have supported the commercialization of past technologies and the means by which they might be applied to space. Chapter one examines the challenge of space commercialization, comparing the vision of commercial activities in space to the practical difficulties of achieving it. Chapters two and three provide a history of government activities used in the past to help create commercial markets for new technologies. Chapter two examines previous government support for transportation technologies while chapter three covers agriculture, mining and energy production, housing, higher education, and overseas investment. Chapter four analyzes the manner in which cost, schedule, and risk affects private investment strategies. Chapters five through nine present the five scenarios outlined above. Chapter ten reviews the obstacles confronting public officials seeking to expand government support for space commerce and briefly reviews the effect that increased commercialization might have on the way in which the executive branch is organized to promote space activities.

1. Government Roles and Private Markets

Rarely did they do it alone. Throughout the history of the United States, entrepreneurs launching businesses based on new technologies invariably have received government assistance. The assistance has taken many forms, but its provision has been essentially constant.

When the Wright brothers, local inventors of seemingly independent means, set out to construct a powered flying machine, they asked for government help. In the Spring of 1899, Wilbur Wright requested that experts at the Smithsonian Institution in Washington, D.C., provide him with a list of current publications on the problem of flight. The Smithsonian Institution had been established by the U.S. Congress some fifty years earlier for the purpose of increasing and distributing knowledge. The Smithsonian Secretary, Samuel Pierpont Langley, was himself engaged in experiments with flight. Using a U.S. War Department contribution of $50,000, matched by an equal allocation of Smithsonian funds, Langley had constructed his own flying machine. He launched his powered Aerodrome eight days before the Wright Brothers successful ascent at Kitty Hawk. His effort collapsed into the Potomac River, prompting one congressman to complain that "the only thing he ever made fly was government money."

Seeking to develop a commercial market for flying machines, Orville Wright came to Washington, D.C., in the hope of securing a purchase order from the U.S. Army Signal Corps. He conducted the necessary demonstration flights in 1908 at Fort Myer. In spite of a crash that put Orville in the Fort Myer hospital and killed his passenger, Lieutenant Thomas Selfridge (a member of the Army reviewing board), the Army purchased the airplane for the substantial sum of $30,000, which included flight lessons for two persons on the device.

The history of aviation began with private entrepreneurs seeking government help for the commercial development of this new technology. The history of space flight began in a somewhat different way. Officials at the National Aeronautics and Space Administration (NASA) contract out of much of the agency's work to commercial firms. Nonetheless, NASA civil servants retained control over the design, verification, and operation of most spacecraft. Instead suppose that local entrepreneurs had designed and flown those missions. Such an approach would not have been as fanciful as it now seems. In the classic science fiction movie "Destination Moon," a 1950 release, private rocketeers financed with industry support conduct the mission after civil servants decide the trip is too risky to invest government funds. In the 1929 German movie, "Frau im Mond," industrialists excited by the prospect of precious gems decide to finance the voyage.

Such an approach would have been analogous to government policies undertaken 100 years earlier for the purpose of constructing a railroad across the continent, the 19th century equivalent of reaching for the Moon. Members of Congress decided that the railroad should be designed, constructed, and operated by private entrepreneurs, a consequence of the fact that federal leaders were preoccupied with a civil war. Lawmakers favoring the transcontinental line resolved that the federal government would "do enough, and only enough" to cause capitalists to complete the venture.

With the Civil War underway, the federal government had no cash surplus sufficient to subsidize private construction of any civilian railroad line. Members of Congress searched for a means of providing government support without providing government cash. They settled on the distribution of land. Private firms constructing railroad lines that met government specifications received grants of federally-owned land. Owners of the Union Pacific and Central Pacific railroad companies, racing to join the transcontinental line, received land grants that extended up to ten miles on either side of their iron road. The prospective worth of the land raised the value of company assets, causing return on investment to rise. This had the effect of attracting additional investors who provided the necessary capital that led to the completion of the line at Promontory Point, Utah, in the Spring of 1869.

Government support of this type effectively creates a subsidy – an incentive that closes the gap between the money required to mount a successful business enterprise and the resources available to the people who manage the firm. Subsidies take many forms. Sometimes they appear as direct cash grants or as money that public officials use to purchase goods and services from private firms. Sometimes cash appropriations indirectly support business expansion, as when the government funds research and development activities that lead to new products. However, subsidies more often occur when public officials provide support that has monetary value to entrepreneurs but do not take the form of cash appropriations. Public officials may provide land grants, establish tax credits, guarantee loans, or create secondary markets for private lending. They may issue regulations that protect fledgling industries, clarify property rights, restrict trade, or stabilize prices. They create government authorities and charter corporations with a social purpose. They issue insurance.

Historically, subsidy methods have varied with the times. What is technically feasible and socially acceptable to one generation is often not compatible with the political realities governing another. When members of the U.S. Congress 200 years ago set out to encourage the development of a domestic merchant marine, they utilized their newly acquired powers over inter-state commerce and foreign trade. This proved compatible with the primary source of government revenue at that time, tariffs and duties laid upon goods transported by ship. Congress thus enacted so-called cabotage laws, restricting trade between domestic ports to ships owned by Americans and registered under the U.S. flag. Such regulations still exist today.

During the Great Depression, wage and price supports were fashionable. Thus members of Congress used price stabilization as a technique to encouraged farmers to invest in new technologies. Stabilization policies guaranteed farmers a base price for their products, which in turn encouraged depression-era farmers to invested heavily in new technologies. Overcoming their reluctance to make capital investments during uncertain economic times, farmers purchased tractors and other farm implements. Agricultural productivity increased rapidly, creating larger markets for American farm products.

Much can be learned from past methods of government support for industries like aviation, the railroads, the merchant marine, and the American farm economy. Support mechanisms created under previous conditions may not exactly fit current legal and political constraints, but they do provide lessons for persons contemplating future means of support. A substantial portion of this report consists of a historical review of those

methods. The remainder applies those lessons to the challenge of expanding commercial activities in space.

The vision of commercial space

In the decades following the first space flights, experts presented an ambitious vision for the commercial potential of this new realm. They expected space to support a range of activities as broad as those arising from previous epochs of discovery. Before space flights ever began, experts correctly predicted that communication satellites in Earth orbits would create a worldwide network for which consumers would happily pay. Later on, entrepreneurs suggested that satellites with cameras derived from military reconnaissance technology could provide images of the Earth and other data of commercial value. Business leaders foresaw the value of space-based global positioning systems. They anticipated a private market for transportation services to and from space. By the year 2000, communication satellites, Earth observation satellites, global positioning systems, and privately-provided space transportation had grown into a $80 billion per year industry worldwide, about 40 percent of that spent in the United States. The dollar value of revenues generated by private space commerce in the United States currently exceeds the sum total of all tax revenues directed toward the U.S. government's civil and military space activities.

Throughout history, tax supported expeditions of discovery have fostered commercial development. This is an old and familiar tale, stretching during the last 500 years from the voyages of Christopher Columbus through the settlement of the American West. In the United States, trappers, miners, and ranchers followed trails opened by government explorers and military officers. Government support for more advanced means of transportation encouraged settlement. Settlement produced new industries. Visionaries anticipated a similar process for what they called the space frontier. From their point of view, space would be used for a wide variety of commercial activities. Drawing on the analogy of western gold rushes and other mining activities, experts presented visions in which space provided a limitless supply of energy and precious metals. Scientists touted the benefits of Helium 3, a substance readily accessible on the surface of the Moon but unavailable on Earth, as a fuel source for potential fusion reactors. Experts explained the advantages of manufacturing special alloys, crystals, and pharmaceutical products in the micro-gravity environment of space, so much so that the process became the primary justification for construction of the International Space Station. When President Ronald Reagan asked business leaders at a 1983 meeting for one major initiative that would give coherence to the government's effort to promote commercial research and manufacturing in space, the leaders told him: build a space station.

These were processes designed for products or resources for consumers back on planet Earth. Visionaries on Earth, however, looked beyond the planet for the ultimate commercial markets. They looked forward to the creations of markets in space itself.

All of the great visionaries who have studied space flight, from Robert Goddard to Stephen Hawking, have advanced the notion that humans will one day live and work in space. This, they say, is an inevitable development for a technological civilization. Exponential population growth, threats from cosmic bombardment, the depletion of terrestrial resources, and the ever-expanding need for energy will push humans into

space. A long-lived civilization must become spacefaring or perish, observed Carl Sagan shortly before he died.

According to the full vision of space commercialization, humans will take their business activities with them as they move into space. This will begin with commercial activities focused around simple need to extract water, fuel, and breathing air from local resources. Eventually it will move to the commercial requirements of self-sustaining colonies. Within the scope of this vision, substantial commercial opportunities exist for resource extraction, energy production, space transportation, electronic communication, and tourism.

What a wondrous vision this has been. In 1974, the Princeton physicist Gerard O'Neill predicted that the vast number of people migrating to space colonies would reverse the population rise on Earth by the mid-point of the 21st century. Stanley Kubrick and Arthur C. Clarke predicted orbiting hotels and large lunar bases in the movie "2001: A Space Odyssey," released in 1968. Both the space shuttle and large, rotating space station in the Kubrick-Clarke movie were operated by commercial firms. Pan American Airways operated the winged space shuttle and the Hilton Corporation managed the station's hotel.

The Reality

The reality of space commercialization has not progressed with the same force as the vision anticipated for it. In some cases, the reality has satisfied expectations. In others, it has fallen far short.

The early history of satellite communication provided hope for persons contemplating commercial opportunities in space. Satellite communication began with a supportive government policy and produced substantial business profit. In 1945, Arthur Clarke published a paper in which he observed that a trio of human-made objects placed in geosynchronous orbits would allow the transmission of radio and television signals between any two points on the globe. Experimentation followed. Business leaders and government officials tested a series of experimental satellites of ever-increasing sophistication. The critical test occurred in 1963, when the experimental communication satellite Syncom 2 began operating from an orbit 22,000 miles above the surface of the Earth. The satellite, built by the Hughes Aircraft Company, was financed with both corporate and government funds. Company officials began investing in satellite research in 1959 and two years later received a NASA contract that helped them launch the device. Syncom 2 was followed by Syncom 3, which demonstrated not only the technical feasibility of Clarke's concept but also the ability of corporate and government officials to support each other's work.

In 1962, Congress chartered a jointly-managed corporation for the purpose of commercializing satellite communication technology. Control of the Communications Satellite Corporation (Comsat) was vested in a board of directors consisting of six public stockholders, six representatives from the telecommunications industry, and three presidential appointees. The legislation authorized corporate officers to raise operating capital by borrowing money and selling stock. To make the corporation attractive to investors, Congress granted it monopoly status and continued to finance basic research on communication satellite technologies with government funds. As a corporate body, Comsat represented the United States in the formation of the world-wide system of communication satellites known as Intelsat and in 1964 became the managing company

for that system. One year later participating officials launched the first commercially operational geosynchronous communication device, the eighty-five pound "Early Bird" satellite.

The business proved enormously profitable. In 1976 Comsat officials reported revenues of $154 million. By 1998, revenues had grown to $616 million annually, with net income of $26 million. Other business firms entered the market and by 1998 worldwide revenues for all sectors of the satellite communication business topped $56 billion.

Many entrepreneurs believed that the model of corporate growth established by communication satellite firms like Comsat would reoccur in other commercial space activities. In 2001 financial journalist Lou Dobbs predicted that space commerce would be the hottest new technology since the Internet. It would happen in the first decade of the 20th century, he said, creating financial opportunities that would rival the Internet for the attention and financial support of the business community.

> In the frontier of space we will create entirely new forms of technology, new forms of manufacturing, new forms of recreation, and even new materials. The creation of these entities and pursuits will lead to a whole new world of commerce built on doing business in space.[1]

With few exceptions, this is not proving to be the case. In spite of the fact that annual commercial revenues from space have pushed beyond the $100 billion mark, the full range of expectations are not being realized. Firms promoting satellite phone service, satellite radio, microgravity research and manufacturing, alternative launch vehicles, and space tourism are struggling to earn a place in the commercial marketplace. More advanced applications such as space mining and space-based solar power are even further away.

Experience with satellite telephone systems, one of the most promising commercial space technologies, illustrates the obstacles involved. Some thirty years after the creation of Comsat, executives at the Motorola Corporation announced their intent to create a world-wide system in which individual telephone users using hand-held units could communicate with each other nearly anyplace on the globe. Unlike Comsat, which employed geosynchronous machines, Motorola executives planned to use low-Earth orbit satellites. Such satellites cost less than their geosynchronous counterparts cost and require less elaborate sending and receiving devices. Unlike geosynchronous satellites, which sit at one spot relative to the face of the Earth, low-Earth orbit devices speed around the globe. A fully operational communications network set close to the Earth requires many satellites and an extensive switching system in order to work. Planners of the Iridium system predicted that the technical difficulties of constructing such a system would be compensated by the ease of deployment and customer use.

Executives originally envisioned a constellation of seventy-seven satellites and established a corporation named after the element possessing the seventy-seventh number on the periodic table of elements. The element Iridium is a metallic substance resembling platinum. As a business, according to one commentator, it was a debacle, symbolic of the excessive optimism accorded space commerce during the latter stages of the 20th century.[2] As business plans progressed, Iridium executives settled on a sixty-six satellite constellation instead of seventy-seven, but kept the company name. Dysprosium, the

sixty-sixth element, does not possess such an attractive label, sounding more like dyspepsia than an icon for the commercial space frontier.

Executives in the aerospace business estimated that manufacturers could produce 125 low-Earth orbit communication satellites for about $700 million. That would provide the necessary redundancy and spares as well as a head start on replacements once the satellites began to run out of fuel in about seven years. The cost of launching smaller satellites was commensurately small. Technicians prepared to launch Iridium satellites on a combination of McDonnell Douglas Delta 2 and Russian Proton rockets. At 1,600 pounds each, the satellites were small enough into fit in a bundle of five to seven per rocket, reducing launch costs on the Delta 2 to about $10 million per machine. Altogether, the satellites could be built and launched for about $16 million each, for a total satellite start-up cost of slightly more than $1 billion. Iridium executives believed that the demand for satellite telephone service would justify such an investment.

The aggregate start-up costs for the Iridium Corporation, however, were actually five times that much. Iridium executives spent about $5 billion during the 1990s organizing their business and building the satellite system. They had planned to spend about $3.5 billion. The total cost included satellites, launches, ground stations, engineering centers, the operations contract, licensing around the world, marketing, and the expense of supporting business activities for nine years before the first customer appeared.

Iridium executives began serving customers in November 1998. By then, they were spending $440 million every three months. The company was saddled with about $2 billion in long-term debt. Company executives hoped to attract five million users. If that number of subscribers paid an average of just $30 per month to use the system, the business would break even. In practice, Iridium executives planned to charge far more, making themselves and their investors terribly rich.

By the end of March, 1999, the company had attracted only 7,200 satellite telephone subscribers – far less than their corporate goal. In the hands of users, the phones felt like bricks, with an eight inch antenna protruding above the handset. Subscribers had to pay more than $3,000 to purchased the phones and were charged as much as $6 per minute to make calls. Handsets required direct line of sight to satellites to avoid signal break-up. Designed to work practically anywhere on Earth, the telephones were susceptible to failure when high-rise corporate office buildings blocked signal paths.

Ten months after commencing service, in the Fall of 1999, Iridium executives gave up and declared bankruptcy. They had attracted only 63,000 customers. The financial bubble for investment in all forms of high technology burst a few months later. Iridium executives consulted NASA engineers concerning the best way to drop the satellites into the atmosphere for a flaming end to their commercial adventure.

The federal government did not assist the Iridium corporation in a manner commensurate with the support granted to Comsat some thirty years earlier. This was probably wise. Analysis of financial records suggests that the level of government support necessary to make Iridium financially successful would have been prohibitively high. Before the satellites crashed back to Earth, a group of investors bought the $5 billion, 66-satellite system for a liquidation sale price of $25 million. The new investors retained the company name but none of the old executives. They reduced service charges to about $1.50 per minute. They pitched the system at users who needed to communicate

from remote locations, particularly workers at oil and gas companies and military officers in the field. Company executives signed a $3 million per month contract with the U.S. Department of Defense that provided them with roughly half of their initial revenues.

The new owners of Iridium Satellite predicted that their company would break even if it could enlist about the same number of customers that had signed on to the service when the previous Iridium failed. With practically no debt, the new company consumed only about $20 million in operating expenses every three months – less than 5 percent of the cost of operating the Iridium Corporation. At that level, sixty-three thousand customers paying about $100 per month would be sufficient to drive Iridium Satellite into the profitability zone.

Even having paid so little for the operating system, corporate officials at Iridium Satellite still encountered obstacles to profitability. They had to deal with price competition from firms like Globalstar, another satellite telephone start-up. They faced the prospect of having to spend substantial sums of money to replace aging satellites, out of which system engineers hoped to squeeze performance lasting ten years. Still, their hopes for business success were high. As one commentator observed, "you don't have to do a whole lot to have success with a $25 million investment."[3]

It is hard to imagine how any reasonable form of government assistance might have allowed the original Iridium Corporation to prosper. To give it a fighting chance at profitability, the government would have had to provide a subsidy equal to the cost of constructing the system and operating the corporation through its development phase. Executives at the Iridium Corporation spent $5 billion to create assets for which a successor firm intent on profitability paid $25 million. Additionally, public officials would have been obliged to act as "anchor tenants" for the system, providing roughly half of the demand for the system through the firm's formative years. Those are the conditions on which the successors to the failed Iridium Corporation based their plans, with only one small difference. The successors acquired their principal subsidy through a bankruptcy sale rather than through government support.

Space commerce: the challenge

Two barriers exist to the realization of the commercial space vision. The first, well demonstrated by the Iridium experience, is the very high cost of doing business in space. The high cost of space operations means that terrestrial alternatives frequently displace space based systems, even though the latter may be technologically preferable. Fiber optic cables buried beneath the surface of the Earth are more cost effective than orbiting satellites for the purpose of transmitting large amounts of information, except in remotely populated or undeveloped portions of the world. The competitive advantage of underground cable has deflated many of the financial expectations upon which optimistic forecasts about satellite communications have been based. Fuel cell technology based on terrestrial resources may shove out space-based sources of energy, in spite of the fact that space-based sources more completely cut ties to non-renewable fossil fuels. (Fuel-cell technology requires the combination of hydrogen and oxygen to produce electricity. For the initial stages of the technology, the hydrogen would likely be obtained from oil.)

When he helped write the screenplay for "2001: A Space Odyssey," Arthur Clarke predicted that the fare for a single seat on a winged space shuttle bound for an orbiting space station would by the year represented in the movie title rest at $50,000. For a 200 pound individual, that works out to $250 per pound. Official NASA studies of

which Clarke was aware anticipated that a reusable space shuttle would cut launch costs to about $100 per pound. The real cost turned out to be considerably more. In 2001, NASA officials conducted seven launches of their reusable space shuttle for a total charge of $2.9 billion. That works out to about $400 million per mission or – given the payload capacity of the vehicle – approximately $7,500 per pound. Even adjusting for inflation, that is considerably out of line with expectations. A 200 pound passenger on the technology that actually developed would wind up paying $1.5 million for a ticket just to transport his or her body into space, exclusive of the food, air, water, and necessary equipment for which the passenger would also have to pay.

High costs are not confined simply to space transportation. Devices designed to operate in the radiation-soaked vacuum of space, often with no one nearby to maintain them, are extraordinarily expensive. When business executives decided to launch the satellite radio system called Sirius, they purchased three SS/L-1300 broadcasting satellites from Space Systems/Loral. The three satellites, purchased in 2000, were launched into elliptical orbits such that each device spent about 16 hours each day above the continental United States. At least one satellite was always above U.S. customers who purchased satellite radio units. Corporate officers valued the three satellites at about $270 million each and ordered a fourth satellite at the reduced price of $115 million to serve as a spare. The total value of the satellites alone exceeded $900 million – and that did not include ground stations, telemetry, tracking, and satellite control.

An additional barrier to space commercialization is government policy. Many commentators believe that the policies of the U.S. government serve to retard space commercialization in ways that are as significant as the high cost of hardware and operations. Says Dobbs: "Any expectations that government will lead the way toward the future of the space business are sorely misplaced. Even though NASA makes public overtures to supporting commercialization of space, the fact is that it is inherently incapable of doing this successfully."[4] At least one ex-NASA Administrator agrees. "They want to do the right things," James Beggs said of NASA employees. "But this is an area they don't understand."

This is a harsh indictment, but one that is widely held within the business community. Rather than excite space commerce, some public policies have worked to retard it, a reversal of the commonly envisioned process by which governments encourage private markets to emerge from new technologies. Commentators often cite the development of NASA's space shuttle as a means to illustrate this point. The space shuttle was advanced as a means to cut the cost of space access by the much-desired "factor of ten." Anticipating sharply lower launch costs, NASA officials reduced the price charged to commercial firms interested in flying commercial payloads on the shuttle. Relative to the actual cost of flying it, this had the effect of creating a substantial subsidy for a government owned spacecraft that in turn discouraged private investment in alternative launch technologies. NASA officials believed that shuttle costs eventually would fall, justifying their pricing policies. However, their vision exceeded their capacity for technological innovation, with the result that commercial development of alternative launchers suffered.

To many business commentators, NASA is a wonderful organization, a national treasure created for the purpose of exploring space and gathering information in this new realm. Its original charter, however, makes no reference to the agency's role in

promoting commercial opportunities in space. Throughout its formative years, NASA officials remained committed to the principle of operating their own spacecraft with their own employees. The first two administrators, Keith Glennan and James Webb, did commit NASA to a heavy reliance on contractors, so much so that the agency routinely contracted out 90 percent of its work. Nonetheless, a commercial space sector founded on government contracts is not the equivalent of one founded on markets. Government contracts tend to extend the risk-averse nature of public servants to commercial operations. This conflicts sharply with the model of free enterprise, in which the vast majority of new start-ups are likely to fail as the market separates winners from losers. Government officials are often motivated by the need to achieve mission success at any cost, whereas business executives responding to competitive pressures need to cut costs in order to succeed.

To a certain extent, these twin obstacles perpetuate each other. Government space policies oriented toward the purchase of goods and services through government contracts perpetuate the high cost of space operations, which in turn ensures that most space activities must be carried out by government agencies financed by tax receipts. In spite of the best efforts of space agencies to promote competition in the awarding of government contracts, government workers often find themselves in the position of the sole customer for an exotic machine that is being produced by a single firm. This violates the conditions under which cost innovation is most likely to occur, namely the existence of markets populated by many buyers and many firms. To an economist, relationships within the realm of government space activities often resemble those of a bi-lateral monopoly, with single producers supplying one customer.

Promoting commercial development under such conditions is exceptionally challenging. The enabling legislation of the National Aeronautics and Space Act now contains a clause directing agency leaders to "seek and encourage, to the maximum extent possible, the fullest commercial use of space." The vast preponderance of resources that NASA officials annually receive from the U.S. Treasury, however, are devoted to the conduct of missions of over which agency officials exercise governmental control. NASA officials do not possess the legal authority to utilize many of the techniques, such as land grants or loan guarantees that have been used by other government agencies to promote other commercial activities. Even if officials in the U.S. space agency possessed that authority, some commentators believe that they would not know how to exercise it. Promoting independent, privately funded space missions is not part of NASA's central heritage. As a large government institution, the habits that arise from that heritage are hard to change.

Realization of the full commercial potential of space will occur when the cost of space operations begins to fall relative to terrestrial alternatives. It will not occur through private initiative alone. Rarely have private entrepreneurs been able to move new technologies into the marketplace without government assistance of some sort. Not only will government support be necessary to lower the high cost of doing business in space (to a great extent a result of government policies). It will also be necessary to close the help fledgling business concerns establish a foothold in this new realm.

Fortunately, the history of government support for other commercial developments provides many lessons for people contemplating its use in space. The next two chapters deal with the mechanisms that public officials have used historically to

promote the commercialization of new technologies, followed by a discussion of how those mechanisms might be applied to space.

2. A History of Government Roles: Transportation

Government officials in the United States commonly use their regulatory and spending powers to accelerate the commercial acceptance of new technologies. Occasionally, they appropriate tax revenues in direct support of affected industries. More frequently, they provide support that makes use of the considerable resources available to government officials of a non-cash sort.

When federal officials decided to expedite construction of an interstate highway system in the mid-twentieth century, they chose to do so with direct supplies of cash. They could have retired the federal gasoline tax and allowed the states to finance the national highway system with a replacement gas tax of their own, an approach many governors favored. They could have established a Federal Highway Corporation that would have issued special revenue bonds, an approach favored by a presidential advisory committee. Theoretically, they might have left the development of highways to private corporations, as had been the practice with early toll roads, canals, and railway lines. The federal government could have removed itself from the business of highway construction altogether, but in the minds of business leaders spearheading the national highway movement, this would have retarded the development of the transportation network necessary to link centers of population and industry and encourage post-war economic growth.

To encourage construction of super-highways, federal officials promised to finance 90 percent of the construction cost of interstate highways built by the states that met federal route and safety standards. At the insistence of Senator Harry Flood Byrd of Virginia, construction was controlled on a "pay as you go" basis, funded by a one cent increase in the federal gasoline tax and other highway user tax charges. President Dwight D. Eisenhower signed the necessary legislation in 1956. As a young Army Lt. Colonel, Eisenhower had completed a cross-country caravan in 1919 as a means of publicizing the need for an interstate highway system

Like President Franklin Roosevelt before him, Eisenhower justified federal support for highway construction in part as a national defense effort. Among the penalties imposed by a deficient highway system, Eisenhower noted the inability of the United States "to meet the demands of catastrophe or defense, should an atomic war come." The enabling legislation was titled the "National System of Interstate and Defense Highways;" qualifying roads had to meet military specifications as well as civilian standards.

The history of federally financed highways illustrates one of the leading circumstances under which Congress is likely to use tax revenues and direct appropriations in support of new industries. The interstate highway system was accomplished in part in the name of national defense. Significantly, the civil space effort arose from a similar impulse. The Cold War promoted Congress to appropriate tax revenues in support of civil space activities which, under the doctrines promulgated by the first NASA administrators, served to expedite the development of an American aerospace industry.

The legislation creating NASA, like the legislation promoting interstate highways a few years earlier, might have led some people to conclude that vast sums of money

were available for the commercial development of new technologies. They might so conclude, but they would be wrong.

The whole history of government support is striking for the rarity of the "pay as you go" approach. American governments historically have supported the commercial development of industries to arise from new technologies, such as automobiles and rockets, but the means commonly used are those of a non-appropriation nature. Except for the objections of a conservative Southern senator, the interstate highway system would have been supported with bonds, as the original legislation prescribed, not with cash appropriations.

Table 1 lists the most common means of government support for commercial activities, along with examples of the industries to which they have been applied. The means of support range from direct cash subsidies, such as those used to support the interstate highway system, to government bonds, land grants, tax credits, secondary markets, insurance policies, and loan guarantees.

The past history of government support contains a number of lessons for persons looking forward toward new industrial applications. First, the range of devices used to encourage the development of commercial activity is quite broad. The inventiveness of federal officials in devising financial support mechanisms is exceeded in cleverness only by the technological inventions the mechanisms support. Non-cash mechanisms are viewed as more business-like, more reliable in their availability, and less subject to inappropriate political interference. They are often easier to obtain than annual appropriations. Sometimes they are favored simply because the treasury does not possess the needed cash.

Second, government officials tend to combine a number of devices when seeking to support a single commercial activity. They rarely confine themselves to solitary mechanisms, relying instead upon forms of financial redundancy similar to that engineered into the inventions they support. Not uncommonly, one finds regulatory devices combined with tax credits and supplemented with small cash subsidies.

Third, the mechanisms tend to be associated with particular time periods and circumstances. In the 19th century, land grants were more popular than bonds issued by government corporations, whereas in the 20th century the reverse was true. Particular mechanisms are bounded by the legal, political, and economic realities of their time. As such, what worked in the past may not be directly applicable to future endeavors of a similar sort. Nonetheless, each of the mechanisms contains underlying features that do span broad periods of time.

The latter point deserves illustration. Consider the manner by which the federal government has encouraged the commercial development of the vast store of natural resources found in the United States. The specific mechanisms have changed considerably, but the underlying principles have not. During the 19th century, government officials were motivated by the desire to transfer into private hands the large tracts of land acquired through actions such as the Louisiana Purchase. The federal government took title to the land, then sold or gave it away. Toward the end of the 19th century, notions of common property and public domain began to replace the policy of divestiture. Largely as a consequence of the conservation movement, the federal government began to reserve large tracts of land. On many tracts, previous uses such as

Table 1
Common Means of Government Support
for Commercial Activities

Type of Support	Example of Activity
Direct subsidies	Construction of roads, merchant marine
Land grants	Railroads, canals
Anchor tenancy, secure contracts to provide services	Airlines
Government-financed research	Aviation industry
Public authorities	Airports, docks
Government regulation	Airline industry
Cabotage laws	Merchant marine
Price supports	Agriculture
Tax credits	Housing, energy, merchant marine
Secondary markets for privately-issued loans	Housing, student loans
Insurance	Overseas

logging and grazing continued, but under federal supervision. Federal officials often subsidized those activities. They also issued regulations so as to maintain the rights of persons who wanted access to the land, persons like cattle ranchers or the increasingly large number of hunters, hikers, and vacationers.

The land policies of various governments now extent to outer space. The present treatment of outer space builds upon the conservation approach dominant throughout the 20th century. The current legal regime holds that space resources be held as common property for the benefit of all humankind. No single government owns the land and none can dispose of it. The U.S. government may never enact a Homestead Act for the Moon, transferring lunar tracts to private individuals or corporations. However, the principles that underlay the Homestead Act are quite applicable to extraterrestrial lands. The Homestead Act, along with legislation affecting the development of 19th century railroads and mines, sought to clarify the property rights of western settlers and entrepreneurs. Early in the 19th century, those rights were often confused. Farmers and miners often squatted on public lands without filing legal claims. Prior to the resolution of national disputes, the first settlers did not even know to which of the competing governments they should turn to register their claims.

Clarification of property rights reduces the time and expense that entrepreneurs must otherwise spend resolving disputes regarding resources they wish to utilize. As economists point out, such clarification is an item of value to users that is as real as a cash subsidy. Historically, entrepreneurs have relied upon governments and courts of law to resolve property issues. With its judicial powers and enforcement mechanisms, this is a role for which government is especially well suited. In that respect, whether the government grants land "fee simple" (in its entirety) or merely assigns rights for resource removal is not as significant as the willingness of the government to clarify the rights of users.

This and the chapter that follows present histories of government mechanisms used to support commercial development of new technologies in the past. As such, they provides the historical background for the consideration of roles that might be used to support the commercial development of space activities in the future. Since the development of space, like so many territorial realms before it, depends upon the quality of access to it, the discussion begins with histories of government support for the business of transportation.

Railroads and the Land Grant Experience

In few areas is the practice of government support more developed than in the realm of transportation. Since the early 1800s, the federal government has encouraged the commercial development of a succession of transportation technologies. State and local support has been widespread as well. Beginning with ship transport, roads and canals, then railroads, air transportation, automobile superhighways, and spacecraft, American governments have subsidized the commercial development of the transportation industry. "We've subsidized the railroads," observed past-NASA Administrator James Beggs. "We've subsidized the aviation industry. Now, we've got to spend some money and subsidize the space transportation business."[5]

The first roads and canals following the formation of the United States were built without government help. Private entrepreneurs built canals linking seaports like Charleston, South Carolina, and Boston, Massachusetts, with local rivers not directly

connected to them. Private individuals built roads and established river crossings. By 1800, more than seventy turnpike companies had been chartered and a large number of toll-bridge corporations organized, supplanting older but also privately owned ferry crossings. In spite of these improvements, Secretary of the Treasury Albert Gallatin reported to the Congress in his landmark Report on Roads and Canals that two circumstances particular to the United States "naturally check the application of private capital and enterprise to improvements on a large scale."

The two circumstances are as applicable to modern conditions of space transportation as they were to early century roads and canals two hundred years earlier. The very conditions that give rise to the need for transportation networks retarded its private provision, Gallatin reported. Those conditions were "the extent of the territory compared to the population" and the difficulty of raising capital given the "prospects of remote and moderate profit."[6]

Anxious to create a transportation corridor across the Appalachian Mountains, but faced with the absence of population and reluctance of private investors to lend capital, the state of New York in 1810 undertook as a public work one of the largest engineering projects of that time -- construction of the 363 mile long Erie Canal. Legislators authorized the appointment of Canal Commissioners and established a Canal Fund with the authority to raise and spend money. As one historian of the period has noted, "the raising of this money itself involved innovation."[7]

State officials attempting to raise money by borrowing on the credit of the state encountered the same difficulties that had frustrated private developers. Investors were reluctant to lend money for an unfinished canal. Only when heavy use of the canal began to yield substantial toll revenues did large investors show much interest in purchasing securities. By then, of course, the need for funds had dissipated.

The difficulty of attracting investors, joined with the general reluctance of legislators to provide cash subsidies drawn from meager tax receipts, caused public officials to experiment with a number of devices for financing internal improvements. State legislators experimented with mixed enterprise measures (joint ventures between governmental bodies and private firms). They granted monopoly status to corporations willing to construct transportation corridors. State lawmakers purchased stock in transportation corporations. Legislative bodies made loans themselves. Federal legislators waived duties on iron imported for rails, an early form of tax credit.

The most innovative technique for internal improvement was the use of public land. Initially, the federal government took proceeds derived from the sale of newly acquired lands such as the Louisiana Purchase and gave that money to the states for road building and other improvements. In 1850, the practice shifted from one of apportioning money derived from sales to direct granting of the land itself. Federal legislation provided that promoters of railroad systems from the coast of Alabama to northern Illinois should receive alternative sections of land along a corridor extending six miles outward from any qualifying line. The practice quickly spread to other railroad proposals, including the famous transcontinental line.

Land grants were utilized as a subsidy to increase the rate of return to prospective investors and thus attract venture capital. The transcontinental line provides a marvelous illustration of how this was done. Once proponents of a southern route left the Union, federal legislators chose a northern route from Omaha, Nebraska, to Sacramento,

California. The 1862 act recognized the intent of the Union Pacific Railroad Company to build from the east and the Central Pacific Railroad Company to build from the west. As amended in the 1864 act, the privately owned companies were to receive twenty sections of land for every mile of completed railroad line. The value of the land was expected to appreciate rapidly once operations began. Using the land as collateral, the companies sold stock and issued bonds to private investors. The federal government also loaned money to the railroad companies. The government loans, called subsidy bonds, took the form of a second mortgage, an obscure but financially significant provision. Relegation of federal subsidy bonds to second-mortgage status meant that private investors had a higher claim on the assets of the corporations should the venture fail, thereby encouraging the raising of private capital through what effectively constituted a first mortgage. Bonds were repaid through revenues generated by railroad operations and by proceeds derived from the sale of the land.

The railroad experience is analogous to commercial development of space in a number of respects. Venture capital for 19th century railroad lines was very hard to obtain. Railroad entrepreneurs were obliged to construct lines through vast territories within which little commercial activity was taking place. In a phrase, railroad entrepreneurs were expected to "build ahead of demand." In England, where settlement preceded railway construction, government support on a similar scale was not required. England was a settled country, where railroad corporations made money as soon as they completed lines -- a circumstance favoring private investment. In a similar fashion, venture capital for space commercialization is hard to obtain in all but those areas (such as satellite communications) where markets already exist. Like the railway barons before them, entrepreneurs constructing space infrastructure are forced to "build ahead of demand." Such investments are risky, uncertain in their consequences, and hard to sell.

Along with other forms of government aid, land grants effectively increased the rates of return that private investors received for providing capital to private corporations constructing internal improvements in 19th century America. The effect has been measured. Rates of return to private investors increased from 1 percent to 5 percent, depending upon the railroad line. In the case of the Union Pacific Railroad, for example, investors received 13.1 percent instead of 11.6 percent as a result of land grant policies. Land grants created a subsidy that attracted private investment. On that point, little controversy exists.

Much controversy does exist on the question of whether or not the government subsidies were necessary to attract needed capital. Rates of return for private investors in the transcontinental line were above the general rates of return that 19th century investors could expect regardless of whether or not federal government made grants of land. With or without the land grants, investors received handsome returns. Moreover, settlement followed the completion of some railroad lines so rapidly that the notion of "building ahead of demand" lost much of its power as justification. In those cases, investors did not wait long periods for settlement to produce anticipated returns.

More than one hundred years after completion of the transcontinental railroad, economists still debate the necessity of land grants and other federal subsidies for internal improvements. In some cases, unsubsidized rates of return were sufficient to attract private capital in the requisite amounts. In other cases, government subsidies made poor investments attractive relative to the general rate of return. In some cases, entrepreneurs

did "build ahead of demand." In other cases, they did not.

The methods used to expedite 19th century internal improvements might not have been needed in all cases. Land grants, the most commonly used method, were not always as efficient as alternative mechanisms such as direct cash subsidies. Whatever its economic merits, the land disposal approach was the most politically feasible given the conditions of the time. Land grants helped to overcome investor uncertainty and reduce the perception of risk associated with dispatching funds into a commercially undeveloped realm. They accelerated the completion of internal improvements, which in turn expedited the settlement of the American West. It is worth noting that the debate over the necessity of governmental participation continues while completion of the internal improvements is long since done.

Long after it succeeds, the wisdom of government investment in space may be debated in a similar way. At the present time, however, the promise of space commerce shares many features in common with 19th century canals and railroads. People want to see it accomplished. Private capital is hard to raise. Risk is high, success is uncertain, and to a great extent entrepreneurs are expected to "build ahead of demand." Government subsidies naturally arise under such conditions. They may not be specifically the same as in the past, but as in the 19th century their success is likely to be determined by same spirit of experimentation and inventiveness.

Government Support for the Early Airline Industry

Following 19th century governmental intervention on behalf of railroads and canals, public officials involved themselves in the commercial development of aviation technology. They authorized funds for aviation research in government laboratories, they purchased services from fledgling airlines, they regulated routes and fares, and they invented a mechanism for the creation of infrastructure -- the public authority. Government support helped create a multi-billion industry out of a collection of craft workers and bicycle shops and propelled the United States to the forefront of commercial aviation.

In spite of being the first to fly, entrepreneurs in the United States did not lead the world in aviation commerce during its early years. Europeans produced more airplanes and airports; officials in five European nations established aeronautical research laboratories under government support. Visionaries promised a bright future for commercial aviation in the United States, but actual accomplishments lagged. The Wright brothers bogged themselves down in legal fights over patent rights, commercial operators could not attract sufficient business or capital, and the American military ordered only a handful of planes. The designs to emerge from European laboratories, according to one historian, "were beginning to show clear evidence of superiority over American aircraft."[8]

This situation was not unlike that faced by astronautical pioneers late in the same century. An American, Robert Goddard, successfully flew the first liquid fueled rocket from a Massachusetts farm in 1926. However, the Soviet Union, not the United States, led the world in early space accomplishments. Commercial opportunities in space did not materialize for American firms on the expected time scale and the U.S. lost ground in the production of launchers to competitors like the French Ariane. Many of the people who remain optimistic about future commercial opportunities in space activities draw their hope from the reversal of fortunes that followed the early years of disappointment in

American aviation.

The first major demonstration of support for commercial aviation in the United States occurred when the Congress appropriated funds for a national research effort. As with the highway and space programs to follow, it was done in the name of national defense. Citing the glaring discrepancy between European and American military aviation, legislators attached a rider to the Naval Appropriations Act that authorized the establishment of a National Advisory Committee for Aeronautics (NACA). President Woodrow Wilson signed the act in 1915, but not until 1920 did NACA officials receive the funds necessary to organize their first research laboratory. For five years, the desire to further American aviation was not matched by the willingness of Congress to appropriate public funds. In 1920, the advisory committee acquired a research facility and wind tunnel at Langley Field, Virginia. Appropriation support for the research facilities of the NACA was generous in the years that followed, but tailed off as commercial aviation matured. The space race rescued this appropriation-dependent function with a fresh infusion of funds when public officials used NACA as the backbone around which to construct NASA in 1958.

The second means of government support for commercial aviation occurred as the indirect result of a routine government appropriation. Carrying on a tradition that led back to the founding of the country, the Congress annually provided public funds and the authority to collect revenues to a cabinet level department charged with distributing the mail. Beginning in 1918, officials at the Post Office Department began to use airplanes as a means of transporting the mail. The officials reached an agreement with officers in the War Department by which the latter would provide aircraft and assign military pilots to fly them.

Early airmail service was nearly as risky as war. Pilots flew in open cockpits through bad weather under conditions that left fliers numb. Fliers carried liquor to fight the effects of cold weather, further impairing their judgement. One early pilot remembered that the task of carrying the mail on military aircraft was "considered pretty much a suicide club."[9] As with the first space flights one half century later, commercial operators did not involve themselves, given the substantial risks involved.

In 1925 the U.S. Congress reversed this policy. Legislators passed the Contract Airmail Act, better known as the Kelly Act, which transferred responsibility for flying the mail from the War Department to commercial carriers. Commercial interest in carrying the mail led within five years to the creation of now-familiar carriers like United, American, Delta, Northwest, and TWA. Officials in the Post Office Department wrote contracts with the carriers providing transport services. Carriers used mail contracts as the principle source of revenue from which to purchase aircraft and employ pilots. They supplemented that revenue, and thereby made a profit, by crop spraying, forest seeding, aerial mapping, surveying petroleum sites, and carrying passengers. Functions like forest seeding and aerial mapping were also supported by government contracts. In the beginning, passenger transport was incidental to the more financially secure revenues obtained by government contracts.

A small change in the rule by which the government paid for mail transport expedited growth in the passenger market. When commercial flights began, the Post Office compensated carriers on the basis of the weight they carried. In 1930, Congress legislated a standard that paid airlines for the space available within an aircraft for

airmail. This encouraged manufacturers to build larger aircraft, which incidentally could carry more passengers. Within five years, business executives at the Douglas Aircraft Company introduced the 21-seat DC-3. To their delight, airline executives learned that a fleet of DC-3s could make a profit solely by carrying passengers.

Early government support for aviation took the form of direct and then indirect annual appropriations, first for research and then for mail delivery. Public officials undertook incremental changes in policies affecting that spending, notably the compensation system for mail transport, which spurred further commercial growth. A half century later space advocates undertook similar actions to encourage development of an aerospace industry -- government funds for NACA/NASA research laboratories, government purchases of industrially-manufactured spacecraft, and contracts with commercial manufacturers of expendable launch vehicles to transport satellites and spacecraft.

The most notable difference between early government support for aviation and early support for aeronautics was based more in attitude than in method. The methods were similar, but the attitude of governmental officials toward commercial development was different. Government support on behalf of aviation was designed to create commercial firms serving private markets; initial support for aeronautics was designed largely to encourage a domestic industry serving government needs. As a consequence, public support for aeronautics has relied for an extended period of time upon tax-supported appropriations that flow to industry through government contracts, whereas in the aviation public officials quickly learned how to devise support mechanisms that depended hardly at all upon the necessity of annual appropriations. As a consequence, the government policies that allowed the air industry to mature were more innovative than those associated with the commercial development of space. One need look no further than the invention of the public authority to see how this was so.

Public Authorities for Private Transportation

When the U.S. Congress turned the transportation of airmail over to private companies in 1925, few cities possessed airfields with facilities adequate to accept commercial flights. In New York City, for example, pilots approaching the economic center of the nation were obliged to land across the Hudson River in Newark, New Jersey. New York did not possess a single airfield adequate to receive the mail. In Washington, D.C., fliers were obliged to land at a "gypsy field" on the site of the present-day Pentagon.

As they had done with their own railway terminals, business leaders began to construct privately owned airports. Executives at the Curtiss-Wright Corporation, a leading aircraft manufacturing firm, built a series of airfields and service centers reaching from New York to Los Angeles. Leaders of the newly formed Pan American Airways constructed an international network served by flying boats. The airport in Washington, D.C., named Hoover Field after the then Secretary of Commerce Herbert Hoover, was built by a local streetcar owner.

In spite of private efforts to establish early air terminals, most civic leaders turned to governmental bodies and not business firms to make airports grow. The impetus for public support arose from the specter of competition. City leaders in locales such as New York wanted to gain the commercial advantages associated with being a transportation hub for what appeared to be a technology of the future. They did not want to lose that

advantage to neighboring areas nor did they want to wait patiently for private financiers to construct new fields. Short of cash, city leaders who had competed for railway lines and terminals in the mid-nineteenth century depended upon capitalists to raise the necessary funds. By the early nineteenth century, however, cities had acquired a new financial instrument that made public provision more attractive. The airport history of New York is instructive.

Unlike the situation in Europe, where central governments directly supported airport construction, federal officials in the United States left this function to municipalities. By law, city officials in New York could construct public facilities by issuing bonds. In practice, the state constitution severely limited the power of city officials to raise funds through borrowing and tax levies. Bonding capacity quickly disappeared in the face of demands for schools, hospitals, and other vital services.

Searching for the means to construct a more modern airfield, city officials fell upon a small sum of money in the budget for the New York City Department of Docks. Legislators had appropriated funds for the construction of municipal piers. Piers sat in wetlands; so did the plans for two small runways on a city-owned wetland known as Floyd Bennett Field. City officials used the funds to construct runways instead of piers, with the consequence that the airport was operated by a department originally organized to supervise docks and shipping.

As constructed, Floyd Bennett Field was not substantial enough to compete with the larger facility in Newark. With municipal competition at stake, New York civil leaders pressed for the construction of a larger field. This involved substantial risk, since much uncertainty remained about the ability of airline operators to generate the landing fees necessary to repay municipal construction bonds. If expected revenues failed to materialize, city leaders would have to divert general tax revenues to retire bonds. This in turn would reduce the ability of city leaders to finance the construction of other vital services through tax supported bonds.

To alleviate the financial risk associated with the construction of facilities for an industry with an uncertain future, city officials transferred control of what become known as LaGuardia Airport to the Port of New York and New Jersey, a public authority. Under the terms of the agreement, the Port Authority agreed to lease all New York City airports and pay annual fees into the city treasury.

The Port Authority of New York and New Jersey had been formed in 1921, the first public authority so organized within the continental United States. It was originally created to promote the development of another transportation technology – the automobile. In its purist form, a public authority is a government agency chartered by a legislative body in the form of a statutory corporation. The authority is headed by a governing board, which hires a general manager. It raises funds by charging fees for the use of its facilities and selling bonds backed by the expectation of revenues derived from those fees. Public authorities create facilities that serve a public purpose (such as parks or bridges) that may in some cases be so risky as to discourage private investment.

A public authority can attract investors in ways that private entrepreneurs cannot. For new technologies, the public authority is one of the most financially stable mechanisms for promoting commercial development. The Port Authority of New York and New Jersey achieved financial stability in a most ingenious way. It began its work by constructing bridges between Staten Island and New Jersey. To entice investors to

purchase the bonds needed to finance the bridges, legislators from both states advanced working capital in the form of no-interest, no-principal loans. Using the working capital as collateral, Port Authority officials sold bonds. By collecting tolls from motorists using the bridges, the Port Authority rewarded its investors and repaid the working capital. Occasionally, a project failed to generate sufficient revenue to meet repayment requirements. To avoid the possibility of default, officials diverted revenues from profitable facilities into a general reserve and issued consolidated bonds that pledged the revenues of all facilities toward new projects. Financial stability was achieved through a clever scheme by which working capital was converted into money-generating facilities that provided collateral for new bonds to complete new projects. Under this approach, officials maintained tolls on old facilities long after the original investment bonds were repaid.

Public authorities were used extensively throughout the United States as a means to construct airports, effectively providing a subsidy that accelerated the commercial development of the airline industry. In hindsight, private airport companies could have done the same. Revenues from this new industry proved so sufficient that they could have retired even privately issued bonds. In the minds of investors, however, public authorities with their broad revenue base and governmental backing provided a level of financial stability that exceeded what a private entrepreneur developing a single airfield could provide. Along with the impulse provided by urban competition and the desire of city leaders to avoid private control of transportation facilities, airport construction was removed from the private domain. By so doing, public authorities undoubtedly accelerated the development of this commercial sector more rapidly than that which would have occurred under a system of private investment.

Regulation and Deregulation

The experience of persons working to develop commercial aviation is analogous in many ways to the challenges facing persons trying to develop space. The industries are (or were) immature; investors confront uncertain financial returns. Competition exists but the market is very small. (In the beginning, only wealthy private citizens flew.) Government purchases and support made up much of the revenue received by early operators, in some cases as much as 80 percent.

The economic and social conditions existing during the infancy of aviation, moreover, favored government support. In 1938, during the depths of the Great Depression, Congress passed the Civil Aeronautics Act. The act sought to encourage airline expansion by stabilizing revenues and fares. Any airline carrying passengers or mail was required by law to obtain a Certificate of Public Convenience and Necessity from a newly created regulatory body, eventually called the Civil Aeronautics Board (CAB). Through its authority, the CAB established a system of rates that was uniform throughout the industry. Airlines receiving certificates for the same routes could compete to provide speed or comfort, but they were protected against price wars.

The existence of this simple regulation, which cost the federal government practically nothing to produce, created the equivalent of a huge financial subsidy for struggling airlines. A free market would have produced competition in fares, but according to the advocates of government support it could have also produced financial ruin. At the time, transport in low flying, propeller-driven aircraft was much less comfortable than riding in buses and trains and many Americans were afraid to fly. By

calculating the size of the probable market and establishing fares sufficient to cover expenses, the government provided a period of stability during which airlines firms could develop commercially. By so doing, the federal government probably accelerated the era of jetliners and mass transportation that followed.

The system of rate stabilization proved very controversial. Advocates of open markets argued that consumers making individual purchasing decisions would act more wisely than public servants working in a centralized bureaucracies. Competition within unregulated, intrastate markets (such as California) suggested that regulated airlines were charging too much for their services and avoiding reforms that might increase productivity. Confronted with arguments such as these, along with the existence of an increasingly mature industry, the federal government abolished the regulatory regime. The Airline Deregulation Act of 1978 eliminated the CAB and created an open market for new carriers and fares. Subsequent experience suggests that consumers voted for lower fares and forced airlines to adopt more cost competitive practices.

In hindsight, commercial aviation might have developed with less government support. As with the transcontinental railroad before it, government support was not always necessary to secure favorable rates of return. Unfortunately, aviation advocates did not have the benefit of hindsight, a circumstance also denied to investors in railroads. Given the substantial uncertainty that accompanies the creation of a new industry, government support helped accelerate investment. For aviation, this support took many forms: government-funded research, purchase of goods and services, public authorities, and regulation of routes and fares.

Merchant Marine

The term merchant marine refers to ships registered under the law of a particular nation and privileged to fly its flag. Since the administration of George Washington, government officials in the United States have sought to maintain a U.S. merchant marine that is far larger than the private market would otherwise produce. As with other forms of transportation, this has required government support.

Especially in modern times, the cost of transporting goods on ships built and owned by persons overseas is substantially less than the cost of U.S. lines. Just as a private manufacturer operating within a context of free trade will produce goods in factories overseas if the cost of production is less than that found in the United States, so the same manufacturer will choose to transport those goods on less expensive foreign carriers.

Still, the U.S. government supports a strong merchant marine. According to its advocates, a strong merchant marine serves social purposes not always achievable under free trade. Domestic ship ownership improves the U.S. balance of payments. It helps to maintain local shipbuilding industries, advocates say. It serves the national defense. In times of war or national emergencies, the nation's requirements for ship transport might be compromised if those ships flew foreign flags. American carriers can be compelled to carry goods under conditions that foreign carriers cannot.

The situation is similar to the transport of goods into space. If foreign carriers can transport goods into space for less than U.S. carriers, why should the U.S. government maintain a domestic launch industry? Again, arguments like the balance of payments and the needs of national defense prevail. When NASA officials inaugurated a program of low-cost spaceflight during the 1990s, they did not specify that spacecraft be launched on

the least expensive vehicle regardless of national origin. The Discovery program directed participating organizations toward the U.S.-built Delta 2. NASA regulations as of 2003 broadly prohibited any organization receiving tax dollars from paying money to a foreign body for a ride into space. Although the NASA Discovery program was undertaken to save money, cost saving did not extend as far as the use of foreign-made rockets.

Having decided that the maintenance of a strong merchant marine serves a social purpose, officials in the U.S. government have maintained a series of devices designed to accomplish this goal. Some involve direct cash subsidies. For example, the Merchant Marine Act of 1936 established what is known as the construction differential subsidy. Shipyards and ship buyers can apply to the federal government for a subsidy designed to reduce the price that a domestic builder would charge relative to the cost of a vessel built overseas. A differential operating subsidy is also available.

The most interesting aids do not involve cash outlays. In 1817, the U.S. Congress passed a law prohibiting foreign vessels from transporting goods from one U.S. port to another. Prior to that, foreign vessels were taxed at a rate eight times that of domestic ships when entering U.S. ports, a tax policy that likewise discouraged foreign provision of intra-state trade. The practice of reserving internal trade to domestic carriers is known as "cabotage," a derivation of the Spanish word *cabo* for the capes that border open sea and the transport that occurs between them. Throughout the history of the U.S., cabotage laws have been one of the principal means for maintaining a strong merchant marine. Other laws require a certain proportion of government cargoes bound for foreign destinations, such as agricultural aid, to be carried on U.S. ships. These laws cost practically nothing to administer, but they create a subsidy that is as good as cash when the bills are paid. One analyst calculates the size of the subsidy between 1950 and 1970 to be worth $8 billion – revenue that domestic ship owners would have otherwise not received if foreign carriers had transported the loads. That is equal to the total amount that space flight officials spent during the same period to prepare the giant Saturn V rocket that transported the first Americans to the moon.

In addition to regulatory assistance, government officials have granted special tax relief to shippers who fly the U.S. flag. Ship owners who earn a profit can delay the onset of tax payments by investing a proportion of that sum in new ships or equipment. Unlike other persons who do not submit their tax payments on time, ship owners pay no interest or penalty. As such, the tax deferral effectively constitutes an interest free loan from the government to ship owners. Although the accounting requirements are intricate, the deferral is accomplished without the procedural requirements that would otherwise be necessary to qualify for a government loan or loan guarantee.

"Every imaginable type of subsidy, except for the most bizarre and implausible, has probably been tried somewhere, sometime," one observer of the U.S. merchant marine concludes.[10] The same could be said for transportation in general. Promoters of transportation technologies have made use of a broad range of fiscal and non-fiscal aids to create domestic economic activity that would not have been so large nor so rapidly achieved in the absence of such aid.

3. Government Roles Beyond Transportation

In spite of the known advantages of innovative technologies and the promise of expanding markets, new businesses often fail to materialize at the rates one would expect given the circumstances involved. Business owners have a propensity to stay with old technologies and familiar markets whose risks are known rather than experiment with new dangers. A well known economic principle states that people tend to pay more to avoid losses than they do to acquire the same value in gains. The 2002 Nobel Prize in Economics was awarded to economist Daniel Kahneman, who with the late Amos Tversky, empirically demonstrated the validity of this principle. Uncertainty can act as a barrier to commercial expansion. Such circumstances invite governmental intervention, helping people overcome the uncertainty threshold and create new markets.

Tractors and Price Supports

One of the best examples of this phenomenon is provided by the advent of the tractor. Tractors, combines, mechanical crop pickers, and other implements powered by internal combustion engines appeared in the American marketplace during the first decade of the 20th century. The first tractors were large, clumsy affairs that appealed to people tilling the largest farms. After World War I, producers like Ford and Deere & Company introduced technological improvements that made their products easier to use and hence more appealing to middle-range farmers.

The productivity advantages offered by these new machines were well known. The International Harvester Company produced a 1931 advertisement that showed Elza C. Larson of Steward, Illinois, astride a McCormick-Deering 15-30 tractor. "Tractors are on countless farms today," the manufacturer explained, "but the idea of power farming is still young."[11] The advertisement contained a detailed accounting of Mr. Larson's expenses in raising corn through power-driven plowing, planting, hoeing, and harvesting. The U.S. Department of Agriculture statistic for raising corn in Illinois was $16.33 per acre. With his mechanized approach, farmer Larson produced his corn for $7.23. Accounting for marketing costs and land taxes, Larson's revenues from the sale of his corn exceeded his costs by a handsome margin of $2,007.

Annual sales of tractors in the United States increased steadily from 3,000 in 1910 to 133,000 in 1927. With the advent of the Great Depression, they fell precipitously -- to just 25,000 in 1932. In spite of the known advantages of mechanized technology, farm productivity increased at a rate only one-third of that experienced in the manufacturing sector. One of the primary reasons was the reluctance of farmers to purchase tractors and mechanical pickers. Confronted by unstable markets and declining cash flows, farmers were reluctant to unhitch themselves from their horses and mules.

The experience of tractor manufacturers is analogous to that of firms operating in space. Risk and uncertainty plague both. Rather than invest in new technologies, entrepreneurs facing uncertain outcomes often choose to remain with less efficient methods where the risks are better known.

The case of farmer Lawson is instructive. The marketing team at International Harvester failed to point out in the advertisement that a neighbor farming with less efficient methods would still profit from his work. Economists recognize that the utility people place on factors like risk may cause them to take lesser gains and be content with them. Based on practical experience, farmers knew that by producing too much they

could cause the price of a commodity to fall, leaving those who mechanized with large debt and less income to cover it. Under conditions of uncertainty, farmers behaved in a rationally conservative way.

Seeking to revitalize the farm economy, the federal government intervened in agricultural markets in many significant ways. Federal officials encouraged research through land grants to state agricultural and mechanical colleges, they provided farmers with low interest loans, and they adopted a number of policies designed to restrict output and thus prevent price decline. No policy had more effect on farm productivity than the lending of money to farmers based on the value of the crops they raised.

The system worked this way. Rather than sell a crop in a depressed market, a farmer could go to a local bank and obtain a loan derived from a target price established by the federally chartered Commodity Credit Corporation (CCC). The bank paid the farmer cash on the spot, just as if he had sold the crop on the open market. The federal government backed the CCC loan; the farmer used the crop as collateral and stored it under seal on the farm or in a state warehouse. If the price of the commodity rose after the end of the harvesting season, the farmer could sell the crop and repay the loan, with interest and fees that amounted to about 4 percent per annum. If the market remained depressed, the farmer simply defaulted on the loan. The government got the crop and the farmer kept the cash.

Farmers were skeptical when the program first appeared. With prodding from federal officials, local newspapers ran articles similar to those that tractor companies had featured earlier. One illustrated story in the Des Moines Register photographed W. W. Eral of Pocahontas, Iowa, displaying $585 in cash to fellow farmers outside the local bank. "Cash Handed Over in 24 Hours," the headlined explained.[12]

Federal officials chartered the Commodity Credit Corporation in 1933. By 1936, its funding was secure. The effect was dramatic. In the depths of the Great Depression, tractor purchases increased eight-fold to 221,000 by 1937. Gains in farm productivity, which had earlier lagged, surpassed gains in the manufacturing sector by 50 percent.

Critics feared that the Congress would have to appropriate large sums to cover farmers who defaulted on their CCC loans, straining the federal treasury at a time of shrinking tax revenues. In fact, no congressional bailout occurred. Corporation officers used a number of techniques to avoid the need for large annual appropriations, including the practice of borrowing funds from financial markets based on the value of the crops they had acquired.

The price stabilization system did have a long-range effect that few anticipated. The capital outlays necessary to purchase heavy equipment and land in an era of increasing mechanization changed the economics of farming. Family-owned farms of modest size began to disappear. Federal interventions originally devised to spur farm productivity were turned upside-down and used to protect farmers who could not make a profit under conceivable conditions. Once in place, the system served to prevent efficient practices rather than promote them.

This is not an uncommon pattern – and one about which persons proposing devices designed to overcome investor uncertainty in the realm of space commerce need be aware. The price stabilization system used to jump-start the farm economy during the Great Depression became the farm subsidy system of later years. A similar transformation occurred in the airline industry. The regulation of routes and fares

developed in the 1930s so retarded competition that Congress felt obliged to discontinue it in the 1970s. Devices used to overcome uncertainty regarding the commercial acceptance of new technologies tend to lose their utility once the market develops and the uncertainty disappears.

Mining and the Recovery of Natural Resources

Space is full of natural resources, such as Helium 3, that are not readily available on Earth. The utilization of natural resources for commercial gain poses special problems for government officials. Throughout history, public officials have encouraged private individuals to discover and develop natural resources. People who discover or develop natural resources have a natural interest in laying claim to those resources and public officials have often utilized governmental power to defend such claims. From a slightly different point of view, minerals and other natural resources constitute a common legacy that belongs to humanity at large. The clash between the desire to encourage commercial development, the claims of developers, and the concept of common property defines much of the struggle to formulate governmental policy in this area.

Space is a form of common property, similar in some respects to the public domain. Within the United States, the public domain refers to lands acquired by governmental bodies once the government was formed. The original thirteen states ceded territory they held beyond the Appalachian mountains to the new federal government. Federal officials acquired additional land through purchase, conquest, and annexation. Congress reserved much of the public domain for common use, such as the open range for grazing and the national parks. It sold or gave away the rest as a means of fostering the rapid settlement of the continent.

Individuals who utilize common property often devise means to lay claim to it, even in the absence of government. When miners rushed to the gold fields of California in the middle of the 19th century, they found practically no governmental officials with whom they could assert their claims. Instead, the miners formed local associations. These associations wrote regulations, resolved disputes, and both accepted and enforced claims. When the federal government through its General Land Office sought to sell the land, associations plotted the location of each claimant, appointed bidders to purchase the land in the names of the claimants, and discouraged outside bids.

The first settlers to arrive in Oregon simply squatted on what they perceived to be open land. The British and American governments, which did not resolve their contested claims to the Oregon territory until 1846, encouraged the practice prior to 1846 so as to increase the number of persons loyal to each side. Squatting was a practice that began shortly after Europeans arrived in America and increased in popularity after the American Revolution. The movement of settlers proceeded with more haste than the ability of government agents to survey and distribute the public domain. Easterners tried to forbid squatting out of respect for orderly sales and agreements with First Americans, but achieved little success. Anti-squatting legislation was generally ignored. Says one historian:

> Surveys and sales proceeded so slowly that the Western lands had to be occupied illegally if they were to be occupied at all....Congress recognized the facts of frontier life by repeatedly passing special laws which, in effect, legalized occupation by squatters.[13]

Initially, the federal government attempted to sell public land to people seeking to occupy it, although few could afford to pay $1 per acre for a 640-acre section. Public officials then gave away various parcels in order to encourage public education and the construction of canals and railroads. Congress eventually passed the Homestead Act, but not until 1862. The legislation allowed any citizen to obtain up to 160 acres from the public domain provided the person or family lived on and cultivated the land for five years. In spite of the myth surrounding the promise of free land, the legislation did not promote extensive settlement. The best territory was occupied by 1862 and most homesteaders struggled to retain parcels not suitable for small-scale cultivation. The General Mining Act was more generous. Passed in 1872, this legislation provided that any prospector who discovered a valuable mineral deposit on the public domain could claim ownership of the substance simply by driving stakes into the ground and reporting the location to a designated official. Miners could take full title to the land by paying a small fee and making improvements.

With the birth of the conservation movement, the federal government began to reserve vast tracts of public land. Congress set aside federally owned lands for national forests, grazing lands, and parks, effectively closing the era of disposition. The use of land grants as the primary means of encouraging economic development gave way to the use of tax credits. One of the most generous policies is the percentage depletion allowance. This subsidy allows mining firms and oil companies to treat a portion of the resource value removed from the ground as tax exempt. The provision encourages exploration and mining by allowing entrepreneurs to treat terrestrial resources for business purposes as if they were assets being drawn down. The tax rules for claiming allowances are complicated. A 1974 study estimates that the allowance creates a net tax benefit equal to 15 percent of gross income for oil and gas, 10 percent for uranium, and 5 percent for coal.[14] The size of the allowance is based on the value of the resource, rather than the cost of the company's investment, producing odd consequences in some cases. For some firms, their whole profit margin may be due to tax subsidies.

When the OPEC-generated oil crisis created petroleum shortages in the late 1970s, public officials attempted to encourage the development of alternative energy sources. Again, they turned to tax credits.

The cumulative effect of all federal policies seriously distorts the market for natural resources. Petroleum companies that remove oil and gas from government-owned lands must pay royalties. Under the General Mining Law, firms removing minerals need not. This creates a subsidy favoring the removal of minerals. But oil and gas producers benefit disproportionately from tax policies that favor the production of energy from petroleum relative to firms that mine coal.

When entrepreneurs begin to invest in the space resource business, they will not do so on a level playing field. Space entrepreneurs will need government help simply to stay even with terrestrial producers. If public officials decide for political or social reasons to favor extraterrestrial sources, they will need to do even more. Such intervention is likely to take the forms employed in the past -- clarification of rights to the resources being developed and tax credits that subsidize the development of new sources.

Guaranteeing Housing and Student Loans

Some of the largest government subsidies used to encourage the development of commercial markets are to be found in the area of housing and higher education. Public

officials heavily subsidize the markets for housing and student loans and do so without spending very much money at all. The primary mechanism used to achieve this is the creation of secondary markets for privately issued loans. Loan guarantees and tax credits are also utilized. The strength of these mechanisms in directing private investment toward housing and higher education has not gone unnoticed by people in the other commercial fields. Tax credits and loan mechanisms are among the most frequently advocated mechanisms cited by people seeking help for new and struggling businesses, including the space field. Understanding how these mechanisms affect housing and higher education provides guidance as to how they might be used in space.

In the classic movie, "It's a Wonderful Life," Jimmy Stewart (as George Bailey) explains to the residents of Bedford Falls who use his bank why they cannot retrieve their deposits. He has lent their money to neighbors so that the latter can buy homes and start small business firms. Once the deposits have been lent (less a small amount kept in reserve), Stewart can make no more loans. As the town's folk discover, he is short of cash and has little collateral. A run on the bank ensues and Stewart nearly looses control of the bank.

Were this situation to be transferred to the nation at large, the market for American family home would be smaller than it actually is. The massive migration from farm to cities that took place in the first half of the twentieth century, with its commensurate demand for new housing, would have been slowed. Public officials might have been forced to appropriate tax dollars specifically for the purpose of constructing housing -- as they did for government-run public housing for low-income Americans. Instead, the government took a different approach. Law makers established a secondary market designed to make home ownership affordable and accessible to Americans seeking new homes.

The system works this way. Banks and other lenders (organized by people like George Bailey) make long-term loans to customers seeking to purchase homes. After making a series of home mortgage loans, the lender packages those loans and sells them to a secondary lender. The federal government has chartered two institutions for the purpose of purchasing those loans: the Federal National Mortgage Association (known as Fannie Mae) and the Federal Home Loan Mortgage Corporation (known as Freddie Mac). Fannie Mae was established during the Great Depression; the government created Freddie Mac in 1970. Both were aimed at providing a secondary market for the very large number of home loans made to middle-income Americans and handled virtually all of the mortgages made in that realm.

Having purchased packages of locally made loans, officers at Fannie Mae and Freddie Mac repackaged the loans and sold them as notes, backed by the income the mortgages would generate. Investors purchased the notes and received interest. Fannie Mae and Freddie Mac received cash, which they used to purchase more loans. Local lenders received cash from Fannie Mae and Freddie Mac, from which the lenders made more loans. The little engine created by these transactions drove $1.3 trillion worth of the American housing market (as of 1995).

Investors treat Fannie Mae and Freddie Mac securities as if the federal government backed them. In fact, it does not. Although the two institutions enjoy privileges accorded to government transactions (such as exemptions from certain disclosure requirements), they are in fact owned by shareholders and traded on the New

York stock exchange. The two businesses possess federal charters and a social purpose, but their financial instruments are not government guaranteed. Nevertheless, a general perception exists within the financial community that the federal government will not allow Fannie Mae and Freddie Mac to fail. As a consequence of this, plus the privileges they enjoy, the notes issued by these two firms are worth more than similar instruments from purely private institutions. Officials at the Congressional Budget Office estimate that those advantages are worth (as of 1995) $6.5 billion per year. The existence of this advantage is exactly equivalent to the effect that would be produced if Congress annually appropriated $6.5 billion and dropped it into the American housing market. This effect is created without the appropriation of a single dollar. Both Fannie Mae and Freddie Mac are entirely self-supporting.

A similar system exists for student loans. In 1972, Congress chartered the SLM Corporation, more commonly known as Sallie Mae. For twenty-five years, Sallie Mae acted as a secondary market for student loans, with one important difference relative to housing loans. The federal government insured the loans, assuming the loss created by students who, for various reasons, failed to repay the money they had borrowed. In 1997, the government instituted a privatization process, by which the responsibility for defaults was more broadly distributed. A market for defaulted loans now exists. Within this market various institutions purchase loans in default, file for partial reimbursement from the U.S. Department of Education, and then work to recover payments from borrowers in amounts that exceed the difference between the loan purchase and the reimbursement amount.

The existence of government-chartered secondary markets is a powerful mechanism for providing investment capital for housing and higher education. It is far more powerful than simple loan guarantees. The Federal Housing Administration and the Department of Veterans Affairs, for example, provide insurance to homeowners seeking to obtain loans. These insurance policies effectively guarantee the loans. The policies cover loans only at the lower end of the housing market, however, not across the full price spectrum. The secondary market activities of Fannie Mae and Freddie Mac, which are not guaranteed, cover a much larger portion of American housing market measured in dollar terms. (The high end of the housing market is covered by private institutions.)

Tax credits are used to subsidize the housing market as well. In fact, tax credits subsidize a wide range of commercial activities, from crop production to hospital care. Tax credits, or more properly tax expenditures, are defined as revenue losses attributable to provisions of the tax code that permit a special exemption, a special credit, a preferential tax rate, or deferral of a tax liability.[15] A tax credit provides a subsidy that is the equivalent of a legislative appropriation. To the person or business firm receiving it, the tax credit is as good as cash. The extensive use of tax credits as a means of subsidizing socially desirable activities is due to means by which they combine both liberal and conservative points of view. Tax credits combine the liberal desire for a government subsidy with the conservative need for tax reduction.

The effect of tax expenditures is profound. As noted above, the existence of government-chartered secondary markets for home mortgages creates an effective subsidy worth about $6.5 billion per year. Three federal tax credits – the mortgage interest deduction, the property tax deduction, and the exclusion of capital gains on the sale of homes – pump more than $100 billion annually into the U.S. housing market.

Federal tax credits for education (primarily directed toward colleges and universities) are worth nearly $20 billion per year. These tax credits have the same effect as if the federal government collected those funds through the corporate and personal income tax and appropriated $120 billion for housing and education.

Economists worry about the effect of tax expenditures on consumer and business choice. For example, in the area of energy policy, various governments have turned to tax credits as a means of encouraging energy conservation or the development of alternative fuels. Rather than directly subsidize the purchase of more efficient appliances or the search for alternatives to fossil fuels, legislators across the United States have used tax incentives as a means to expand these markets. Various methods are used. Some governments permit taxpayers to deduct a proportion of the cost of qualifying purchases from their income tax bill. Others allow deductions from gross taxable income or the exclusion of qualifying items from sales taxes or the base used to calculate property taxes.

In theory, tax incentives should increase demand for favored products by a predictable amount. In a case of perfect elasticity, where the demand for a product is exactly proportional to changes in its price, a tax credit reducing the price of a new technology by 10 percent should increase sales of that commodity by 10 percent. In practice, this rarely happens, even adjusting for actual elasticity. First, existing tax expenditures are so numerous that they tend to act in conflicting ways. The federal government, for example, provides tax credits of approximately $1.4 billion per year for energy conservation and alternative fuels. The credits cover a wide range of energy alternatives, from wind power to the generation of electricity from poultry waste. The effect of these subsidies is negated by the $1.3 billion tax subsidy that is provided to producers of petroleum products. The large number of tax expenditures seriously distorts existing markets, so much so that new technologies require tax subsidies simply to pull even with traditional products.

Second, tax incentives often constitute a windfall. Business firms or individual consumers may have decided to use that product anyway, so the tax credit has the effect of a rebate that such groups did not plan to receive. Analysts suggest that the effect of tax incentives in the face of such factors reduces their effect to a level as low as –0.3. In other words, a government tax subsidy of $100 million will encourage increased demand in the amount of only $30 million. In such cases, the government would be better off providing a direct cash appropriation in the sum of the larger amount.

Tax credits have been extensively advocated for the purpose of spurring investment in space commerce and new space transportation technologies. As the literature on this approach suggests, they should be used with care.

Insurance programs and overseas investment

People investing in space face substantial risk and uncertainty. The business is new; the environment forbidding. Material launched into space can fall back to Earth in unexpected ways. Business firms commonly turn to insurance as a means of spreading the cost of the risks they incur. To date, investors in space have been unable or unwilling to obtain private insurance sufficient to cover the full extent of the losses they face while operating in this realm.

For federal agencies that have historically dominated space, insurance is not an issue. Federal agencies typically carry no insurance, relying instead upon the vast

resources available to the Treasury to create a form of self-insurance. Business firms are not so blessed. They face issues of liability (as from falling debris) and loss (as from prematurely failing satellites) that commonly lead them to purchase insurance. Without adequate insurance, business firms cannot attract sufficient investors. In some cases, the search for adequate insurance leads to business-government partnerships.

The current regime for liability insurance involves such a partnership. Business firms operating in space commonly purchase liability insurance coverage up to what the government deems to be the maximum probable loss. Under U.S. law, the federal government assumes the liability for any claims resulting from a catastrophe that exceed that amount, subject to the availability of appropriations and up to a set amount. Beyond that set amount, the firms at fault assume the remaining liability.

In the past few decades, the U.S. government has assisted firms operating in an area nearly as hazardous as outer space. The area is overseas investment, especially in poor and often politically unstable countries. The lessons from that experience are directly applicable to space.

The national commitment to world trade proceeds from the assumption that entrepreneurs will invest in those countries that promise the highest rates of return. Manufacturing thus moves to countries with advantageous labor costs, which in turn raises local incomes and helps to reduce world poverty. This simple relationship often fails in practice, due to the substantial risks that flow from foreign investment. Fear of political upheaval, seizure of corporate assets, and sudden fluctuations in local currencies create a level of uncertainty that reduces corporate investment in poor countries. Because of their aversion to losses and uncertainty, business executives left to their own devices will tend to under-invest in poor countries relative to the likely economic returns.

In the same way, entrepreneurs worried about risk and losses and the uncertainties associated with space commerce will tend to under-invest in these ventures even when the forecasted economic returns are strong. The common solution to this situation is to insure against losses. In the realm of overseas investment, however, private insurance policies tend to require premiums that are excessively expensive relative to the actual risk. Moreover, the policies are often available for time periods that are too short for investing firms. The result is a classic case of market failure. Investment fails to flow at the rates that the economic advantages of investment would prescribe, even adjusting for the actual risks involved.

In the late 1960's, the federal government intervened in a way designed to correct this deficiency. It chartered an Overseas Private Investment Corporation (OPIC), a small, and little-known institution that works to encourage private investment in regions of the world where firms encounter substantial risk. The issuance of insurance policies to protect against risks associated with overseas investment is the principle means for accomplishing this. OPIC is essentially self-sustaining; its officers pay insurance claims by tapping revenues that are created by the premiums it collects. The premiums are far lower than those that business firms could expect to pay in the private market. OPIC activities effectively constitute a publicly derived subsidy.

How does OPIC manage to operate an insurance business by charging less than private insurers would otherwise require? First, it is chartered with a social purpose – to encourage overseas investment. That purpose acts as a counter-balance against the uncertainty that prompts private insurers to over-charge for the same policies. Because

OPIC has a social purpose, its officers are motivated to accurately calculate the true risks involved and not overcharge for them. Second, OPIC provides extensive technical assistance to firms that request insurance. Employees who are highly skilled in the intricacies of business operations in less high-risk countries scrutinize the business plans of prospective investors before issuing policies and make suggestions. As a consequence, the federally chartered corporation not only charges premiums well below those of private insurers, it has also returned millions of dollars to the U.S. Treasury. According to some observers, it offers one of the closest analogies to the type of institution that might be used to encourage investment in the risky realm of space.

4. Promoting Space Commerce

The challenges confronting public officials seeking to encourage the commercial expansion of space activities are familiar ones, not unlike the difficulties faced by project scientists and engineers. In designing space missions, scientists and engineers frequently balance the need to reduce cost with the need to eliminate delay and lessen risk. The nature of the cost-schedule-risk equation forces scientists and engineers to make trade-offs, taking losses in one area so that they can make gains in another. Thus a mission conducted at low cost with great speed incurs risk, while mission planners working on tight schedules often incur high costs.

Cost, schedule, and risk also affect entrepreneurs seeking to construct businesses that operate profitably in space. In the business realm, risk takes the form of substantial uncertainty about the size of markets and the demand for products, as well as the physical risks of operating under the severe conditions that exist in space. For many years, space advocates have insisted that extraterrestrial resources such as solar energy and Helium 3 will provide substitutes for fossil fuels. Earth-based technologies, such as hydrogen-powered fuel cells, compete against them. Given the current state of understanding, it is difficult to know which approach will be cost effective. Uncertainty about markets and the future demand for various products naturally occurs.

For business firms, the scheduling issue often appears as concern about the length of time between initial investment and expected economic return. In space, as with other new technologies, the length of time can be abnormally long. Venture capitalists were reluctant to invest in American canals and railroads because those facilities ran through sparsely settled lands. Most people agreed that the lands would be settled someday and generate transportation demand, but that settlement might take a long time to occur. Lacking a clear vision of the future, new investors calculated their financial participation as if the time between investment and use would turn out to be very long. In their minds, it was safer to demand higher rates of return than to anticipate immediate profitability. Many railroad investors got happily rich by assuming (incorrectly) that they would have to wait a very long time before settlement produced adequate returns.

To private entrepreneurs and public officials promoting space commerce, this creates a challenge commonly known as "building ahead of demand." It is one of the principal reasons that public officials involve themselves in the commercialization of new technologies. For economic and political reasons, the United States has benefited from the commercial acceptance of various technologies that appeared in the marketplace earlier than they would have appeared in the absence of government intervention. American leadership in such areas as aviation, farm productivity, automobile transport, pharmaceutical products, and computer technology has benefited from the ability of entrepreneurs and public officials to force new commercial developments in advance of market demand.

Costs appear in the conventional way. Space is an extraordinarily expensive place in which to do business. The cost of launching material into space commonly approaches $10,000 per pound – and that is just to low-Earth orbit. The cost of spacecraft and satellites is even more. High-end equipment can in some cases exceed $200,000 per pound for design, test, and fabrication. Once the equipment reaches space, its designers incur the considerable expense of operating it remotely, generally through

communication networks located on the ground. In spite of their extraordinarily high cost, space activities have moved ahead in the United States. Such progress has been motivated by considerations of national security and absence of cheaper terrestrial alternatives as in the case of communication satellites.

In assessing the commercial viability of various space activities, one can gauge the relationship between cost, schedule, and risk. For a given cost, what is the chance that a particular space activity can compete successfully with terrestrial alternatives? How long must investors wait before the activity becomes profitable? What is the probability that a given enterprise will fail, either for technical reasons or because the cost and schedule estimates are untenable?

Much of what NASA and the Defense Department continue to do in space is characterized by high costs, high risk, and long schedules. The activities are not commercially viable, at least not in the form that government agencies conduct them. It is hard to imagine how private entrepreneurs could have raised sufficient capital to send the 5,551 pound Cassini probe on a seven year journey to Saturn when the spacecraft cost $297,000 per pound to build and $35,000 per pound to launch. Current space activities are so costly, so risky, and take so long to complete that the size of any government subsidy necessary to commercialize them would be prohibitively large. Public officials would have had to provide a subsidy worth upwards of $3 billion in order to encourage private entrepreneurs to complete the Cassini mission as the government undertook it.

The size of any government subsidy necessary to encourage an otherwise unprofitable activity is proportional to the gap between mission cost and commercial return. To the extent that cost, schedule, and risk factors can be reduced, commercialization becomes more feasible. At this point of the argument, advocates of space commercialization divide. Some favor government support as a means of encouraging the innovations that may cause costs to fall. Others, mainly from the business community, fear that government subsidies will simply perpetuate a system that maintains costly and lengthy missions to the detriment of commercialization.

Traditionally, cost and schedule and risk have been viewed as factors to be exchanged. This is the dominant view on governmental projects. Many business entrepreneurs take an alternative point of view. To them, cost and schedule and performance are features to be simultaneously improved through advanced technologies and new methods of management. Many people do not trust the government to break away from its traditional culture and take the steps necessary to make commerce work. "It's not because NASA and its people are bad or misguided," states business analyst Lou Dobbs. "It's because they aren't set up to make business work."[16]

Any system of government support for space commerce thus incurs two requirements. Not only must the support be sufficient to bridge the gap between business profitability and the excessively high expense of operating in space, it must also create incentives for reducing the forces that create those expenses. Many people believe that the private market, particularly the engine of competition, creates a much stronger incentive for improvements in cost, schedule, and performance than any government policies will ever provide.

The case of satellite radio provides a practical illustration of these forces at work. Satellite radio works much the same way as satellite television. Broadcasters use ground stations to beam radio programs to satellites in Earth orbit, which beam the signals back

to radio receivers on the surface of the Earth. Subscribers purchase radios that are capable of receiving signals and pay a monthly fee designed to cover the costs involved and produce a profit for investors.

A number of corporations have entered the satellite radio market. In the United States, two firms recently began offering satellite radio broadcasts: XM Satellite Radio, which launched its service in 2001 and Sirius Satellite Radio, which commenced broadcasting in 2002. XM Satellite Radio relied upon two geostationary orbit satellites named "Rock" and "Roll," while Sirius employed three, in elliptical orbits, that ensured that at least one satellite appeared above the continental United States at all times.

The satellites are very expensive. Corporate officers value each of the three Sirius radio satellites at a dollar amount that is equal to the entire cost of the 1997 Pathfinder mission to Mars. The entire Pathfinder mission -- spacecraft, launch, operations, and data analysis -- cost $265 million. Each Sirius satellite is valued on company financial statements at $270 million. To save money, Sirius executives arranged for their satellites to be launched on Russian Proton rockets. The Pathfinder spacecraft flew into orbit on an American-built Delta 2.

Corporate officers raised sufficient capital to purchase and launch the satellites, acquire ground equipment, and cover business expenses during the start-up phase. They purchased insurance to cover the possibility of launch or operational failures. Since the insurance did not sufficiently cover the expected life of the satellites, corporate officers set aside sufficient funds to begin construction of a fourth, replacement satellite.

Sirius offers its U.S. customers 60 channels of original, commercial free radio, plus 40 channels of sports, news, and entertainment. Subscribers pay $12.95 monthly for this service. The cost of doing business amounts to about $113 million every three months. The largest items are interest expense ($25 million), depreciation of equipment ($22 million), and marketing ($31 million). The cost of programming and broadcasting is small by comparison – about $13 million each quarter. The corporation spends an equal amount ($13 million) on research and development.

To be profitable under these conditions, the Sirius Corporation needs to enlist about 3 million subscribers. As of mid-2002, they had attracted about 3 thousand. Revenue from subscriptions plus a small amount of advertising generated $70,000 for the quarter ending June 30, 2002. With reserves of approximately $325 million, the company had enough money to stay in business for less than one year.

What might the government have done to encourage the commercial development of satellite radio? Public officials could have assisted with the acquisition of insurance. They could have provided low-interest loans, loan guarantees, or tax credits. They could have sponsored research aimed at reducing the cost of the underlying technology. Both Sirius and XM paid more than $80 million each to the federal government for the right to broadcast in a portion of the "S" band allocated by the Federal Communication Commission. Public officials could have granted these broadcast rights in the form of a non-cash asset, that is, for free, although this would have required a substantial change in the government policy that requires payment for broadcast rights.

Given the scale of the investment required to start this commercial activity, any governmental contribution would have been small relative to overall financial needs. Total investment costs for the satellites used by the Sirius Corporation approached $1 billion, and the corporation sought an additional $600 million in 2002 as a means of

bridging the gap between mounting expenses and future revenue. The federal government could have helped through cash or non-cash subsidies, but to a great extent the success of the enterprise was determined by forces in the market, not government.

The key strategy within the Sirius business plan required the corporation to form alliances with other businesses that could provide a ready pool of customers. Only in that way would the corporation attain the customer base necessary for profitability. The Sirius business plan focused on the automobile radio market. Consumers purchasing automobiles are accustomed to pay large sums for high-end items like radios. If only a small proportion of customers purchased satellite radios as an option on new cars, the business would grow. For that reason, Sirius formed business partnerships with BMW, DaimlerChrysler, and the Ford Motor Company. XM Satellite Radio formed an alliance with General Motors. In turn, automobile manufacturers invested heaving in Sirius and XM.

The extent of government involvement can be determined by the nature of the challenges faced by business executives seeking to make money in space. Table 2 presents those challenges in graphic form. Uncertainly about the commercial demand for a given product depends upon the risk and cost of producing it in space relative to terrestrial alternatives. Uncertainty about the commercial demand for satellite radio is greater than uncertainty about the demand for satellite television. The latter market is more established than the former. Investment schedules present a second dimension. The amount of time between business investment and business return is relatively low for satellite radio. Not much time exists between the purchase of radio satellites and the knowledge of whether sufficient customers will sign on. This is especially true when satellite radio is compared to alternative investments in other space technologies such as new launch vehicles. Satellite radio executives are not expected to build very far ahead of demand whereas investors in space transportation systems are.

In combination, these two factors foster situations for which potential government roles may differ considerably. For a few commercial applications, the market demand is both certain and immediate. In such areas, markets function reasonably well and the appropriate government role is likely to be limited. Satellite radio tends toward this realm. It would benefit from government assistance but could succeed without it. The market for satellite radio works relatively well. Competition exists. The market is likely to reward clever business plans while punishing those firms that fail to innovate or cut costs relative to their competition. In such cases, the market is likely to provide clearer incentives than ones fashioned by civil servants struggling to employ public laws.

To the disappointment of people promoting space commerce, the number of applications that fall into this first sector is quite small. Most of the applications envisioned by people promoting commercial space activities are characterized by higher degrees of uncertainty and longer periods of return. Substantial reductions in the cost of space transportation, for example, would surely save money -- but business analysts are uncertain about the degree to which this would increase demand. Projects of expected payloads suggest that demand in the near term may remain quite small, regardless of the transportation cost advantages. Perhaps payloads will grow in the future, but not soon. This creates a classic problem in "building ahead of demand," similar to that which previously affected railroads and canals.

Much of what government continues to do in space falls into the fourth category –

high cost, weak private demand, and distant returns. The most common solution to technologies so affected is public provision. The government taxes citizens for services they would not privately purchase and provides funds to governmental agencies. As will be seen, this approach does not preclude commercial involvement. However, the incentives necessary to create that involvement are likely to differ considerably from those used for more marketable products such as those found in the first sector.

Consideration of such factors will now be used to analyze five potential roles that NASA or the government at large could play in assisting space commerce. The five roles correspond to future opportunities in space: Earth applications, space transportation, extraterrestrial resources, human migration, and scientific exploration.

Table 2
Commercial Acceptance of New Technologies

	Uncertainty about Commercial Demand for Product	
	Low	High
Length of Time between Investment and Economic Return Short	•Satellite communications •Satellite radio 1	• Space mining 2
Long	3 •Space transportation	4 •Search for extraterrestrial life •Space colonies

5. Scenario #1: Commercializing Earth Applications

The use of satellites to transmit information and provide data about the Earth generates billions of dollars in commercial revenue each year. Telecommunications, global positioning, and Earth observation activities in the year 2000 produced business revenues of $75 billion worldwide, with satellite communications providing the dominant share. Revenues are growing at an average rate of 18 percent annually. Experts believe that this sector will expand through low-Earth orbit satellite communications, satellite-based Internet access, live public and private broadcasting, satellite television, satellite radio, and transmission of medical information. So promising are such applications, predicts one author, that space during the next decade will have as much influence on the business community as internet communication did during the 1990s.[17]

In the minds of its advocates, this business arena is one in which investors can expect strong private demand and rapid returns. As such, it falls into a sector in which the most commonly recommended public role is for the government to get out of the way and allow market forces to run their course. "The private sector's growth in space," says one commentator, "has been unduly stunted because the field has remained effectively the domain of the public sector."[18] According to this point of view, government involvement hinders commercialization and maintains costs at levels that would quickly fall if private entrepreneurs became more involved.

The terms "space industry" and "space commerce" appear frequently in government sponsored commercialization studies. This is a provocative point. To commercial entrepreneurs, space is not a business. It is a place. To someone in the private sector, speaking of space as a commercial activity is as incorrect as talking about California as a business. Corporate leaders make decisions about products and services that may be created entirely, in part, or not at all in space. To them, place is important only insofar as it provides marginal advantages in such areas as production and distribution.

Persons who take this point of view frequently cite NASA's role in developing the space shuttle as an example of the manner in which good government intentions retard commercial development. Around 1970, when public officials debated the wisdom of developing the space shuttle, advocates of low-cost space flight advanced the proposition that NASA could produce a reusable space vehicle capable of flying to Earth orbit and back at a cost in today's dollars of about $50 million per mission. Armed with this expectation, government officials priced private use of the shuttle at a level considerably below its actual cost. This created a subsidy designed to encourage use of the shuttle for activities that included commercial applications in space. But it also had the effect of retarding the development of privately constructed launchers that could not compete with the subsidized price. By interfering in fully functioning markets, government agencies consume funds that might otherwise be directed to private investment and consumer purchases.

Had NASA officials competed with private providers of space transportation on a level playing field in an open marketplace, this might have produced a workable technology. It certainly would have provided a penalty for NASA's inability to meet its original cost goals. Instead, NASA created a thirty-year old subsidized technology that does not provide cheap access to space and is no longer available for the frequent

delivery of commercial payloads as originally promised.

To business advocates, the free market is a far superior mechanism for picking winners and punishing losers than a government bureau. Where demand for a new product is strong, the market will integrate a new technology into the commercial marketplace far more rapidly than public officials, no matter how well intentioned the latter are. That, at least, is what advocates of privately-funded space activities profess.

The actual record is somewhat different. Consider the case of global positioning systems (GPS), one of the most viable sectors of the new space commerce and a frequently cited example of market forces at work. Producers of GPS equipment sold more than $6 billion worth of equipment in 1999, over half of that accruing to U.S. firms. The business is expected to top $10 billion worldwide in 2003.

The GPS concept is based on an ancient concept. A person can determine his or her position by knowing the distance and relationship to points that are known. A well-instructed high school geometry student can perform the required calculations. The known points need not be on the surface of the Earth. Early mariners used the known positions of celestial bodies like the sun and stars to calculate the location of ships on an otherwise featureless sea.

Two advances in technology permitted the use of space for position determination. One was the advent of satellites in predictable orbits; the other was the development of extremely precise clocks. The distance from between the person using the system and any properly equipped satellite can be derived from the time required for a signal from the satellite to reach the user. The distance between the user and four GPS satellites provides sufficient information (three coordinates plus time) to determine the user's latitude, longitude, and altitude to a remarkable degree of accuracy.

The basic satellite system was developed by the U.S. Department of Defense, beginning in the 1960s. The original idea was prompted by the need to precisely determine the position of nuclear submarines at sea. Once funded, the military developed a wide range of uses for the technology, from the location of troops on patrol to the ability to guide missiles to precise locations.

In the 1980s, even before the system became fully operational, government leaders in the United States stated their intention to make the signals from military GPS satellites available to private users. (The signals can be degraded in such a way as to make them unusable to someone without the proper equipment, much in the manner that satellite television scramble their broadcasts.) Significantly, federal officials in the Reagan-Bush administration promised that the signals would be provided free of charge. President William Clinton reiterated this position in a 1996 policy. In a formal policy statement, the White House announced that the U.S. government would continue to provide GPS signals "on a continuous, worldwide basis, free of direct user fees."[19]

Military use of the still-incomplete GPS system during the 1990-91 Gulf War excited public interest in the technology. If military pilots and troops could use receivers to fix their position with ultra-precise confidence, so could sailors, surveyors, oil and gas explorers, vehicle drivers, pilots in commercial and private aircraft, even mountain climbers. A large number of private firms began producing receivers for commercial use. The military completed its 24-satellite system in 1993 and by 1996, worldwide revenues for GPS producers topped $3 billion.

Government deregulation was required to make the private market work

effectively. Prior to 1991, U.S. manufacturers who sought to sell receivers to customers in other countries had to comply with government export restrictions and obtain a license for each shipment. Suppliers complained that less stringent restrictions on foreign producers gave foreign firms a competitive advantage in commercializing a U.S. technology. The restrictions were lifted in 1991.

The GPS market works in much the fashion that advocates of privatization propose. A relatively large number of firms producing GPS equipment compete with each other to reduce costs, satisfy customers, and locate new markets. To characterize this commercial activity as a purely private one, however, is most inaccurate for the simple reason that the government provides the GPS signals for free. The signals take the form of a government asset obtained for purposes unrelated to commerce that has commercial value. In the same manner that 19th century government leaders provided land as a means to spur the development of railroad technology, 20th century government officials provided electronic signals as a method of encouraging a global positioning industry.

The cost of the satellite system is not insignificant. The satellites themselves, including launch, cost about $5 billion through the initial deployment of the system in 1993. Analysts believe that continuing modernization of the system will require an additional expenditures of about $10 billion through 2016. This does not include the cost of operating the system, estimated to run at about $250 to $500 million per year. Taken together, these expenditures amount to a public subsidy in the range of approximately $1 billion a year to an industry generating $10 billion in revenues. It is doubtful that any entrepreneur could have raised the capital necessary to construct and maintain a privately-run system of positioning satellites.

As such, the GPS system represents a pleasant amalgamation of government support and private activity. Through an annual appropriation process, public officials created an asset provided at no charge to private users. An industry of relatively small competitors arose to provide paying customers with equipment that would allow them to use the system. Beyond the existence of the GPS signal, the industry required little government support in the form of loan guarantees, price supports, tax credits, or direct cash subsidies.

The tendency to decry government interference while accepting government subsidies is a noble tradition in American politics. It is a theme that dominated the settlement of the last great American frontier. Some of the greatest advocates of individual enterprise in the history of the United States made their fortunes profiting from federally subsidized timber, water, and transportation in the American West. Accurately speaking, advocates of space privatization request two types of government assistance. First, they are pleased to receive the benefits of government spending when it supports research such as that used to launch the communication satellite industry or weather satellites or the creation of assets such as the global positioning satellite system. They are nervous about the prospect that the government may hold on to a technology for too long once it is mature, but in general private entrepreneurs are pleased to let the government bear the burden of initial investment.

Given their disconnection from profit and loss statements, well-intentioned public servants may seek to improve new technologies for periods of time after which private firms would have let them go. During the 1960s, NASA scientists who helped to develop

weather satellite technology wanted to keep improving satellite design. NASA Administrator James Webb wanted to move the satellite program out to the Weather Bureau. "This thing is not ready," one of Webb's associates remembered the scientists saying. "It is still R&D." The associate told the head of the research program to let the satellite go. The satellite program went to the Weather Bureau in 1965.[20]

Second, advocates of privatization are grateful for help in adjusting the terms and conditions under which new commercial markets are allowed to develop. As with the global position system, new industries do not arise in a regulatory vacuum. Existing subsidies and regulations distort emerging markets in what are often undesirable ways. If officials in the U.S. government decided to promote the development of alternative energy sources based in space -- and do so through the open marketplace -- they would be frustrated substantially in their attempt by existing subsidies. The government already subsidizes oil, gas, and coal production through various tax policies. It subsidizes hydroelectric power by establishing public authorities to operate publicly-owned power plants that pay no taxes. The small subsidies received by producers of alternative energy technologies are exceeded in size by the magnitude of subsidies received by large producers. For this reason, promoters of alternative technologies often begin their request for government support by requesting an end to subsidies for competing sources.

Existing government regulations pose a second obstacle. No free market exists for the sale, distribution, and purchase of U.S.-built satellites. The market is highly regulated. In some cases, satellite sales are subject to government review on the grounds that the U.S. government has a national security interest in preventing the transfer of military technology to foreign nations. Generally speaking, as of 2003, the sale of space hardware to foreign nations received the same treatment as domestic firms attempting to sell munitions to armies overseas.

6. Scenario #2: Investing in Space Transportation

Suppose that space were treated like the airline industry. Reflecting on the history of aviation, the federal government might engage in an aggressive program of research support for flight and engine technology, as it did at the beginning of the 20th century through the National Advisory Committee for Aeronautics (NACA). The most extensive support would last about twenty years, through the formative period of the new industry. Funding for NACA grew steadily for nearly twenty years, then declined in a fashion disproportionate to the government as a whole. The decline was due in large measure to the maturing of the airline industry and the Great Depression, as well as critics of the NACA and government efficiency experts who opposed publicly-funded research.

The federal government might remove itself from the space transportation business, except for selected military payloads, relying upon private industry to provide those services under government contract. Public officials performed a similar act for the airline industry by passing the Kelly Act, twenty-two years after the Wright brothers conducted the first powered flight at Kitty Hawk. The 1925 Kelly Act took the federal government out of the airline business.

The government might act as a primary customer for space transportation services, providing the infant industry with a predictable base of revenue upon which corporate executives could construct their business plans. Specifically, this is what the Kelly Act provided. The federal government supported the airline industry by providing firms with contracts to carry the mail, a lucrative business. Concurrently, federal officials adjusted government policy in such a way as to encourage the development of larger and more advanced aircraft. The decision to shift the payment method for mail delivery from weight to volume constituted such an adjustment. This small, apparently insignificant change created incentives that led to the development of a new generation aircraft like the DC-3.

While divesting themselves of the responsibility for operating commercial space transport firms, government officials employing the airline analogy might nonetheless retain responsibility for the operation of spaceports. They would not do so, however, through the annual cash appropriation that supports facilities like the Kennedy Space Center. Rather, elected officials would establish public authorities with the power to borrow money and collect fees. Such authorities would be created with the aim of making them financially self-supporting once the space transportation industry matured. States might compete to develop their own spaceports. The Kennedy Space Center might remain in government hands, but in a different form. Organizationally, it could resemble Kennedy International Airport in New York City more than the old Kennedy Space Center. This is the model used within the United States for the development of airfields.

Why not allow emerging space transportation firms to develop their own spaceports? Again, the history of air transport is instructive. Municipal competition helped to promote government construction of airfields, but so did the fear of corporate monopolies. Public officials in the early 20th century contemplating the design of airfields possessed the hindsight afforded by their experience with railroads. Individual railway companies built most urban railway terminals. Additionally, railroads built their own railway lines and controlled their own track. This practice created local monopolies, in which control of tracks and terminals allowed railroad barons the privilege of setting

their own rates and fares without much regard to market competition. Public concern led to the creation of the Interstate Commerce Commission (ICC) in 1887, which received the power to regulate rate and fare increases. Removal of airport construction from private hands prevented a similar history for air transportation.

Employing the precedent of the ICC, the federal government regulated airline routes, rates, and fares. It did so through the passage of the 1938 Civil Aeronautics Act. The purpose of this legislation was different than the one motivating railway oversight, however. Regulation of air routes and fares was undertaken to assure newly created executives at firms like Eastern and United Airlines that they could expect to generate profits at a time when competition would have driven revenues below the cost of production.

In a similar fashion, routes and fares might have to be regulated for privately run space transportation firms -- at least until the industry matures. At a minimum, public officials might be obliged to establish cabotage laws restricting flights to and from the United States to domestic carriers. In most industries where this is done, some sort of regulatory body promulgates specific rules. The institutional forms used to accomplish this purpose vary enormously. Some regulatory bodies are organized as independent commissions, as with railroad and airline regulation. Other regulatory bodies are closely attached to departments within which research is conducted, such as the Environmental Protection Agency (EPA). Still other regulation occurs through hybrid forms that involve a regulatory commissions within large departments, such as the Nuclear Regulatory Commission in the Department of Energy.

Once such a regulatory body is created, it tends to last a long time. Sometimes it lasts too long, past its useful life. Critics of the ICC have accused the commission of transforming itself from a regulator of surface transportation into a protector of the interests of the regulated firms. The "capture" of regulatory bodies by regulated industries is a recurring problem in American politics. The agonies involved in deregulating the airline industry after more than thirty years of government control demonstrates how difficult transitions can be. Regardless, most economists agree that excessive regulation of mature industries retards efficiency and the rapid adoption of new ways of doing business.

Analogies are never perfect, however. Firms in the space transportation business differ in significant ways from their predecessors in the field of aviation, just as the latter differed from railway lines. Forty years into the era of space flight, the market for space transportation is not as robust as the market for airline transportation when the federal government passed the 1925 Kelly Act. Many people believe that it would develop once privatization occurred. A business firm flying the space shuttle, states Edward Hudgins, "would have a strong incentive to find moneymaking uses for underutilized shuttles."[21] These are hopes, however, not statistical certainties.

Believers in privatization pin their hopes on what they perceive to be an inevitable development – the falling cost of space transportation. They draw inspiration from the airline analogy, where cost per passenger mile fell dramatically with the advent of technological developments like the turbojet engine. Sufficient investment in space transportation technology might produce similar results, many believe.

In the past, improvements in space transportation have been breathtakingly expensive. In the value of today's dollars, the space shuttle cost more than $30 billion to

develop. Development of the Saturn launch vehicles during the 1960s, prior to the first Moon landing, required more than $50 billion in today's currency. Yet when development of the NASA-Lockheed Martin VentureStar approached $2 billion in government and corporate investment, NASA officials in 2001 killed the program.

The absence of money sufficient to develop the next generation of launch vehicles severely retards the space transportation business. Elected representatives are not willing to provide annual appropriations in amounts sufficient to complete this work and neither are venture capitalists. This need not retard such development, however. Looking again at the history of other transportation industries, other options appear.

The basic obstacle to investment in space transportation is the same as that previously perceived by people working to develop the railroad and airline industry. Initial investments precede the development of markets by a considerable period of time. Investors are thus obliged to "build ahead of demand" in the hope that such demand will materialize once the new technologies appear.

Historically, governmental bodies have played significant roles in encouraging private entrepreneurs to build – or invest – in anticipation of demand that may not appear for a decade or more. In the case of the airline industry, this was accomplished largely through the creation of governmental authorities with the ability to borrow money in anticipation of future gains. This was the basic model used to develop airfields.

Suppose that the Congress were to vest in NASA, or some similar body, the power to borrow on the credit of the U.S. sums sufficient to assist in the development of the next generation of space transportation. The money would be repaid to the Treasury from the cost savings incurred by NASA in not having to fly an outmoded technology. The government – or whatever group development the new launch vehicle – could repay the initial investment in less than one dozen years after the end of the development cycle. This could occur even if the new technology cut current transportation costs by a modest 50 percent. The current cost of flying the space shuttle runs about $400 million per mission, so a 50 percent decline would result in a $200 million per flight savings.[1]

In spite of the widespread use of government borrowing authority, few officials called for its use during the last round of space transportation development. Instead, corporate executives requested that the federal government guarantee the loans they were seeking in private markets. Loan guarantees are designed to make more capital available to affected industries at a lower cost than the market would otherwise provide. Guarantees are based on the assumption that recipients will repay their debt, but take longer to do so than lenders normally allow. Again, this addresses a classic problem of building -- or investing -- ahead of demand. The federal government guarantees student loans because economists know that the net gains in lifetime earnings of persons with college degrees far exceed the cost of student loans. Similarly, the creation of government support mechanisms for home mortgages encourages banks to lend money over time periods that home owners need to repay their loans. If bank executives had to wait thirty years to recover the money lent to home owners, not as much money would

[1] For example, a $7 billion investment spread over a seven year development period could be repaid with interest through the cost savings accrued over ten and one-half years of operation. This assumes a 50 percent reduction in operational expenses ($200 million per flight) based on five flights per year and a Treasury interest charge of 5 percent applied to the outstanding balance annually.

flow.

Loan guarantees are a powerful mechanism for directing capital toward industries that must wait substantial periods of time for revenues to grow. Guarantees rapidly provide money and lower the cost of capital to affected industries. A firm that would otherwise have to pay effective interest rates of 16 percent may gain access to funds at 6 percent under government guarantees. From the business point of view, loan guarantees are more effective than alternative mechanisms such as tax incentives.

Loan guarantees are also superior from the government's point of view, providing that assumptions about "building ahead of demand" are true. The relative value of the loss in revenue to the Treasury is less under a loan guarantee program than under a system of tax forgiveness. To issue a loan guarantee, the federal government must in essence set aside a sum equal to the probability that a given number of borrowers will never repay their loans. As an alternative, public officials can create tax holidays (in which new firms are excused from tax payments for fixed periods such as ten years) or tax credits (that result in proportionate reductions in tax payments such as 20 percent). The federal government is better off setting a little money in the beginning to cover defaults than forgoing future taxes generated by an industry that holds the promises of healthy profits someday.

Note the assumption upon which this conclusion is based. Future demand for the investment object must be strong. The demand may be delayed, as was the case with railroads laying track into unsettled territory or as occurs when students forgo present income in the knowledge that future earnings will grow. But demand must be strong once it occurs. Most analysts believe that the demand for space launch services will increase exponentially with the advent of second and third generation launchers that are more efficient and safe. The investment cost of creating such launchers will be high and the time spans to profit may be long. For a program of loan guarantees, that does not matter so long as the probability of future profits is strong.

Legal obstacles exist to the use of loan guarantees for space transportation. Federal legislation requires that the government be compensated in some fashion for the risk it assumes in making guarantees. In some cases, this requires that Congress set aside sums of money that cover anticipated defaults, thereby triggering the very sort of appropriation that a loan program is designed to avoid. Affected industries have evaded this requirement in a number of ways. When supporters of the airline industry succeeded in convincing Congress to establish up to $10 billion in loan guarantees for carriers affected by the September 11, 2001, attack on the United States, they did so with a special device. Section 102(d)(2) of the Air Transportation Safety and System Stabilization Act of 2001 authorizes the guaranteeing agency to enter into contracts that allow the government to share in the future financial gains of participating corporations as a means of compensating "for the risk assumed in making guarantees under this title."[22]

Direct borrowing authority by a governmental body such as a port authority with substantial assets is in many respects superior to the loan guarantee. To be effective, governmental participation must not only provide needed capital, it must also provide incentives for the affected parties to make wise financial decisions. Borrowing authority satisfies this criterion inasmuch as the governmental body must repay the original loan; default for a governmental authority with diversified assets such as the Port of New York

and New Jersey is not a desirable option. As a consequence, the operation of public authorities tends to be much more business-like than typically found in governmental bureaus.

Both borrowing authority and loan guarantees subject participating industries to government oversight and control. To issue a guarantee, the government must establish an administrative agency with the power to review and approve applications from affected industries. For example, the 2001 Air Transportation Safety and System Stabilization Act created a three-member Air Transportation Stabilization Board and required it to review items such as the applicant's overall business strategy and five-year financial plan and certify that any loan would be prudently used. Joint business-industry partnerships associated with capital development of facilities like airports and sports stadiums also requires careful government review. Governmental participation in private financial markets does not come for free.

The risks associated with loan programs often limit their application to new technologies. When various governments began to support the construction of canals and railroads in 19th century American, they sometimes issued loans to private corporations. The governments incurred risk, since the loans were backed by the "full faith and credit" of the government and corporate leaders might not repay their debt. Public officials experimented with a number of devices designed to mitigate that risk, including the acquisition of stock in affected corporations. The dangers associated with loans and stock led responsible officials to advocate the use of land grants as an alternative to direct loans, a practice that came to dominate 19th century transportation policy in America. Governmental bodies lent money and acquired stock, but not on the scale that they gave away land.

7. Scenario #3: Developing Extraterrestrial Resources

In many respects, the risks incurred in developing extraterrestrial resources are qualitatively different than those involved in other commercial applications. As such, they tend to command government roles different than those utilized for space transportation and first-generation satellite applications.

Low-cost space transportation will produce economic benefits, if it ever occurs. That is the advice of experts. First generation space applications, especially satellite communications, already do. The economic advantages of producing materials in space or retrieving natural resources are not as clear. Significant doubt exists with regard to the financial viability of products from space. Some people believe that a huge market exists for micro-gravity drugs and pharmaceutical products. Yet, that market has not appeared, certainly not on the time scale advanced by the first forecasters. Some people believe that solar power and Helium 3 will compete successfully with terrestrial energy sources such as hydrogen-oxygen fuel cells. No one knows for sure. Uncertainty is compounded by the difficulty of predicting which firms will prosper and which will fail. Historically, most new start ups falter, even in sectors of the economy that succeed as a whole.

Private investors compensate for degrees of uncertainty by charging successful firms for the cost of risk. If 50 percent of the firms producing a marketable technology fail, then investors will expect the remaining firms to produce rates of return that are an equivalent amount larger. Successful start-ups, from the investors' point of view, bear the cost of failure. The added cost can act as a barrier that slows the integration of new technologies into the commercial marketplace.

In some cases, the new technology may cost more than alternative forms, but for social reasons turn out to be preferred. The price of producing electric power from space-based instruments may be more than the price of generating electricity from hydroelectric plants, to give an example. Yet the public may collectively favor the former because people are opposed to the construction of more dams. Were the cost to society resulting from the loss of fisheries and scenic wonders included in the price of electricity, the economic advantage of dams might disappear. When such items, called externalities, are not part of the price directly borne by users, a cost advantage accrues to what is from the broader point of view an inferior technology.

Into this realm government officials often venture. The correction of market failures arising from externalities and other shortcomings provides a primary justification for government intervention in otherwise free markets. Rather than allow socially undesirable technologies to dominate a particular market, officials may grant subsidies to more favored ones. Governmental bodies perform this function for technologies like mass transit, which could not possibly cover their costs through direct charges. They also grant subsidies that compensate for the cost of uncertainty in ways that speed the commercial adoption of new technologies. A vivid example of the latter practice is contained in the history of the tractor, discussed in chapter three. Public officials provided price supports as a means of achieving the gains in agricultural productivity that private tractor purchases provided. To spur gains from commercial space products, public officials may be called upon to do this again.

Subsidies can take the form of cash, as is the case with mass transportation. This approach contains significant limitations, since the availability of tax-derived appropriations rarely approaches the subsidy needs of affected industries. To provide

additional support, public officials have turned to a variety of mechanisms of a non-appropriation sort. Tax credits and insurance subsidies are among them.

The overall purpose of such mechanisms is to provide a subsidy. For potentially profitable activities, the subsidy may be small. For risky endeavors, it may need to be large. The subsidy is designed to compensate firms for the risks involved in commercializing a new technology or to close the monetary gap between the price business executives can charge and the cost of doing business.

Tax credits are a powerful means for generating subsidies. The home mortgage interest deduction claimed by American taxpayers is the equivalent of a $70 billion government cash subsidy paid each year to the housing industry. Legislators could appropriate $70 billion in direct grants, but tax credits are easier to enact. Moreover, tax credits leave home ownership decisions with individual consumers instead of placing them in government hands. One of the most ingenious tax credits can be found in government policies supporting the merchant marine. The cost of operating ships that carry the U.S. flag far exceeds the cost of operating ships registered with nations that have less stringent labor agreements and regulatory regimes. Largely for national security reasons, the U.S. government prefers to maintain a healthy merchant marine. To encourage this, the government allows U.S. ship owners who invest a portion of their earnings in new ships or equipment to delay the onset of tax payments on current profits. Someday the taxes will have to be paid, but until then the tax deferral policy creates a subsidy that is the equivalent of an interest-free loan.

Tax credits would be a particularly effective means for encouraging the development of extraterrestrial resources. Rather than ask successful firms to bear the cost of ones that fail, the successful could be compensated through lower tax rates. To the extent that tax rates are lower for firms producing new products in space, demand for these products would grow. This approach has been widely applied to the production of energy. Oil depletion allowances, tax-free public utilities, and tax credits for alternative energy generation lower overall cost and improve the profitability of affected firms.

Tax credits are not the only means for providing subsidies to firms that make investments thought to be socially desirable. Any policy that reduces costs has that effect. When government officials decided to encourage private investment in less developed countries, they did so through the provision of insurance. This was particularly appropriate inasmuch as firms investing in poor countries faced levels of uncertainty far greater than those encountered by firms investing in more industrialized nations. A local currency can collapse; governments can change and expropriate assets of investing firms. To protect themselves against excessive risk, executives in affected firms purchase insurance. One might think that the insurance industry would provide coverage at rates that reflected actual risks. This is not so. The rates charged by private insurers exceed the actual risks. Additionally, the time periods covered by the policies are frequently insufficient for the investing firms.

To compensate for this shortcoming, Congress created the Overseas Private Investment Corporation (OPIC). It has been operating for more than thirty years, providing low cost insurance to firms operating within unstable regions of the world. In order to provide low cost insurance for a high-risk endeavor, OPIC employs a small group of technical experts who carefully screen applications and provide advice. In spite of the obvious risks, OPIC has remained self-supporting, covering potential claims with

the income derived from premiums paid in.

A similar approach could be used to address the risks of operating in the physically challenging realm of outer space. Private insurance premiums for space payloads are expensive. Full coverage is often unattainable. When confronted with the necessity of having to sell a single policy for an investment single act involving substantial uncertainty, OPIC officials do not overcharge or under-provide. Established to serve a social purpose, they do not calculate their exposure like private business executives would do. OPIC officials also modify the uncertainty associated with individual investments through the practice of bundling insurance policies together and selling them to private investors, whereby creating larger insurance pool with more predictable risks.

An Outer Space Private Investment Corporation could perform a similar function, reducing costs associated with high-risk commercial ventures. While chartered by Congress, such a corporation would not depend upon congressional appropriations. Except for minor administrative expenses, it need not cost the taxpayers a dime. Like OPIC, it would pay claims from the premiums it collected. Yet the advantages created by the process of distributing extraterrestrial risk could be as real to entrepreneurs as if the Congress appropriated money.

A similar device has been suggested for the economic development of the Moon. A Lunar Economic Development Authority (LEDA) might assist in the planning of economic ventures, the management of lunar resources, the establishment of policies and standards, and the raising of funds. As part of its fund-raising responsibilities, it might provide insurance. Such a proposal is outlined in the 1999 study by David G. Schrunk et al., The Moon: Resources, Future Development and Colonization. Schrunk and his co-authors also suggest the establishment of a lunar port authority to provide transportation facilities.

The case for any of these arrangements demonstrates a fact well known to economists and business executives. Subsidies need not take the form of cash in order to be real. Any device that lowers the cost of doing business or increases profits creates a real advantage. A substantial portion of the cost of doing business in space is created by government regulations. The legal regime for outer space heretofore has been guided by the twin assumptions of common property and government control. Space resources are treated in a number of legal agreements as the "common heritage" of humankind. The regulatory framework is one that presumes government preeminence.

When prospectors began removing gold and other precious metals from the American West, they encountered a regulatory regime that made little sense relative to their needs. As a consequence, miners formed local associations that wrote and enforced appropriate rules. In many cases, public officials opposed those rules, particularly those that legitimized the claims of squatters. Over time, however, the federal government codified the voluntary arrangements, frequently in ways that recognized the original claims.

This history holds an important lesson, one raised earlier in this study. The necessity of dealing with government regulations (or the lack of appropriate ones) creates a cost to commercial firms that is as real as cash. Any effort to simplify government regulations or clarify the rights and liabilities of firms has the same effect as a subsidy. Studies of space commercialization are full of proposals for improving the regulatory

requirements for firms operating in space. As suggested in various studies, this might include improved procedures for licensing firms, realistic standards for training of pilots and crews, relevant building codes, new laws that limit the liability of firms operating in space, and edicts that appropriately define the rights of firms developing space resources.

Governments of the world may never grant title to space resources in the same manner as the U.S. Congress did with the General Mining Act of 1872. The latter, while possibly appropriate to its original objective (encouraging the risky business of terrestrial prospecting), has in the eyes of more than a few experts "led to many abuses."[23] The General Mining Act defined mining as a higher priority than other uses. It blocked the ability of the government to claim royalties for the resources extracted. It allowed people who acquired the land under the guise of mining to use it for other purposes and resulted in the degrading of scenic and other natural resources.

The commercial development of space is likely to be highly regulated, not left to the discretion of individuals as free of government control as 19th century prospectors who each possessed little more than a shovel and a mule. To the extent that government regulations impose an excessive burden on entrepreneurs already facing substantial risks and uncertainty, they retard the commercial development of space. In a similar manner, alternative regulations can be used to promote the commercial development of new products from space. A simple regulation, as a number of political scientists have observed, can be worth millions of dollars in direct subsidies.

8. Scenario #4: Expanding Human Presence

The ultimate objective for many advocates of space travel is the expansion of humanity into the cosmos. To them, the Earth is neither large nor secure enough to support a multi-billion person technological civilization. Ambitious visions of human migration abound in the minds of people who hold this point of view. Lunar hotels, orbiting space colonies and seemingly dead planets turned into habitable spheres frequently appear. Some of the visions, such as space tourism, could occur soon. Others, such as the transformation of Mars and interstellar travel, would take centuries to accomplish.

Not all human migration need occur through the activities of government agencies. In spite of the fact that nearly all human expeditions into space have been tax funded, advocates of human migration envision an important role for private enterprise. At a minimum, private firms could provide the resources necessary to sustain government-funded bases of operation. Private firms could provide the water, fuel, air, structures, and contract labor needed to maintain government research stations. Generally speaking, this would be done along the lines of current practices in Antarctica. Beyond that, private firms could operate the transportation facilities and operational bases to which tax-funded scientists and engineers ventured. Eventually, private firms might undertake the settlement of hostile lands, beginning with the construction of hotels and space mining and proceeding to self-sustaining human colonies.

From the point of view of capitalists called upon to invest private funds in such schemes, commercial space migration during the next twenty-five years seems like a fanciful dream. Risks and uncertainties are substantial and the time required to generate profits excessively long. Even space tourism, about which much enthusiasm exists, rests upon a potential market that is excessively small. As for self-sustaining colonies on some extraterrestrial body like Mars, the required investment might not produce appropriate rates of return for hundreds of years. By the criteria of risk, time, and return on investment, space migration lies well beyond the promise of alternative commercial opportunities like Earth-to-orbit transportation or commercial products from space.

Still, visionaries continue to dream. They find inspiration in the settlement history of the American West, for which difficult obstacles appeared. The attractiveness of the Western analogy inspired the title of the 1986 report of the National Commission on Space. "Pioneering the Space Frontier" invokes an image of rugged individuals settling new territory. To advocates of settlement, space is often presented as a new frontier, similar to the American West, waiting to be developed commercially. Since the model of Western settlement is often used, a review of the commercial development of the American West may suggest some of the ways in which human space migration might occur.

During the 19th century, the economy of the American West depended extensively on the ability of migrants to supply wheat, cattle, minerals, and timber to markets in the more the more populous East. Few 19th century migrants to the western United States attempted to create self-sustaining colonies. As historian Richard White notes, "there is no such thing as a subsistence logger or miner, and indeed, there are no subsistence wheat farmers."[24] Western settlements drew their profitability from Eastern markets.

Nineteenth century migrants were linked to the distant markets they served

through two principle institutions – the railroad and the telegraph. From the point of view of space migration, analogous institutions exist in the form of the spaceship and satellite communication. The latter is well developed; the former not much at all. In the American West, both institutions were established with substantial government help. In fact, the whole economy of the West depended on government aid – from government-built dams that helped to irrigate Western farms to logging roads that made old growth forests accessible.

From the base of government aid, entrepreneurs sought the help provided by private investors to provide additional funds for railroad transportation, cattle ranching, and mining. The results were often scandalous. "Many promoters found that it was far more profitable to mine investors than to mine ore," says White, "and the very word *mine*, as one Montana judge said, may have been 'almost synonymous with conspiracy to defraud.'"[25]

In the utopian vision that motivates much of the enthusiasm for space migration, hardy pioneers using advanced technologies carve self-sustaining colonies from extraterrestrial materials. Gerard O'Neill's vision of artificial space colonies located at gravitationally stable points in the emptiness of space depended not on materials shipped from Earth, but upon ingenious devices like the lunar mass driver that could shoot extraterrestrial materials to colony assembly points. Such visions are unrealistic, as fanciful as the notion that prospectors, cowboys, lumberjacks, and mountain men settled the American West because of their ingenious ability to carve the resources necessary for survival from hostile land. If commercial space settlement takes place along historic lines, it will occur as a result of a system of production and trade closely linking terrestrial and extraterrestrial economies.

How might the government encourage this, short of providing all the funds necessary to operate extraterrestrial stations? First, public officials could work toward the goal of reducing the high cost of space operations. No single act would further the cause of space migration more than the reduction of cost. This is not confined solely to the cause of creating more efficient space transportation, a process outlined earlier in this chapter. Cost reduction applies to the whole realm of space operations, from transportation to spacecraft, *in situ* material generation, and habitat technology. Transportation expenses are but a small fraction of the high cost of doing business in space.

When Gerard O'Neill developed his plans for large orbiting space colonies, he did so on the basis of calculations that set the cost of Earth-to-space transportation at about $400 per pound (in 1972 dollars), eventually falling to $100 per pound. For raw material obtained from asteroids and the Moon, transportation costs were even less. Using such figures, he calculated that the first space colony could be constructed for about $33 billion – about $10 billion more than the sum spent to send the first humans to the Moon. More elaborate models might cost up to $200 billion.

By the year 2000, O'Neill believed, a middle-class family of four could transport itself (at $100 per pound) to an orbiting space colony for the equivalent of about two year's salary. That is roughly equivalent to the outlay required for a 19th century family to traverse the Oregon Trail. Such analysis seemed to put space migration within the reach of average citizens in the industrialized world. Yet it was based on severely reduced transportation costs – $100 per pound – that were considerably beyond the

capability of existing technologies. Existing rocketry in the 1970s cost $1,000 for every pound of payload and that only paid for the journey to low-Earth orbit, not the further points where space colonies were to lie. O'Neill also conveniently failed to assign the construction cost of colonies to the first colonists, which could amount to as much as $3 million per person. Cost reduction was essential for the realization of O'Neill's vision of space colonization, requiring economies well beyond those actually achieved.

Actual transportation and hardware costs for human expeditions remain so high that they retard even the most inexpensive schemes. A severely austere expedition to Mars, organized by private explorers and employing prices derived from the International Space Station, would cost at least $30 billion for hardware plus $10 billion for transportation. That is well beyond the reach of private investors. Further reduction of transportation costs would leave such an expedition still in the $30 billion range. Were government agents to undertake the expedition, the actual price would be ten to twenty times higher given their well-known tendency to avoid risk.

The most promising strategy for reducing the high cost of space operations is likely to arise from developments in robotics. The price of a Mars expedition is reduced significantly through the deployment of automated factories designed to produce fuel and water from local resources. (All proposals for low-cost Mars expeditions are based on the assumption of some *in situ* production.) Rovers are likely to serve as precursors for human ventures, much in the same way that they precede humans into dangerous situations on Earth. The extension of automation has significantly altered production methods on remote terrestrial sites, such as those above the Arctic Circle. For example, human presence and production footprints at Alaskan oil fields are much reduced due to advances in extraction technology. To the extent that such methods are applied to space, they could produce similar advantages.

Even if costs fall, the full expense of gathering space resources and returning them to Earth is likely to exceed the market price of terrestrial alternatives for a long time. If humans move into space to construct an extraction economy soon, they will do so because government officials decide for social or political reasons to favor space resources over terrestrial ones. In the twenty-first century, justification for such policies is likely to arise from the desire to help nations free themselves from dependence on terrestrial sources, especially those located in environmentally sensitive or political unstable regions. The transition to extraterrestrial sources could be accomplished through a variety of methods – direct subsidies, price controls, tax policies, or government regulation. In essence, public officials would do in space what they historically have done on Earth. They would subsidize the commercial development of new resources.

The first human settlements in space that produce commercial benefits are likely to resemble those currently found on the harshest regions of the Earth, such as Alaska's North Slope. Workers arrive in flying vehicles. They live in dormitory-like structures manufactured in more developed regions and transported to local sites. They utilize only a few local resources, such as water and stone. Most materials, including food and clothing, are flown in. The men and women who work at such sites earn wages high in comparison to those available below, but living conditions are harsh and people frequently rotate back to more developed regions to spend their pay.

9. Scenario #5: Commercializing Science and Discovery

The modern economies of the world rest upon a foundation of classic science and discovery. Beginning with the Renaissance and proceeding through the industrial revolution, the secrets of science have provided the technological backbone for economic growth. Invention of the internal combustion engine, the radio, the airplane, and the computer, along with advances in medical science, have spawned commercial applications of enormous economic value. History provides extensive examples to support the belief that impending discoveries of similar value will propel future growth.

In spite of the commercial value that arises from them, invention and scientific discovery are hard to commercialize. The length of time between the discovery of a technology and its integration into the commercial marketplace tends to be long – often longer than private investors are willing to wait for acceptable returns. No one knows which scientific discoveries will lead to commercial applications, raising the level of uncertainty. Moreover, basic research possesses what economists call a non-exclusionary quality that makes private funding difficult. The products of basic research are hard to assign to individual consumers; when everyone benefits from an activity its producers have difficulty convincing anyone in particular to pay. Uncertainty about commercial returns joined with the non-exclusionary quality of basic research tends to favor a large government role. Governments tax their citizenry as a whole for benefits in which all share.

Most of the basic research that takes place in the United States is funded through tax dollars. In the year 2000, governmental revenues financed 51 percent of national expenditures for basic research. Industrial leaders contributed 34 percent, while colleges, universities, foundations, and non-profit institutions provided the remainder.

Governments will continue to provide substantial sums for basic research through tax dollars and annual appropriations. Does this mean that the private sector has no substantial role to play in areas of basic space research such as comparative planetology, the search for extraterrestrial life, the study of solar wind, and investigations into the origins of the universe? Not at all. A number of options exist that might help to commercialize space research.

Officials at the U.S. National Science Foundation estimate that total spending on basic research in the United States totaled $45 billion in the year 2000. About $3 billion was devoted to space science. Governmental bodies (essentially the federal government) contributed $23 billion. Industrial leaders operating through the private marketplace raised $15 billion, while academic institutions and non-profit organizations provided slightly more than $3 billion each. Commercialization means increasing the private, academic, and non-profit contribution in such a manner as to cause the aggregate total of all funds spent on basic research to grow.

Expansion of the commercial role could proceed in a number of ways. Public officials could use government funds to expand the capacity of private and non-profit institutions to participate in tax-financed space science. Public officials could take steps that encourage private firms and other institutions to increase the use of space for basic research using their own funds. Finally, advocates of commercialization might reframe the definition of space science so as to recognize commercial activities that are not

science in a traditional sense but over the past 150 years have come to be associated with exploration and discovery. Each of these approaches will be discussed in turn.

A significant portion of the money that government officials contribute to basic research is sent to institutions outside of the government, including industrial labs, non-profit organizations, and colleges and universities. Of the $23 billion that public officials allocated for basic research in the year 2000, only $3 billion was actually spent within governmental agencies. The allotment of public funds for basic research as a whole mirrors the general situation within NASA, where close to 90 percent of appropriations received goes to contractors.

With so much of the governmental contribution flowing to outside institutions, how might public officials use tax dollars to expand outside capabilities? The answer lies within a shift in philosophy. Traditionally, NASA officials have asked contractors to provide services for missions already approved, generally through a contracting process that requires some degree of competition. In 1992, public officials altered this approach by creating the Discovery Program. According to its congressional mandate, the Discovery Program was designed "to stimulate and develop small planetary or other space science projects, emphasizing those that could be accomplished by the academic or research communities."[26] Instead of bidding on existing missions, industrial firms, small businesses, universities, and government laboratories competed to win public funding for innovative proposals of their own. To receive government funds, groups making proposals had to hold overall mission costs under a strict ceiling (currently below $299 million) and promise to move from conception to launch in less than thirty-six months.

The philosophy underlying the Discovery Program mirrored a larger movement underway within the public sector. Known as the "new public management," the movement posits a new relationship between public officials and private firms. Beginning with the "quality movement" in business administration some two decades ago and moving through the "reinventing government" movement of the past decade, the new public management is organized around the precept that public officials need to “steer and not row.” The solution to every public problem need not result in the creation of another governmental bureaucracy.[27] Rather, advocates of this philosophy urge elected officials to set policy objectives and allow a variety of institutions the opportunity to fulfill the objectives. Any institution can apply – public agencies, non-profit organizations, and private sector firms. The rationale underlying this movement proceeds from the belief that competition in the pursuit of public objectives will promote cost-cutting and technological innovation to a much higher degree than the simple expansion of public agencies. It forces civil servants faced with the prospect of outside competition to alter their methods and it enhances the capability of non-governmental organizations to provide public services.

Using this approach, NASA selected between 1992 and 2002 ten projects for Discovery Program funding. Institutions competed to win the awards. The first two projects, Mars Pathfinder and Near Earth Asteroid Rendezvous (NEAR), were enormously successful. The Jet Propulsion Laboratory won funding for the Pathfinder mission as a means to demonstrate the feasibility of landing a succession of planetary monitoring stations on the Martian surface. The NEAR mission was awarded to a university-related institution, the Applied Physics Laboratory, after a competition with NASA's Jet Propulsion Laboratory. The Pathfinder team placed a lander and a

sophisticated rover on the surface of Mars for the relatively inexpensive sum of $265 million, including launch and operations. The NEAR team surveyed and landed on the asteroid Eros for $212 million.

Early success provided support for the broader effort within NASA to fashion a "faster, better, cheaper" approach to space exploration. In all, NASA officials attempted to launch sixteen projects between 1992 and 1999 using the "faster, better, cheaper" approach, of which four fell under the Discovery category. Momentum behind the broader initiative was lost in 1999 when four "faster, better, cheaper" projects failed. The protective cover on the Wide-Field Infrared Explorer (WIRE) telescope flew away, Mars Polar Lander crashed at its destination and the twin Deep Space 2 microprobes disappeared. The most embarrassing conclusion occurred after workers at the private firm constructing Mars Climate Orbiter failed to inform flight controllers at NASA's Jet Propulsion Laboratory, who were using metric units of measurement to fly the spacecraft, that the spacecraft's navigation system was constructed around English units of measurement. The resulting navigation error caused the orbiting satellite to plunge into the Martian atmosphere and burn up. Following these failures, another low-cost project was lost in 2002 when the Contour comet flyby spacecraft exploded during an early engine burn.

Disappointment with practical results of the "faster, better, cheaper" initiative retarded efforts to promote low-cost innovation through tax-funded competition. Analysis suggests that advocates of the approach attempted to accomplish too much, too fast, with too few resources inside an overall organizational culture that did not favor cost-cutting. However, within the broader realm of research and development, the philosophy underlying the "faster, better, cheaper" approach is sound. Commercial firms pressured by competition have simultaneously improved cost, speed, and quality and done so through the strategies employed within the NASA initiative – technological innovation, miniaturization, and the use of leaner management teams.

The Discovery program encouraged organizations outside the government to complete space research with public funds. People who foresee an expanding role for commercial space research want industry and other non-governmental institutions to conduct space-based research using their own funds. Many believe that this will occur as a consequence of micro-gravity research. Use of the International Space Station as a micro-gravity research laboratory is based in large part on the promise of commercial returns. To accelerate its use for this purpose, some persons have advocated that firms be allowed to carry patents on the their products for terms longer than those allowed on Earth, a type of subsidy that would help to compensate firms for the longer periods of time necessary to bring space-based discoveries into the marketplace.

Viewed from a somewhat different perspective, the private market for space research is already large and growing. The conventional view of basic research envisions teams of rather sober scientists, supported by outside funding, laboring in relative obscurity for many years in laboratory settings in search of unknown principles. This view is somewhat outmoded. Since the nineteenth century, exploration has been big business – so much so that executives in private firms and non-profit institutions have financed large terrestrial expeditions. As pointed out by one observer some fifty years ago:

Nowadays, being an explorer is a trade, which consists not, as one might

> think, in discovering hitherto unknown facts after years of study, but in covering a great many miles and assembling lantern-slides or motion pictures, preferably in colour, so as to fill a hall with an audience for several days in succession.[28]

The observation contains a touch of exaggeration, but is not entirely false. The 19th century began with two great expeditions in the tradition vein. Meriwether Lewis and William Clark commenced their expedition into the American West in 1803; Charles Darwin left port with the crew of the H.M.S. Beagle in 1831. Lewis and Clarke led a military expedition, financed by the U.S. Congress, ostensibly aimed at discovering a water passage across the continental divide but also designed to assert federal control over the American continent. Darwin volunteered as the ship's naturalist on a mapping expedition financed by the British Admiralty, serving on board a ten-gun brigantine. These two great expeditions were not unlike the Apollo missions to the Moon more than one century later, both in purpose and the nature of their funding.

The 19th century concluded and the 20th began with two great expeditions of the modern kind. In 1871 Henry Morton Stanley "discovered" David Livingston on Lake Tanganyika in central Africa. In 1911 Roald Amundsen became the first human to stand at the South Pole.

Stanley's expeditions were financed by private entrepreneurs, in particular the publishers of the New York Herald and the Daily Telegraph. His travels yielded a succession of commercially-successful books and a minor industry devoted to satisfying the public's interest in "darkest" Africa. Livingston was in Africa as a consequence of the support of a number of missionary groups associated with the Anglican church and the Royal Geographical Society (RGS). Founded in 1830, the RGS was one of the most fashionable intellectual clubs in London, whose members wielded considerable political influence. Amundsen's expeditions were part of a collection of more than fifty privately funded Arctic and Antarctic voyages. One modern analyst has suggested that the privately-funded voyages made more discoveries and required less resources than the state-sponsored ones.[29]

Expeditions such as these won favor not just for the scientific findings they produced, but also because of popular acclaim. Speaking of one leading example, Felix Driver notes that "Stanley had an unrivalled gift for self-publicity...his image, immortalized in Madame Tussaud's, was reproduced in countless advertisements selling everything from soap to Bovril."[30] These ventures represented a new form of exploration, distasteful to serious scholars but with a broader base of financial support than that traditionally provided by government sources.

A suitable environment for the appearance of privately funded expeditions arises from a combination of fantasy, financial accessibility, and concurrent government support. Works of fantasy pique public interest in the subject matter under investigation and invite private support. For example, Darwin's accurate descriptions of exotic beasts followed the precedent set by earlier traveler's journals that described strange creatures both real and imaginary. Writers had been producing books of creatures, often called bestiaries, since antiquity. Governmental support for earlier voyages demonstrated the means necessary to conduct privately funded ones, while the falling cost of travel made subsequent expeditions affordable to private groups.

In a similar vein, public interest in space exploration stands on a foundation of

fanciful exploits and government support. Percival Lowell's discovery of Martian canals, announced in a succession of commercially-successful books between 1895 and 1908, helped to inspire science fiction books by authors such as Edgar Rice Burroughs and Ray Bradbury. The concept of space exploration was so imbedded in popular culture that President John F. Kennedy chose a lunar landing as the principal means for demonstrating the technological superiority of the American system to the world.

Like sensational geography before it, space exploration has turned a multi-million dollar industry. (It could be multi-billion -- no one seems to be counting.) Commercial activities appear in art, film, television, publishing, journalism, advertising, and industrial design, propelled by membership in space clubs, space camps, and scientific societies. Unlike the history of terrestrial exploration, however, interest in the popular aspects of space has not produced any significant expeditions of a private sort. The paucity of privately funded expeditions may be due to the persistently high cost of space flight and the fact that government spending on human space flight diverged from traditional concerns after the landings on the Moon. Decline in popular interest is due in no small part to the concentration of government spending on activities such as orbital laboratories and Earth-to-orbit transport that are inherently dull. When actual activities diverge from popular interest, the industry tends to drift away. Not surprisingly, private entrepreneurs who market exotic experiences for popular consumption have moved away from realistic treatments of space exploration such as those found in the 1968 film "2001: A Space Odyssey" to more fantasy-based vehicles such as the "Star Wars" movies.

Public officials could encourage the development of privately-funded expeditions by directing government spending toward activities such as the search for extraterrestrial life or planetary rovers that build upon fantastic stories from the past. Reducing the cost of space flight and space hardware would also help. Of course, such suggestions are anathema to serious scientists and engineers, but so were the exploits of private adventurers in earlier years.

10. Conclusion

Privately funded space activities today mostly consist of satellite communications, the only large space activity of proven commercial viability. Smaller sums are generated through the private market for Earth observation and global positioning activities. The worldwide commercial launch sector has expanded at a much smaller rate than proponents had hoped. Private spending on micro-gravity research and manufacturing, space mining and resource development, satellite servicing, space infrastructure, and space tourism shows promise, but the reality hardly matches expectations. Expeditions of discovery, the search for extraterrestrial life, and probes into the mysteries of astrophysics could produce revolutionary discoveries, but these activities are stuck behind the slow-moving cart of government appropriations.

Each of these areas, even ones traditionally reserved to government agencies, could attract private investment. The history of government support for the commercial development of previous technologies suggests pathways for future commercial developments in space. Public officials have accelerated commercial demand for previous technologies like airplanes and the tractor. Properly motivated, they could do it again.

Past incentives for commercial development do not provide exact models for future space activities. The institutional and political opportunities that bubble up at one point in time evaporate in another. New legal and social constraints arise. The history of space exploration is full of unexpected and surprising developments, so one should not expect the future course of government support to be exactly like the past. Nonetheless, history provides important lessons. History recounts the techniques whose modification will likely provide models for future policies. It helps people remember how uncertain the path to commercial development of new technologies has always been and how critical the presence of government support remains. In the past, new technologies were rarely launched without government support. In the future, space entrepreneurs are unlikely do it alone.

Like so much about space, commercial opportunities are easy to visualize and hard to achieve. From the perspective of many who have studied this challenge, the chief obstacle to commercial development lies not so much with financial markets as with the government itself. Nearly one-half century of support for government-run space endeavors have created a climate not all together conducive to privately funded activities. Even a casual reading of commentaries on space commercialization reveals substantial apprehension about the capacity of existing government organizations to play useful roles.

Advocates, who for decades have pressed for completion of the classic spacefaring vision of migration and colonization, remain disillusioned with the capacity of civil servants to achieve this dream, particularly as a result of their inability to significantly lower the costs and risks associated with space transportation.

From the point of view of advocates such as these, space commercialization may occur – but if it does, it will occur with the support of governmental institutions significantly different than the ones created four decades ago to compete in the global space race. Some persons favor a broadly organized Department of Space that would combine the needs of commercial operators with the research and development

contributions of institutions like NASA. Others look to the Japanese model in which commercial and engineering activities are divided into two separate and independent government organizations. Roger Handberg, whose book on The Future of the Space Industry is summarized in the appendix to this study, suggests the creation of a Space Business Agency to handle commercial issues and a refocusing of NASA's attention on basic research and development. Still others favor the creation of a federally chartered Space Development Bank or a similar corporation that could provide loan guarantees and liability insurance. Representative Joel Hefley (Republican, Colorado) has suggested the creation of a public corporation, modeled after Comsat, that would take responsibility for developing more efficient launchers. Reestablishment of the National Space Council might provide a means for revising government regulations and promoting space commercialization. This study has examined the possibility of creating a government-chartered Outer Space Private Investment Corporation (OSPIC), modeled after a similar institution devoted to overseas private investment.

To ask the question "what roles might NASA play with regard to significant space markets that are likely to develop by the year 2025" to a certain extent misses an important component of current thinking. Another organization, not NASA, may play the critical role in space commerce. If NASA is involved, it would likely be through an institution that addresses commercial developments in ways quite different than exist today.

Concern over institutional obstacles is not confined to the NASA organization alone. The legal and political climate within which the whole government operates is not especially conducive to space commercialization. This begins with the legal regime. The accumulation of space law over 40 years of government control has favored government dominance of this realm. According to some commentators, commercial activities such as lunar mining may not just be financially risky, they may be illegal under current statutes and agreements. Ambitious commercial development of space probably will require a substantial shift in the prevailing philosophy of outer space as common property dominated by governmental entities to one in which commercial activities thrive.

Extensive proposals for rearranging the legal and regulatory regime can be found throughout space commercialization reports. Proposals for reform begin with seemingly mundane actions such as allocation of proper bandwidth for microwave energy transmissions, the creation of workable regulations for passenger transport, and extension of patent rights to match what appear to be longer commercial development times for space products. They quickly move to major issues such as the exposure of space entrepreneurs to legal liability, the clarification of property rights and mining claims for resource recovery efforts, and procedures for licensing commercial launch vehicles. Many commercialization experts favor a broad review of existing regulations, laws, treaties, and agreements by people in a single organization which has as its primary mission commercial space development. No such organization exists today.

On another level, the current political climate is not conducive to government support. Many of the institutional techniques available to people pressing for government support of previous technologies are not available to public officials attempting to promote space commerce. Consider the issue of loan guarantees. As part of the recent effort to control federal deficits, members of Congress have enacted a series of laws designed to limit the practice of what they call "backdoor spending." Supporters

of previous commercialization efforts relied upon legislative actions that created future financial obligations in the absence of current appropriations. Current legal restrictions inhibit the use of such techniques.

The modern movement toward privatization discourages a strong governmental role. Privatization encompasses a wide range of activities designed to remove what many perceive to be the heavy hand of government from civil activities. Governmental mechanisms like price regulation that enjoyed wide support in the past are now viewed suspiciously by advocates of privatization.

Frustration with the web of legal and institutional constraints has led some commentators to suggest that the best policy would be for NASA and the federal government to simply step aside and allow space markets to function unencumbered by government constraints. This argument is often directed against actions that require public employees to certify the worthiness of private undertakings before providing government support. Loan guarantees carry this provision. Before issuing guarantees, public officials analyze the affected business plans. In some cases, as with airline support, they have refused to issue guarantees because of what they perceive to be planning flaws. Proponents of non-interference believe that the private market is a better mechanism for picking winners and losers than civil servants employed by large and often conservative governmental institutions. They would prefer to forgo government support in exchange for the absence of governmental control.

While seemingly attractive, the notion of unfettered markets governing space commerce is unnecessarily naive. Markets are not free; they depend for their existence upon laws and regulations that govern activities like the enforcement of contracts and the protection of private property. Ultimately public officials and their business colleagues are obliged to address the legal and institutional framework for commerce, if for no other reason than the fact that the existing framework already affects it.

NASA may be well-suited to conduct some, but not all, of these support activities. The civil space agency is uniquely situated to conduct space operations and oversee the research activities associated with them. It is a national treasure. However, promoting space commerce is not its guiding mandate, nor is that activity central to its culture and heritage. As a whole, NASA is not well organized to promote commercialization. It is organized to write contracts, conduct operations, and promote research. Procurement through government contracting is not synonymous with commercial development. In business firms, procurement is just one part of the commercial process and not the dominant one. A number of business executives, along with ex-NASA Administrator James Beggs, have expressed skepticism about NASA's ability to incite the expansion of commercial activities in space.

Whatever institutional forms emerge in the 21st century are not likely to resemble NASA in its original form, not if people want space commerce to grow three-fold with government help. For forty years, NASA officials and their supporters have fought to obtain sufficient tax-based appropriations to keep their dreams alive. If those dreams are to be realized in the 21st century -- if humans are to significantly extend their presence and commercial activities throughout the solar system -- this will occur through more than tax dollars alone. The vast number of activities likely to take place in space during the 21st century will occur as a result of consumers reaching for their wallets rather than citizens signing their tax forms. This will require government institutions, to use a phrase

from history, devoted to the principle of doing just enough to encourage private firms to engage themselves in the business of space.

Appendix
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Abstracts: Government Roles

Generic Works

Aaron Wildavsky and Naomi Caiden, The New Politics of the Budgetary Process, 3rd ed. New York: Longman, 1997. The late Aaron Wildavsky, a well known political scientist at the University of California at Berkeley, published the first edition of this classic work in 1964. The latest editions are an excellent place to gain understanding of the changing manner of government support for national activities.

The 1964 edition described a stable system of traditional budgeting in which congressional committees appropriated tax dollars through an incremental decision making process that focused attention on small changes in the previous year's base. Most agencies received funds through this process. Over forty years, as Wildavsky (and subsequently co-author Naomi Caiden) revised the book, the federal budget process changed. As the authors state in the 1997 edition, the old system of incremental budgeting "belongs to a bygone era" (1997, p. 43).

Recent editions recount the methods that agency heads and their congressional supporters use to circumvent the annual process of discretionary review. The authors describe the expansion of entitlements and indexing, techniques that require mandatory spending for an increasingly large share of the federal budget. (Wildavsky and Caiden estimate that slightly more than half – 52 percent – of the federal budget is devoted to mandatory entitlements.) They describe the rise of federally assisted credit activity (over 1 trillion dollars by 1985), 90 percent of which does not appear in the federal budget. They record the increasing segregation of defense expenditures from traditional appropriation review. The traditional system of incremental review for domestic spending, though never large, now affects less than 18 percent of the federal budget.

NASA's annual appropriation is guided almost entirely by traditional incremental review. As such, supporters of NASA activities are forced to battle over an increasingly diminished share of federal fiscal activity. The decision on whether to join the majority or remain under the old system is fairly simple, the authors maintain. It boils down to a question of "whether you would like more or less" (1997, p. 208).

Railroads and the Use of Land Grants

Carter Goodrich, Government Promotion of American Canals and Railroads: 1800 – 1890. Westport, CN: Greenwood Press, 1960. Throughout the 19th century, the federal government sought to encourage the development of canals and railroads by private companies, much with the same intent as public officials today who seek to encourage private investment in space. (State and local governments also supported canals and railroads on a scale that often exceeded federal activity.) The means by which public officials accomplished this were varied, but were generally designed to reduce the amount of venture capital that private entrepreneurs needed to raise in order to build a particular railroad line or canal. In most cases, the federal government granted tracts of public land along proposed lines. Companies could secure bonds based on the value of

the land, which was expected to appreciate rapidly once lines were built. With the line complete, companies could sell the land to settlers, repay the notes, and pocket what often turned out to be a substantial profit. The government also issued subsidy bonds. In the case of the transcontinental railroad, those bonds took the form of a second mortgage – meaning that the federal government would issue bonds, lend money to private companies, and require reimbursement only after company officials had repaid their privately-financed debt. The Union Pacific and Central Pacific railroad companies that built the transcontinental line were thus allowed to issue first mortgage bonds and sell them to private investors. In spite of relative lack of private investment, Congress held to the principle that private entrepreneurs and not federal agents ought to construct the transcontinental line. Law-makers proposed "to do enough, and only enough, to induce capitalists to build the Pacific railway" (p. 184).

Carter contrasts the American experience with that of Great Britain, where unassisted private entrepreneurs built public improvements. Railways and canals in Great Britain, he observes, ran through "settled country and…established channels of trade" (p.7). Similar facilities in America traversed largely empty territory, where the few occupants lacked both the means and the financial institutions necessary to finance their own improvements. Settlement followed construction in America and the companies promoting improvement could not expect substantial returns until settlement occurred. Under such circumstances, Carter suggests, government support for private investment naturally arose.

Lloyd J. Mercer, Railroads and Land Grant Policy: A Study in Government Intervention. New York: Harcourt Brace Jovanovich, 1982. Government support for space commerce is controversial. Many persons believe that government interference will produce more harm than good. In a similar manner, many historians and economists believe that the practice of granting public lands to private firms constructing 19th century railroads benefited individual entrepreneurs more than society as a whole. In this provocative study, Mercer uses data on investment rates of return to dispute this popular thesis.

Mercer suggests that members of Congress and various state legislators sought through the land grants to improve economic efficiency. In practical terms, legislators supported land grants "because of the immeasurable economic gains that they saw accruing to the nation from the operation of the railroads" (p. 4). As a correlary, most believed "that railroad construction would never occur or would be far slower in the absence of government assistance" (p. 4).

Mercer tests this point of view by examining rates of return on investment for seven major railroad lines. Data on three of the railroads (Northern Pacific, Sante Fe, and Canadian Pacific) clearly support a finding of economic efficiency. Private rates of return to investors in the absence of government assistance were less than the opportunity cost of capital. For two of the lines, rates of return climbed past opportunity costs once land grants occurred. For the third, what Mercer defines as the social rate of return clearly exceeds the opportunity cost of capital, as was the case for all three lines.

In four of the seven systems, economic data support the commonly proffered argument that the railroads were "built ahead of demand" (p. 147) – namely that land grants encouraged the development of this new technology before the time it would have

otherwise occurred. The other three systems (the Great Northern railroad and the Central Pacific and Union Pacific lines that formed the first transcontinental railroad) were so profitable that they would have produced favorable rates of return even in the absence of government aid.

From a strictly economic point of view, land grants might not have been the most efficient incentive to encourage private parties to build these railroad lines. The impact of land grants varied considerably from line to line and probably were not required for at least one of the undertakings (Great Northern). Given that the government owned vast tracts of land and that the courts likely would have held other forms of aid to be unconstitutional, "the policy of land grant aid was politically feasible whatever its other shortcomings" (p. X). Land grants accelerated the economic development of railroads which in turn expedited the settlement of the American West. Without aid, the construction of specific railroad lines might have occurred later or not at all.

Stanley L. Engerman, "Some Economic Issues Relating to Railroad Subsidies and the Evaluation of Land Grants," Journal of Economic History 32 (June 1972) 443-463. The economic effect – and wisdom – of providing federal land grants to encourage railroad construction has been extensively debated in contemporary times. A "land grand legend" justifying the practice has been respectively buried and resurrected as new scholarship has appeared. Popular justification of the practice of making land grants to transportation companies flows from the concept known as "building ahead of demand." In a similar fashion, much of the justification for government intervention in support of space commerce is based on the premise that investment will by necessity precede demand.

The image conveyed by this concept, both for railroads and outer space, is one of nearly empty wilderness into which the introduction of facilities makes possible future settlement and demand. In economic terms, railroad builders sought to produce a shift in the demand for railroad services by increasing supply of the same.

Regrettably, the legend does not hold up well in the presence of modern economic concepts. "Land might have been politically the cheapest way to provide a subsidy, but it was clearly not economically the most efficient" (p. 452). Engerman sides with neither defenders nor debunkers of the practice. He doubts the premise behind the case for "building ahead of demand" (settlement did not lag as much as the model requires) and suggests that even if the premise was true, land grants would not have proven effective in overcoming the paucity of demand. This does not mean that land grants were worthless as development tools. Rather, Engerman suggests that subsidies might have been workable on other grounds (risk avoidance and investor uncertainly figure prominently).

The article demonstrates the manner in which economic concepts can be used to analyze non-monetary aid for new technologies – and how such analysis may ultimately prove irrelevant. More than a century after the land grants occurred, economists like Engerman still debate how to analyze the economic effects involved, while railroad construction and the land grants that accompanied them are long since done. A similar process may affect space. One hundred years after space commercialization occurs, economists may debate the wisdom of the government support that expedited it, while the commercial activity moves on.

Merchant Marine: the power of government regulation

Gerald R. Jantscher, Break upon the Waters: Federal Aids to the Maritime Industries. Washington: The Brookings Institution, 1975. Since the administration of President George Washington, government officials in the United States have sought to maintain a domestic maritime industry of privately owned ships and ship building capability that is far larger than the private market would alone produce. As Gerald Jantscher points out in Break Upon the Waters, no U.S. commercial activity has a longer history of government support. The variety of methods used to support seagoing transportation provide a catalog of means that might be used to support a strong commercial presence in space.

Government support for the U.S. maritime industry takes many forms, much of it of a non-monetary nature. In particular, the history of federal support provides a vivid demonstration of the way in which government officials use regulatory policies to promote particular technologies. Those policies have the effect of restricting trade to favored technologies (in this case American shipping) or group of firms that produce it. Many nations, including the U.S., rely on "cabotage laws." In the United States, these laws restrict shipping between domestic ports to vessels constructed by domestic shipbuilders and registered under the U.S. flag. Another set of laws requires that a certain proportion of government cargoes bound for foreign destinations, such as agricultural aid, move in U.S. ships. Jantschler estimates the value of these regulations to the U.S. shipping industry for the years 1950 to 1970. Cabotage laws, he writes, created a subsidy worth about $3 billion while preference laws created value approaching $5 billion. The $8 billion advantage is the equivalent of one-third the whole cost of NASA's Apollo expeditions to the Moon.

In addition to regulatory assistance, the U.S. government has granted special tax relief to domestic shippers. U.S. ship owners who invest a proportion of their earnings in new ships or equipment delay the onset of tax payments on those earnings. Since the ship owners need pay no interest on those funds, the tax deferral effectively constitutes an interest free loan. Historically, the U.S. government has also provided direct payments or subsidies to its maritime industries. Domestic ship owners can apply for a subsidy that allows them to purchase more highly priced domestically manufactured vessels (rather than less expensive foreign ships). For ships on routes deemed essential, domestic owners may apply for a subsidy that helps close the gap between the higher price of U.S. operations and foreign competition.

Nearly every conceivable type of support, including government contracts to carry the mail, have been used to further the merchant marine industry in America during the nation's 200 year history. Jantscher's book provided a detailed and readable account of them all.

Airports: Public authorities and the use of government borrowing powers to create commercial facilities

Jerry Mitchell, Public Authorities and Public Policy: The Business of Government. New York: Greenwood Press, 1992. No government institution has done more to promote the commercial development of transport than the public authority. In

the future, public officials may use public authorities to promote transportation to and from space. Mitchell has assembled a group of experts who provide a basic introduction to the use of public authorities in America.

Public authorities are widely used in the United States. The practice, which originated with the 1841 creation of a government sponsored savings bank in Australia, was first used in the United States to develop the Panama railroad (1904) and create the Port Authority of New York and New Jersey (1921). In its ideal form, the public authority is a government agency created in the form of a statutory corporation by a legislative body. The authority is headed by a governing board generally appointed by an elected executive (governor or mayor); members of the board serve fixed terms and appoint a full-time manager to run the agency. The legislature grants the institution the authority to generate revenue by charging fees for the use of its facilities and to raise funds from private investors through the sale of bonds backed by the revenues those fees generate.

Public authorities so organized are insulated from the political interference that afflict the work of line agencies and the inconveniences of the annual appropriation process. In their purest form, public authorities have neither the power nor the need to tax and do not receive annual appropriations from the governments that create them. As initially conceived, authorities "were almost immune to financial difficulties because they easily funded themselves through revenue bonds repaid by user fees" (p. 71).

The public authority approach to governmental activity is enormously popular – the author could identify some 50 national authorities and over 6,000 state and local ones. Public authorities operate ports, roads, bridges, tunnels, airports, public utilities, housing projects, hospitals, sewage treatment plants, irrigation districts, schools, economic development agencies, lending institutions, golf courses, parking garages, and sports stadiums. Practically every function of government has been touched by the authority concept.

Contributors to the book relate specific histories and discuss special issues such as political accountability. Many contributors note the recent dilution of the traditional form as its use has broadened. Elected leaders have extended the authority concept into areas not inherently self supporting, such as public transit, causing directors of such institutions to depend less upon bonds and fees and more upon the receipt of intergovernmental aid and general tax revenues earmarked from the support of their activities.

Committee on Public Administration Cases, "Gotham in the Air Age," 1950. This rare but significant monograph relates the history of early efforts to construct airports serving the New York metropolitan area. In so doing, it shows how the powers possessed within public authorities permit the expansion of commercial activities in ways not available to more traditional forms of government, such as departments and agencies. The lessons apply to space.

In 1925, when the U.S. Congress turned over the transport of air mail to privately-owned companies, New York did not possess a single adequate air field. Federal officials declined to provide the necessary funds for airport construction, leaving this task to municipalities like the government of the city of New York.

City leaders in New York, hub of the most vibrant economic activity in the nation, did not possess sufficient financial resources to undertake airport construction. The city

had exhausted its finances by completing an extensive campaign of infrastructure development. The New York State constitution severely limited the power of the city to raise funds for capital improvements through borrowing and tax levies, aggravating the city's inability to finance an improvement about whose financial viability many officials remained skeptical. As a consequence, the first airport to open in the New York metropolitan area opened not in New York but across the Hudson River in Newark, New Jersey.

New York City officials adopted a number of strategies to compensate for their shortcomings. To open a modest airstrip, city officials provided wetlands already owned by the municipality and redirected funds devoted to the construction of landfills and piers. The two municipal runways at Floyd Bennett Field, as a consequence, were constructed in 1931 by the New York City Department of Docks.

Floyd Bennett Field was too small to serve the air transport needs of the New York metropolitan area, so city officials began to press for the construction of larger facilities. This involved substantial risk, since any inability of airlines to generate revenues sufficient to repay municipal construction bonds would limit the ability of the city to subsidize the repayment of other bonds devoted to schools, hospitals, or other vital services with limited revenue streams. Airports were expected to pay their own way, but no guarantees existed that they could do so at this stage of their development.

Into this predicament stepped the Port of New York and New Jersey, a public authority, offering to take over the operation and rehabilitation of all major airports in the two state metropolitan area. Under the terms of the agreement, the Port Authority proposed to lease the airports for a fixed period of time (after which they could revert to the cities) and pay annual fees into the treasuries of the previous owners. The necessary agreements were ratified in 1947.

Port Authority officials agreed to take over this function at a time when no one knew whether the management of airports would prove profitable. The Port Authority did this because of an advantage they enjoyed relative to city governments. New York and adjoining local governments faced substantial demands for spending; public authorities – even though they possessed no taxing power – had money to spare. In the process of constructing public improvements, Port Authority officials had placed tolls on bridges, tunnels, and other revenue generating facilities. Citizen groups constantly pressed Port officials to eliminate those tolls once the debt for particular facilities was retired. Port Authority officials viewed airport acquisition as a justification for the maintenance of their revenue stream and the extensive financial reserves that tolls on previously-constructed facilities produced.

C. J. Kushell, "Operating Aspects of Revenue Bond Financing," The Journal of Finance. 10 (May, 1955) 209-22. Kushell's article explains the way in which one group of port authority executives leveraged a small amount of debt into capital significant to develop a vast transportation network. Supporters of space commerce face a similar challenge today.

In 1921 officials from the states of New York and New Jersey signed what was effectively a treaty establishing the first major public authority in the United States. The compact permitted the officers of this new authority to construct docks, bridges, tunnels, waterfront facilities, and airports as well as rail, bus, grain, and truck terminals and office

buildings. State officials acknowledged that these "facilities of commerce will require the expenditure of large sums of money" (p. 210).

The projects that Port Authority officials commonly undertook were financially marginal. "If profits were readily apparent in the operation of airports, piers, bus terminals, or similar facilities, we would have no need for a Port Authority," Kushell observes (p. 214). In that case, the private sector would provide. An official with the New York and New Jersey Port Authority, Kushell explains how this new type of government organization raised the funds necessary to undertake projects that carried financial risk without the use of direct appropriations or the power of taxation.

Even though the newly created organization had no credit, Port Authority officers decided to construct two bridges between Staten Island and New Jersey by selling special revenue bonds. To attract buyers for the bonds, officers convinced legislators in New York and New Jersey to advance the authority $2 million (one-ninth the cost of the bridges) in the form of a no-interest/no principal loan. The advance, which took the form of risk capital, was repeated for other early projects and repaid in full after the buyers of the revenue bonds had been reimbursed.

Once underway, Port Authority officers secured state authority to divert revenues from their facilities into general reserve fund, monies that otherwise would be earmarked to retire specific bonds. Port Authority executives used the reserves as security for the acquisition of new debt.

When the Great Depression arrived, revenues from some facilities proved inadequate to repay the bonds sold to finance them. In response, the Port Authority developed consolidated financial instruments – the first called a General and Refunding Bond – as a means to reduce the cost of funded debt. As the financial condition of the Port Authority improved, Port Authority officers created a number of practices that enhanced their ability to raise funds through the sale of such bonds. Officers agreed to secure new bonds through first liens on the revenues produced by all facilities, not just those to which the funds were directed. They established the expectation that net revenues would exceed maximum prospective debt service by a margin of 1.3 to one. They maintained the requirement that general financial reserves hold one-tenth the value of all outstanding debt. They adopted business like management and accounting practices designed to shield the Port Authority from political interference and obtained legislation in which the two states agreed not to intrude upon the ability of Port officials to collect transportation tolls.

The history of the Port Authority of New York and New Jersey shows how the mere creation of a public authority with borrowing power is not itself sufficient to assure financial success. It also shows how a cleverly designed financial strategy can permit governments to undertake very large expenditures without taxation or direct appropriations.

The Airline Industry: Government regulation and the purchase of services

Roger E. Bilstein, Flight in America: 1900-1983. Baltimore: Johns Hopkins University Press, 1984. The commercial development of U.S. aviation is consulted frequently by persons seeking analogies that might be employed to promote a viable transportation industry in space. Bilstein presents a general introduction to the

development of the U.S. aviation industry and the means the federal government employed to promote it. The outlook for the development of a viable commercial sector during the early years of aviation was not good. Two of the leading manufacturers of airplanes in the U.S. (the Wright and Curtiss companies) were embroiled in a legal dispute over patent rights, which retarded construction and design improvements. Aircraft orders lagged behind expectations. In spite of rosy forecasts, says Bilstein, "neither the means nor the demand to sustain a freight or passenger business existed before the [first world] war" (p. 28).

The first forces to alter this situation occurred through traditional appropriations. In 1915, the federal government ordered the creation of a National Advisory Committee for Aeronautics for the purpose of spending tax funds to discover through scientific research practical solutions to the problems of flight. The U.S. military, which entered World War I with barely more than 100 aircraft, received "the largest single appropriation for a specified purpose ever legislated in the United States" to improve its air corps (p. 36). The aviation industry, Bilstein reports "matured almost overnight" (p. 37).

Following the First World War, the most important government investments favoring commercial aviation did not involve direct appropriations. The most important development involved carrying the mail. Initially, the Post Office Department had attempted to create its own air mail service, drawing upon War Department pilots and planes. Pilots considered this early mail service as "pretty much a suicide club" (p. 53). Under the 1925 Airmail Act (known as the Kelly Act), operation of the air mail was transferred to private lines under post office contract. The following year, Congress passed the Air Commerce Act, creating an Aeronautics Branch within the Department of Commerce and empowering it to promote the airline industry and navigational aids. Airlines organized to carry the mail made room for passengers. Mail contracts provided the principal source of revenue; passenger fares provided additional but not sufficient monies to support the fledgling firms. Additional contracts for spraying, crop estimates, forest seeding, aerial mapping, and petroleum surveys – often from government agencies – supplemented revenues gathered from carrying the mail. As commercial activities expanded, airline consolidation occurred. By 1930, Bilstein reports, the "now-familiar names like American, TWA, United, Delta, Eastern, and Northwest began to appear" (p. 51).

The earliest commercial efforts at air passenger and package express "never got into the air" (p. 55). Not until the federal government provided a dependable source of revenue did the airline industry take off.

W. David Lewis, ed., Airline Executives and Federal Regulation: Case Studies in American Enterprise from the Airmail Era to the Dawn of the Jet Age. Columbus: Ohio State University Press, 2000. Government contracts dominated the aerospace business in the first few decades following the launch of the first earth-orbiting satellites. In a similar manner, most early airline companies depended for their revenue upon government contracts to perform tasks such as carrying the mail. The transition from government dependence to commerce independence was accompanied by substantial government regulation. In a fine introduction to the early history of American commercial aviation, Lewis explains how this occurred.

Most early airline owners were content to make money simply by applying for government contracts to carry mail. In 1930 Congress passed a law that altered this situation. Participating airlines were thereafter compensated for the space their aircraft devoted to mail (rather than payment by weight). This encouraged owners to purchase more voluminous aircraft that concurrently carried more passengers. A few years later the Douglas Aircraft Company introduced the 21-seat DC-3, the "first airliner ever built that could make money merely by transporting passengers" (p. 11).

According to Lewis, introduction of the DC-3 created chaos in the fledgling air transport industry. Previously an entrepreneur wanting to launch an airline first had to secure an air mail contract from the Post Office Department, where public officials used their contracting policies to promote a stable industry. Now any entrepreneur with enough money to purchase a few DC-3s could start an airline and compete to carry passengers from point to point.

Congress responded by passing the Civil Aeronautics Act of 1938, which required any airline carrying passengers or mail to secure a Certificate of Public Convenience and Necessity (CPCN) from the federal regulatory agency created by the act (the Civil Aeronautics Board or CAB). As part of this process, the CAB established rates that were uniform throughout the industry. Airlines receiving certificates for the same route thus could compete in providing speed and comfort, but were protected against price wars.

This approach, Lewis argues, was necessary to launch the commercial airline sector. Commercial flying was limited to a small group of reasonably wealthy and adventurous customers who were willing to pay substantial fares for the often unpleasant privilege of flying. Price competition would not have attracted large numbers of consumers in the early years of aviation because demand was not high.

Lewis' book tells this story through a general introduction and chapters relating biographies of early transport leaders. Ironically, the regulatory strategy adopted by law makers responding to events during Great Depression was initially conceived by the person most often blamed for it, Herbert Hoover. During his presidency, Hoover was the foremost advocate for what he called the "associative state," a civil society in which business executives would organize themselves into voluntary trade associations and cooperate with government regulators to create stable industries advancing new technologies and economic growth.

Kenneth J. Button and Theodore E. Keeler, "The Regulation of Transport Markets," Economic Journal. 103 (July, 1993) 1017-27. Following a period in which government officials used regulatory powers to stabilize the airline industry, subsequent officials have undertaken a world-wide effort toward decontrol. Button and Keeler summarize the rationale behind this trend as well as research on the effects of deregulation. They provide information not just from the U.S. experience, but from the United Kingdom and other countries as well.

The authors suggest much of the momentum behind deregulation arose from economists who were skeptical about the benefits of control. Microeconomic theory suggests that "welfare is maximized when the price of each good or service equals its long-run social marginal cost" (p. 1018). In plain terms, evidence suggested that regulated airlines and railroads were charging too much for their services, an argument bolstered by the experience of carriers operating in competitive, unregulated intrastate

markets like California and Texas. Careful observers of transportation markets in the U.S. came to conclude that regulation "was causing more economic waste than it was eliminating" (p. 1018). Additionally, economists from the conservative Chicago wing of the discipline came to doubt the value of regulation in areas where it had traditionally seemed justified. Earlier economists had justified regulation for industries where high entry costs restricted the number of providers (what are called natural monopolies) and where the adoption of new technologies required market stabilization or special inducements. Followers of the Chicago school sought to discredit these rationales, suggesting that free markets for transportation would achieve higher levels of efficiency than regulated ones.

Button and Keeler examine studies on the effect of deregulation on productivity, safety, and redistribution of money. Productivity in transport has increased. The long-run trend toward greater safety has been unaffected by deregulation while redistribution has been substantial. In general, users have gained at the expense of wage earners and some investors.

The authors call modern deregulation "an economic success" (p. 1025). They are reluctant to characterize the original period of regulation as a policy failure, however. This remains a matter of much controversy. Clearly, government deregulation occurred for what was a mature and not a fledgling technology. In a similar fashion, persons interested in space transport debate whether that industry should begin under conditions of government regulation or free market competition, especially when private demand is relatively low as it was for the services of the first air passenger companies.

Guaranteed loans: federal credit programs

William G. Gale, "Economic Effects of Federal Credit Programs." American Economic Review 81 (March 1991) 133-52. People seeking government support for commercial space activities often request credit assistance in forms such as long guarantees. Federal officials utilize credit assistance as a means of encouraging private investment in a wide variety of activities. By pledging its "full faith and credit" behind selected loans, the federal government encourages private borrowing for activities such as housing, farming, education, and small business development. Such policies create subsidies. When public officials allow borrowers to delay interest payments – or when government agencies cover defaults – they effectively create a cash transfer from the government to the affected sector. Federal subsidy costs are fairly high, Gale says. For every dollar of new private investment (beyond what would occur in the absence of a subsidy), the federal government contributes the equivalent of fifty cents.

In this paper, Gale develops a formal economic model to test the effect of federal credit programs on private investment decisions. Federal credit programs raise overall private investment only slightly – no more than 4 percent, Gale suggests. However, the programs do "exert important effects on the allocation of funds" (p. 134). In simple terms, students, farmers and other target groups gain access to funds they would otherwise not receive. Not surprisingly, the degree of reallocation arising from this access depends upon the size of the particular federal subsidy, not on the general volume of credit extended. Where specific borrowers cannot find loans, a government credit

program where the subsidy is large "can exert very strong effects, by releasing the rationing constraint" (p. 134).

With the economic model he uses, Gale is not able to judge whether subsidized credit encourages new economic activity in the targeted area. Borrowers may simply substitute one form of economic activity (such as loan-financed capital investment) for another (such as wage-compensated labor). Based on findings such as these, the value of federal credit assistance for space commercialization is not as clear-cut as it may seem.

Housing: tax incentives and loan guarantees

U.S. Congressional Budget Office, (Paul H. Houts, ed.), Assessing the Public Costs and Benefits of Fannie Mae and Freddie Mac. Washington: Government Printing Office, May,1996. Federal credit assistance for new industries is not confined to simple mechanisms like the government loan or loan guarantee. Much of the government's support for credit activities occurs through the creation of secondary markets for privately-made loans. The Congressional Budget Office explains how this process works for the nation's housing industry.

Thirty years ago, Congress chartered the Federal Home Loan Mortgage Corporation (Freddie Mac) and the Federal National Mortgage Association (Fannie Mae). Freddie Mac was a new creation; Fannie Mae had been part of the federal government since the administration of Franklin D. Roosevelt. These two federally-chartered, privately owned corporations act as intermediaries. They purchase home mortgages from lending institutions and bundle those mortgages into securities that are sold to private investors. They also borrow money for the purpose of purchasing and holding mortgages within their own institution.

By connecting banks and other institutions that lend money for mortgages to people with cash to invest, these two entities create a more robust market for home mortgages than would otherwise exist. Banks no longer have to wait for individuals to deposit funds that the banks can use for new mortgages. Using these intermediaries, banks can sell the mortgages they grant, creating a new supply of cash that can be used for more home lending.

The securities created by Freddie Mac and Fannie Mae are not guaranteed by the federal government. The two institutions enjoy certain advantages as a result of their government charter, but a pledge of the "full faith and credit" of the federal government is not one of them. In other words, if one or both of the institutions lose money, the government is not obliged to bail them out.

In spite of this fact, the advantages that these corporations enjoy – and the fact that the Congress chartered them – create a perception within the financial community that their securities "are nearly as safe as if a federal government agency had issued them" (p. x). Some of the advantages are simple; some are arcane. Earnings received by investors are exempt from state and local income taxes, a fairly straightforward proposition. More arcane is the fact that Congress has exempted the two corporations from having to register under the Securities Act of 1933, removing a regulatory burden that other private lending institutions must endure. In many respects, federal law treats the financial activities of the two institutions the same way it treats Treasury debt.

"The federal seal of approval is immensely valuable" (p. 10). The authors of this study estimate that the value of these advantages is worth $6.5 billion annually (as of 1995). That is what a fully private lending institution might pay for those advantages if the federal government marketed them for sale. Lawmakers create this value without appropriating a single dollar or backing a single security. Yet the $6.5 billion is as real as if the Congress actually appropriated the funds.

> The benefit has "no cost" to the government or taxpayers only in the same restricted sense that the government would incur no out-of-pocket cost in providing free hydropower to an aluminum producer or giving federal lands to a developer (p. x).

In creating these corporations, Congress transferred some of the federal government's credit standing to them. These benefits are not as tangible as electric power or free land, but they are just as valuable nonetheless.

Much of the report is devoted to an examination of the benefits and costs created by this ingenious device. Although they are chartered by the federal government, Fannie Mae and Freddie Mac are in fact owned by shareholders. Stock from the two corporations is traded on the New York Stock Exchange. Corporate officers receive large stock options and other incentives that encourage attention to earnings and stock price growth. The two corporations are so large, and dominate the market for home mortgages to such a degree, that the authors characterize them as duopolies (twin monopolies). As is common to the behavior of monopolies, officers within the two corporations retain for internal consumption a substantial share of the funds they handle. The authors estimate that corporate insiders absorb $2.1 billion of the $6.5 billion effective subsidy they receive, passing on $4.4 billion to the housing market.

Congress could improve upon this situation by creating a government agency with less overhead or by simply sending a $6.5 billion cash appropriation directly into the U.S. housing market. However, either of these actions would require a congressional appropriation, an action that lawmakers were loath to undertake. Instead, Congress has been content to create a federal agency (the Office of Federal Housing Enterprise Oversight) that imposes risk-related requirements on the two corporations. The requirements are designed to reduce the possibility that one or both of these government sponsored corporations might become insolvent, thereby triggering investor demands for a taxpayer-financed bailout. The federal agency, along with the involved congressional committees, create a line of political accountability designed to counterbalance the perspectives of corporate shareholders and the executives responsible to them. At the same time, such oversight strengthens the overall perception within the financial community that the federal government really does stand behind the financial activities of these unusual corporations.

Energy: the use of federal tax credits

Leonard Rodberg and Meg Schachter, State Conservation & Solar Energy Tax Programs: Incentives or Windfalls? Studies in Renewable Resource Policy. Washington: Council of State Planning Agencies, 1980. Rather than directly subsidize the commercial

development of new technologies, lawmakers often turn to tax incentives to encourage private parties to do the same. Rodberg and Schachter offer one of the few studies to summarize recent experience with tax incentives designed to encourage the growth of private markets, in this case with reference to energy conservation and alternative sources. The book mainly presents data on the states, which proves useful inasmuch as this provides a greater variety of results than an examination of federal incentives alone.

Tax incentives designed to encourage the purchase of energy conservation measures take three general forms – promises not to include such items in the base for calculating sales or property taxes, laws that allow consumers to include approved purchases as deductions from taxable income, and direct tax credits that permit consumers to deduct a proportion (ranging from 5 to 55 percent) of the cost of qualifying measures from their income tax bill.

In theory, tax incentives that reduce the effective price of a new technology by 10 percent should increase sales for that technology by 10 percent, constituting an elasticity ratio of –1.0. In a perfectly rational world, moreover, the cost produced by the tax incentive (in the form of lost government revenue) should be exceeded by the value of the technology to society (the value of energy not consumed). Thus a $1 billion tax incentive would produce more than $1 billion in energy conservation.

Rodberg and Schachter explain why this does not occur in practice. For some consumers, the tax incentive constitutes a windfall – they planned to install the device anyway regardless of whether the tax incentive had been adopted. Social factors (such as plentiful energy supply) create thresholds for the adoption of new technologies that require more incentives than produced by simple economic savings. Under such situations, the elasticity of private investment relative to tax savings is less than -1.0 (a federal study produces estimates as low as -0.3). A tax incentive that reduces the price of an alternative technology by 10 percent thus might produce an increase in sales valued at only 3 percent.

Tax incentives have been a popular choice for public officials attempting to loosen the public's grip on traditional energy sources. Rodberg and Schachter remain skeptical. They suggest that the evidence as of the date of this publication fails to show "unambiguously that these incentives have stimulated, or will stimulate, new levels of investment in energy alternatives" p. 35).

Agriculture: government price stabilization

Sally H. Clarke, Regulation and the Revolution in United States Farm Productivity. New York: Cambridge University Press, 1994. Business executives can encounter resistance to the commercial acceptance of new technologies. This most often occurs among buyers reluctant to forgo old technologies whose risks are known in favor of new technologies whose risks are not. Overcoming such reluctance is a primary justification for government intervention in private markets.

Sally Clarke provides a marvelous illustration of this process with reference to the commercial acceptance of an early 20th century technology – the farm tractor. Confronting the conventional wisdom that laments the presumed economic inefficiency of farm subsidies, Clarke argues that government regulation of agriculture during the 1930s was necessary for the diffusion of this new technology. Clarke argues that the

steep rise in farm productivity during the middle third of the twentieth century can be traced to the advent of this technology and the government regulations that supported its use by farmers previously hitched to horses and mules. Moreover, the federal government accomplished this without extensive cash outlays.

During the first three decades of the twentieth century, farm productivity increased at a rate only one-third of that experienced in the manufacturing sector. Confronted with unstable markets and diminutive cash flows, American farmers delayed the large cash outlays needed to purchase tractors and mechanical pickers. During the heart of the Great Depression, tractor purchases increased more than eight-fold and farm productivity surpassed that of manufacturing by 50 percent. Using economic data drawn from the mid-western corn belt, Clarke analyzes why farmers adopted tractor technology at rates that varied from the levels predicted by an analysis that focuses only on competitive markets and potential cost savings.

During the 1930s, the federal government intervened in agricultural markets in three significant ways. Prior to that time, government intervention consisted largely of land grants and research support in forms such as the Extension Service and the Land Grant University. With the advent of the Great Depression, Congress provided government backing for low-interest loans that farmers could obtain at less than market rates, helping farmers secure credit and avoid foreclosure. The federal government adopted a number of policies designed to restrict farm output and thus restrain commodity price decline. Finally, federal officials established a corporation with the power to lend farmers money based on the cash value of the crops they produced.

Under the latter initiative, which had the most pronounced effect, farmers could effectively sell their crops to the federal government whenever the price of their products fell below adequate levels, then buy them back when prices rose, paying a modest interest charge for the transaction. In the event that prices for a particular commodity never rose, farmers could simply default on the loans, keeping the cash that the federal government had lent in exchange for the original product.

In its formative years, this system of agricultural stabilization required very small monetary appropriations by the Congress. Even when farmers defaulted on their loans, the governing corporation found a way to avoid a congressional bailout. Corporation officers went into financial markets and borrowed funds on the value of the crops they then owned. With the depression raging, law-makers by necessity had to find non-appropriation strategies to finance market stabilization.

In the long-run, farmers paid for the productivity gains fostered by these policies in an inconvenient way. Clarke traces the manner in which the large capital costs of modern farm technology required production units of increasing size, driving small farms and poorly capitalized farmers out of business some forty years after stabilization began.

Miscellaneous

Alfred Runte, National Parks: The American Experience, 2nd ed. Lincoln: University of Nebraska Press, 1987. Many people believe that tourism will provide substantial revenues for commercial operators in space. Nearly one hundred years ago, government officials and railroad owners forged a coalition that vastly expanded public use of unsettled areas – America's wilderness areas. The consequential use, particularly

by people in their own vehicles, were not those exactly intended by the railroad executives and conservationists who provided the first public access to remote parklands.

The people who created America's national parks originally intended that the parks be preserved in their natural state, not developed with commercial activities. Initially, few people visited the parks. Preservationists recognized that the protection of wilderness depended upon their ability to enlist an enthusiastic clientele. The few thousand hikers who visited places like Yosemite Valley in the early twentieth century hardly counterbalanced the millions of city dwellers who needed mountain resources like water reservoirs and electric power dams. City leaders dismissed preservations as "selfish 'nature cranks' and traveling elitists" (p. 89). To enlarge support for the park movement, preservations agreed to the construction of roads, hotels, and tourist facilities. Says Runte: "preservations clearly preferred roads, trails, hotels, and crowds to dams, reservoirs, power lines, and conduits" (p. 91).

Congress would not provide the Interior Department with funds to complete such facilities, however. In fact, the Congress did not even create an agency (the National Park Service) dedicated to the management of parks until 1916, twenty-five years after the first parks were set aside. Lacking access to government funds, preservations turned to the railroads. Motivated by what one commentator called "enlightened selfishness," railroad executives promised to assist park managers by constructing hotels, roads, trails, and other park amenities. For example, executives for the Santa Fe Railroad extended a branch line to the south rim of the Grand Canyon where they completed the magnificent El Tovar Hotel, while executives for the Great Northern Railway assembled a series of chalets and two large hotels that served visitors to Glacier National Park. In exchange, government officials provided railroad executives with land leases, favorable concession contracts, and protection from competitors. Park tourism increased rapidly, but in a manner not anticipated by the railroads. Attracted in large part by railroad publicity campaigns, Americans in large numbers began driving primitive automobiles to the parks for the purpose of car camping. Visitation soared, creating a popular constituency for national parks and a new social phenomenon, the family vacation.

Abstracts: Future Space Markets

Existing Space Markets

U.S. Department of Commerce, Office of Space Commercialization. "Trends in Space Commerce" prepared by Futron Corporation, no date. This report provides data on the growth of space markets between 1996 and 2002, with actual data through 2000 and projected estimates through 2002. It is a basic work for people seeking to understand the scope of space commercialization. The report describes the most profitable commercial space activities: space transportation, satellite communications, remote sensing, and global positioning systems (GPS). Growth is calculated on the basis of revenue and total number of employees. Overall, the space industry has experienced growth at a rate of 16 percent per year with revenue growing from $43.71 billion in 1996 to an estimated $104.99 billion by the close of 2002. "Satellite communications dominates the industry in total revenues. GPS and space transportation are the next largest segments, respectively, followed distantly by remote sensing." (sec. 1, p. 4)

Deregulation of the telecommunication industry and the increasing demand for services such as satellite television caused the satellite communications segment to grow at an average rate of 17 percent per year. With the passage of the Satellite Home Viewer Improvement Act in 1999, all legal barriers to broadcast of local transmissions through satellite connections were eliminated. Retail subscriptions grew rapidly in 2000 as a result. Bundled offerings such as Internet access combined with television service will cause this segment to grow at or above its current rate for years to come, the authors predict. However, one component of this segment, satellite manufacturing, should experience an estimated drop in revenue between 2001 and 2002 due to a change in law that shifted responsibility for licensing equipment from the Department of Commerce to the Department of State.

Growth in commercial space transportation is subject to large fluctuation from year to year due to variance in launch schedule. Globally, the increase in this market can be traced to the inclusion of launch vehicles from the Soviet Union and China. Larger, more complex satellite communication equipment necessary to meet demand generated by the Internet has caused an increase in payload requirements. Domestically, commercial launch sites are being added and new spaceports have been licensed. Additional business generated by firms manufacturing reusable launch vehicles will likely generate additional revenue, the report predicts.

Until mid- 2000, the U.S. government intentionally degraded its GPS signals. When this ended, GPS positioning accuracy improved dramatically, along with commercial opportunities in this area. Additionally, the Federal Communication Commission (FCC) now requires wireless carriers to track cell phone signals in order to accelerate response in emergency situations. This should drastically increase the demand for GPS products. The segment has grown and is estimated to continue growth at a rate of 19 percent per year.

"Key trends in remote sensing include a greater demand for high-resolution panchromatic, radar, and multispectral or hyperspectral imagery." (sec. 4, p. 1) This

segment has grown at a rate of 14 percent per year. Various governments expressed interest in using remote sensing products in resource management, military, and strategic planning. In response to the emerging international market, the White House authorized U.S. manufacturers to sell products to foreign countries. Demands in applications generated by the personal computer market have caused additional growth. This market is expected to grow rapidly in the near term.

As the space industry develops and matures, the authors of the report note, additional segments may be included in future versions of this report.

Visions of Space Commerce

United States National Commission on Space, Pioneering the Space Frontier. Bantam Books, Inc., 1986. In 1986, ex-NASA Administrator Thomas Paine chaired a commission that attempted to forecast future directions and set overall objectives for civil activities in space. The report presents an ambitious vision leading to human settlement of the solar system and includes substantial commercial opportunities. Its vision of human activities in space represents the early optimism that gripped proponents of human expansion at a time when commercial opportunities seemed extensive. The report appeared in 1986, the same year as the loss of the Space Shuttle Challenger. The Challenger accident distracted attention from Paine's recommendations and dampened much of the optimism about cheap and easy pathways into space. The report is valuable for persons studying space commerce because it projects the optimistic outlook of the pre-Challenger era.

Several commercial initiatives are detailed in the report, which as a whole emphasizes developments in space technology. Important resources such as iron, carbon, hydrogen, and oxygen could easily be mined from the moon and/or the several asteroids that orbit near earth once the appropriate infrastructure is in place. Sources of energy to meet the needs of under developed countries are in plentiful supply in space and advances in materials research are possible by working in the microgravity environment. History demonstrates that the involvement of private industry facilitates the selection of productive technologies within government sponsored programs. Therefore, the authors of the report conclude, attracting private capital is critical to the development of new space technologies. However, space endeavors are risky, high cost ventures, often requiring extensive capital investment. Large infusions of private capital are difficult to obtain. Additionally, the lag time between investment and return is long, making such ventures less attractive to savvy investors.

The book suggests several options to promote commercialization of space. Developments in space related technology would greatly reduce cost and encourage private investment. In 1986, launch insurance was a tremendous issue. Companies that might engage in independent launch activities were forced to compete against government funded launch activities making it almost impossible for private firms to enter the arena. The long term solution to this problem rests with the research and development of more reliable launch vehicles to reduce transportation costs, the authors argue. They advocate investigation of more extensive use of robotics. Robotic facilities would allow operations above the Earth to function 24 hours a day with minimum human

interaction. Finally, the report contemplates future uses for components such as shuttle tanks, which arrive in space but are not used and plunge back to Earth.

During the time that the report was written, NASA attempted to promote commercialization by signing Memorandums of Understanding (MOUs) with several large corporations. These MOUs were designed to foster partnerships between NASA and private industry that would encourage future business by reducing costs to the private company. Additionally, a Joint Endeavor Agreement (JEA) offered private companies the chance to board the shuttle free of charge for the purpose of investigating the potential for future space commerce. The report's authors note the power of the government as a large customer of commercial services. In this respect, the authors suggest that NASA operate as a "pump primer" (p. 92), stimulating space technologies in the manner that previous agencies stimulated the commercial air travel industry by providing contracts for mail transportation.

Involvement of the Departments of Defense, Commerce, State, Transportation and the Office of Science and Technology Policy dramatically complicate procedures affecting space commercialization, the authors note. Therefore, the book recommends reestablishment of the National Aeronautics and Space Council, provided for by the NASA enabling legislation. This body could act as a facilitator between the private organizations and the government agencies. The Council could resolve issues and prepare the way for private companies to operate in space by reducing the amount of time needed to start up new activities and realizing a return on investment, making space commerce far more attractive to private investors.

Tom Logsdon, Space Inc.. New York: Crown Publishers, Inc., 1988. Tom Logsdon presents another work containing much of the early optimism for a bullish future in commercial space operations. This 1988 book was inspired by a three hour conversation the author had with an inquisitive high school student. After concluding a presentation to approximately 250 people at Cape Kennedy, the author was approached by a student representing the generation likely to bring commercialization to space. The author quotes Pennsylvania Congressman, Robert S. Walker, who stated that "given the right kind of policy direction by Congress, we can create a trillion dollar space based economy by the year 2010. That would be the 1984 equivalent of 35 million new jobs. If we are serious about doing it right, we can create a $4.5 trillion economy, roughly the size of our economy today by the year 2050" (p. 222). The interested student sought to understand how this would happen and what industries could be created. The author realized how many individuals could benefit from this information and began to write this book.

The author compares the Challenger failure to the sinking of the Titanic to illustrate that a tragedy need not end economic development when profitability is probable. He begins the examination of space commercialization by discussing ventures then being pursued, then transfers focus to new opportunities still in their infancy. "Space commercialization is a highly profitable enterprise that takes advantage of the beneficial properties of space – hard vacuum, wide angle view, and microgravity" (p.13). Commercial satellites are already being pursued, Logsdon observes as he notes the wide range of information gained from satellites use. Commercial satellite opportunities include telecommunications, world wide weather prediction, data transfer, mapping and

navigation. The author discusses possibilities for privately owned launch facilities, booster rockets and the recycling of space products. Most of these are fairly well known possibilities.

Logsdon provides additional information on opportunities that have received less attention. He predicts that the best space ventures will be those that take advantage of microgravity. He suggests that the production of crystals is an important development, and notes the interest of companies like 3M in growing crystals in space. Research has revealed that higher quality crystals can be produced in space because operators can eliminate the container that on Earth causes contaminants to touch the crystal as it forms.

Logsdon notes the interest of specific corporations in other microgravity applications. John Deere had been conducting experiments involving the development of cast iron in the microgravity environment. Such research could be used to give the company an advantage by identifying new foundry operation techniques. General Motors had an interest in conducting similar research with the hope that the information could lead to the development of smaller, more effective electronic motors. Pharmaceutical companies were interested in medicines that could be made in space. In theory, chemicals could be separated more easily in space, attracting the interest of a variety of firms. With exploration and subsequent colonization of space, opportunities for advances in architecture, manufacturing and the provision of general services would emerge. Even Kentucky Fried Chicken dispatched people to study the space environment, in this case to investigate the effects of microgravity on embryos. Company officials thought that this information would be useful if animals were ever to be housed or transmitted in space – although the image of orbiting fast food restaurants tended to be symbolic of the excessive optimism that characterized this phase in the space commercialization movement. While Logsdon suggests opportunities that deserve examination and summarizes the ways in which companies might attract capital, most of the opportunities outlined in the book did not develop at the pace predicted by the author.

G. Harry Stine, Halfway to Anywhere. M. Evans and Company, New York, NY, 1996. Belief that the space shuttle would provide cheap and easy transportation motivated much of the early optimism about commercial opportunities. Loss of the space shuttle Challenger dampened that optimism. In the years following the Challenger accident, commercialization advocates revisited the need for cheap and easy access as a means for revitalizing space commerce. Stine's book provides insight into the relationship between space transportation and commercial opportunities. The book title is drawn from a 1950 statement by science fiction author Robert Heinlein: get to low Earth orbit and you are halfway to anywhere in the solar system.

Like many others, Stine insists that the price per pound of payload must decrease in order for space travel to be a routine occurrence. The search for cheaper modes of transportation is examined by the author. Ultimately, he favors sophisticated single stage to orbit vehicles (SSTOs), but in the short-term considers what he calls a Big Dumb Booster, "a large relatively cheap, extremely crude, and very "stupid" (from the viewpoint of its autopilot and other control devices) expendable single-stage-to-orbit rocket" (p. 64). He provides a detailed summary of the development of these concepts, discussing the scientific aspects as well as the political facets.

The author indicates that the Challenger accident marked the end of space development dominated by NASA. Space is the next frontier and it will be citizens rather than government agents who settle that frontier. It will be bankers, investment brokers, and venture capitalists, rather than Congress that must be approached for the capital to complete the effort (p. 204). The author provides a detailed account of what outside investors will want to know in order to support space activities. He suggests that their evaluation process will differ significantly from attempts to secure tax payer dollars.

In the final section of the book, the author addresses opportunities for space commercialization. In a fit of optimism, he quotes the Commercial Space Transportation Study final report suggesting that the sector could grow into a $3 trillion per year industry by 2003 (p. 218). For this to happen, entrepreneurs will be obliged to grapple with the difference between want and need. In commercial circles, need has far more influence over purchasing decisions than want. Consumers do not need what most firms try to sell, so firms attempt to convince them that they do. Firms can attempt to penetrate existing markets and convince consumers of their product's superiority, or they create new markets and convince consumers that the new product is something they need. For space commerce to succeed, consumers must come to accept products they previously did not need as items indispensable to modern life.

The author concludes by discussing how the space market will likely develop. He indicates that services such as "Global Express" will emerge, offering travel between continents in only minutes. This type of service will be used to generate initial revenues as more complicated services are developed, according to the author. Space tourism will follow rapidly once affordable launch vehicles appear. According to the author, the first Hilton Marriott in space will be very busy. Scientific research will develop quickly as researchers begin to exploit microgravity effects. Spaceports will develop and operate as airports, providing opportunities to extend human reach further into the void. The author predicts that within ten years of the publication of the book, we will be halfway to anywhere in the solar system.

David G. Schrunk, Burton L. Sharpe, Bonnie L, Cooper and Madhu Thangavelu, The Moon: Resources, Future Development and Colonization. Wiley-Praxis Series in Space Science and Technology. Chichester, West Sussex, England: Praxis Publishing, Ltd., 1999. The next proving ground for space commercialization beyond near-Earth orbit is likely to be the Moon. This publication provides an in depth examination of the process for colonization and commercialization of the Moon in the 21st century. The authors predict that by following a "Moon First" strategy for space development, the energy, manufacturing, communications, and transportation sectors of the economy will be well represented on the moon by 2100 AD. The book summarizes ways in which the exploration and development can by accomplished using exploration of the Antarctica region as a model.

The authors demonstrate that as Antarctica was explored and colonized, regulations and statutes were established "posteriori" or after the fact. Base camp leaders had authority with regard to governance issues. This approach, while historically the norm, is not the appropriate approach for colonization of the Moon. Serious issues involving complicated international treaties could result from a multi-national colonization effort on the Moon. Therefore, the authors recommend a "priori" approach

to governance and commercialization issues. In this situation, a lunar government would be established in advance with the goal of "facilitating the efficient, responsible and peaceful exploration and development of the Moon under the guidelines of outer space treaties of the United Nations" (p. 111). One of the first activities of the new government would be to establish a lunar port authority modeled after traditional examples such as the New York Port Authority or the Denver International Airport.

A suggested model known as the Lunar Economic Development Authority (LEDA) has been developed by the United Scientists in Space and the World Space Bar. The LEDA would handle a multitude of activities such as the planning and coordination of future development ventures, the management of lunar resources, fundraising for lunar development, and the establishment of policies and standards for lunar development. Such an organization will greatly facilitate the orderly and effective development of the Moon, the authors argue.

One of the first industries likely to develop on the Moon is energy production. The book notes this as one of the first milestones for development. A prototype referred to as the Lunar Electric Power Company provides an example of the potential opportunity for electric power generation. The book estimates that the amount of electric power necessary to run the Earth could increase ten-fold by the middle of the 21st century. Without extraterrestrial sources, demand could cause the price per kilowatt-hour to increase twenty-five fold (p. 330). Eventually, sources of lunar electricity will be able to connect to the power grid providing pollution free electricity to the Earth. Investors who purchase stock in the Lunar Electric Power Company will realize not only a financial advantage, but also a social advantage generated from the reduction of pollution produced by conventional power sources.

The authors acknowledge that to date, expensive insurance for the risky endeavors associated with exploration of the Moon remains a hindrance to development. However, exploration and colonization of the Moon is certain to occur within this century, they say. A governing body established to coordinate the efforts could facilitate exploration by supporting technological developments that ensure mission safety and investment return.

John S. Lewis, Mining the Sky. Helix Books, Reading, MA, 1996. Beyond the Moon exist commercial opportunities among the asteroids. Humans seeking to address the effects of ongoing pollution and provide resources for energy production will venture into space in search of resources, the author insists. They will go to the Moon and beyond. For this to happen, a conjunction of two schools of thought must occur. First, Lewis refers to the scientists who feel that advances in research are important at any cost. Second, he points to business managers who are most concerned with short-term economics. Through this book, Lewis attempts to provide information on the two points of view as a means to prepare the way for agreement.

Lewis states that in order for an agreement on strategy to be reached, a full inventory of the resources available on the moon and asteroids is necessary. The availability of resources is determined by the structure and development of these bodies. The geological history of the Earth is complicated while that of the Moon is short and simple. Several minerals that are sought on the Earth's surface require abundant water to arise. This is not the case on the Moon, where these elements occur naturally without

interaction with water. The author suggests that these minerals are readily available and easily extractable.

The author suggests that the process of extracting resources from the Moon will occur in several stages. The Apollo missions satisfied several requirements. The next milestone is the construction of a lunar base. The first objective of this station would be to extract resources to support life in order to enable the unit to be self sustaining. This would defer the cost associated with the project. Later, the base could generate income by exporting products such as rocket propellant and surplus energy. The author acknowledges that mining resources from the Moon, asteroids and comets requires a significant amount of capital to transport equipment into space and to return products to the Earth. He examines several scenarios by which this could be achieved economically.

The author indicates that the key to successful mining of extraterrestrial resources is the much-sought reduction in transportation costs, suggesting that a thirty-fold reduction in the present cost of moving goods to and from space would make such mining economically feasible. The author suggests that once the Moon, asteroids, and comets have been explored, the possibility for exploration of Mars must be examined. The author uses the same economic model to justify the expense associated with the project. He suggests that self sustainability of a base station is the first milestone and examines possible resources located on the Martian surface that could be used as propellant. He examines solid carbon and ozone, both of which would require a different type of rocket engine to be utilized as effective fuels.

In concluding, the author indicates that mining the sky is the first step to establishing a thriving civilization in space. In a presentation that conjures memories of the American West, Lewis suggests that space resources are abundant and available for taking and that extracting them would provide a way for space colonies to establish themselves and grow.

David P. Gump, Space Enterprise: Beyond NASA. New York: Praeger Publishers, 1990. This publication provides an interesting perspective on the relationship between space transportation and space commercialization. Where several authors indicate that the Challenger accident retarded space commercialization, Gump believes that the accident encouraged commercial development by forcing the transfer of space activities from government to private firms. Such companies, the author argues, can develop concepts faster and cheaper than the NASA bureaucracy. Prior to the Challenger accident, any firm wishing to engage in space related activities needed a contract with NASA to participate. After the accident, lack of confidence in the space program on the part of Congress and the general public strangled NASA appropriations. This created a vacuum into which private enterprise could move.

Gump acknowledges that the expense of space launches has created an entry barrier for many private firms; however, he insists that a substantial portion of the costs associated with space launches are generated by NASA overhead as opposed to equipment and fuel. By focusing missions on fewer activities, he believes that the price per mission would fall. Each space shuttle mission is designed to achieve a multitude of objectives, whereas reducing objectives would result in a substantial reduction in capital requirements. Due to the weight of bureaucratic procedures, government spending on space research is far more costly than privately-conducted research. As a consequence,

Gump suggests, the next space frontier may have to evolve from private innovation rather than tax dollars.

The author describes several opportunities that will develop in space. He focuses first on the advantages in the micro gravity environment. The 3M company was one of the first to realize that it could gain competitive advantages from microgravity experimentation. While executives at 3M were reluctant to comment on actual products that might be produced, they indicated that research was being conducted on adhesives that stick on command by manipulating molecules. A super strength plastic that does not melt when subjected to high temperatures was being developed. Work on optical crystals, 3M's first zero gravity experiment, was proceeding. Inspired by 3M's activities, General Motors and Dow Chemical were also engaged in similar research.

Medical research could benefit from the micro gravity environment as well. Universal mixing enables chemicals to merge effectively due to weightlessness. Motionless heating reduces the churn of fluids and gasses in boiling temperatures. The author speculates that cancer research could be accelerated by conducting activities in a space laboratory, where substances grow and develop in different ways. Microgravity procedures might enable patients to receive substances like new bone marrow from their own body that would combat cancer.

The Moon is a source of several resources that are in demand on Earth. Lunar dust contains oxygen, raw glass, iron, aluminum, and silicon. Such materials can be removed from the moon's surface using only 5 percent of the energy required to extract them on Earth (p. 4). At the time the book was published, three private companies were investigating the possibility of providing booster rockets and launch services that might be used to transport resources from the Moon to Earth. Reducing the price per trip to the Moon would not cause space mining and manufacturing to develop immediately, but it would stimulate the activity necessary to develop this sector, the author suggests.

Gump discusses several additional future possibilities such as advancements in the space communication sector, the development of space real estate for space stations, and the establishment of a new trade route. He believes that humans have entered a new era in which space discoveries and developments will advance civilization and that several of these opportunities will be implemented by the year 2050.

Neil Dahlstrom, ed., "Commercial Space Policy in the 1980s: Proceedings of a Roundtable Discussion," Space Business Archives, Alexandria, Virginia, July, 2000. In 1999, the NASA History Office assembled many of the principal policy-makers who helped formulated the space commercialization initiatives of the 1980s to reassess the expectations and disappointments of that decade. This publication contains a transcript of that meeting, along with copies of the major space commercialization directives and laws from that period.

Represented on the roundtable were one NASA Administrator (James Beggs), one member of Congress (Robert Walker), two White House aides (Gil Rye and Mark Albrecht), two Congressional staff members (Martin Kress and James Muncy), and one industry executive (James Rose).

The participants defined their vision of space commercialization and outlined the policy initiatives undertook in the hope of accelerating it. "Everyone meant something very different by commercialization," Muncy observed (p. 5). To some, it meant

technology spin-offs and commercial use of government facilities. To others, it meant privatization – the transfer of government functions to business firms. However, to the seven assembled for the roundtable space commerce meant space industrialization – the extension of normal commercial activities like manufacturing into the area beyond the Earth, not as a "privilege" bestowed by dominant government agencies but as the "right" of business firms to conduct commercial operations after satisfying minimal government requirements (p. 20).

Among the public policy steps undertaken in the mid-1980s to expedite space commercialization were Joint Endeavor Agreements (JEA's) between NASA and industries ready to conduct research on the space shuttle and prospective space station assured access to space (by which commercial users could predict exactly when their experiments would fly), and subsidized transportation as a means of reducing start-up costs for new endeavors. "We've subsidized the railroads," observed Jim Beggs, "We've subsidized the aviation industry. Now, we've got to spend some money and subsidize the space transportation business" (p. 17).

Expectations for commercial prospects, in the words of Martin Kress, were "euphoric." The level of interest was "going to rise so high, everyone could jump into this boat and we were all on our way" (p. 13). Companies like McDonnell Douglas and Johnson & Johnson prepared to produce space materials like Erythropoeitin and recruited their own astronauts, the U.S. Department of Commerce established a commercial space transportation office, and the Reagan administration issued a new commercial space policy. "Then someone pulled the plug out of the boat," Kress confessed (p. 13).

The immediate events precipitating the demise of the 1980s commercialization initiatives were the Challenger accident and the unplanned departure of Jim Beggs, one of the chief champions of commercial growth, as NASA Administrator. "The Challenger really changed everything," Rose observed. Corporate teams counting on assured access "had nowhere to go" and fell apart (p. 7).

In a larger sense, NASA and the government as a whole were unprepared for the philosophic shifts required by true commercialization. "NASA isn't a commercial entity," Muncy and Beggs agreed (p. 17). It is neither culturally nor historically attuned to working with industry in such a way as to promote independent commercial growth. Many of the participants agreed with Rose's statement that for space commerce to flourish, "we need to get it out of NASA into something like a quasi-government-industry organization that could work more freely with industry on a more timely basis" (p. 18).

The Vision: Business perspectives

Jonathan N. Goodrich, The Commercialization of Outer Space: Opportunities and Obstacles for American Business. New York: Quorum Books, 1989. This is a book on space commercialization from the business point of view – written by a business school professor for business executives contemplating involvement in space markets. Although more than thirteen years old, it reflects much of the skepticism that currently exists within business circles about the degree to which civil servants understand the requirements of executives seeking to launch space-related enterprises. Much of the information, such as the discussion of U.S. goals in space and the government procurement process, may seem elementary to participants in the space policy field. The book is particularly useful for its

discussion of two often under-emphasized challenges confronting executives contemplating space activities: the problem of obtaining insurance to spread the high risks involved and the various legal issues affecting corporate rights and liabilities.

Like other writers, Goodrich leads readers through the various market opportunities placed before space entrepreneurs. A full chapter on materials processing provides a substantive review of the products that have been and could be made in space and the many obstacles, such as government regulation, that force Goodrich to conclude that commercial viability is "several decades away" (p. 53). He devotes a full chapter to the commercial opportunities created by the government's desire to establish a workable missile defense system and the technologies involved. Beyond these areas of potential space commerce, Goodrich briefly assesses more exotic opportunities such as space medicine, robotics, space tourism, the business openings created by the search for extraterrestrial life, even "a cadre of new professionals called space attorneys who deal with everything from product liability for space-made products to satellite collisions and malfunctions in space" (p. 8). Overall, the treatment of these areas is balanced and factual.

Goodrich regards the challenge of space insurance as one of the most significant factors impeding private sector commercialization. Firms doing business in space require insurance for a variety of needs: to protect investments in many types of equipment and hardware, including habitats, to insure the lives of astronauts, and to protect against legal claims for the risks that passengers and tourists face. Insurance mechanisms (except those addressing a few of these needs) "are in their infancy," Goodrich proclaims (p. 114). He concludes that some type of government assistance will be necessary to overcome the potential for excessively high rates and general unavailability.

His discussion of space law provides one of the most substantive summaries in this area. Goodrich reviews major laws, treaties, and agreements through the Commercial Space Launch Act of 1984. Although dated, the discussion introduces readers to the legal issues likely to confront space entrepreneurs for some time. Lawyers will be required to resolve issues related to space insurance claims, proprietary rights, trade secrets, mineral rights, national jurisdiction over activities conducted on international space stations, patent law (both private rights and government protections), neglegence, product liability, export law, and eventually the question of which country's laws apply to criminal acts in space.

Uncertainly over the framework for resolving legal issues and the resulting deadlocks are likely to retard commercial development, Goodrich says. For example, the 1979 Moon Treaty (Agreement Governing the Activities of States on the Moon and Other Celestial Bodies) may prohibit private mining on the lunar surface. At the least, some international system for allocating rights will have to be established before resource extraction begins since the treaty prohibits private expropriation in favor of maintaining resources as the "common heritage" of humankind. Goodrich suggests a system similar to that used to govern activities on the bottom of the Earth's seas. "Space law," he concludes, "will evolve like sea law: slowly and by trial and error" (p. 146).

John L. McLucas, Space Commerce. Cambridge, MA: Harvard University Press, 1991. Five years prior to the Challenger accident, the idea of space commerce generated significant excitement. New companies as well as government backed-ventures arose to

address expected demand. After the accident, these new ventures were placed on hold. The author concludes that shifts in U.S. policy can dramatically affect space commerce and provides several historical examples to illustrate this concept. A Department of Commerce booklet, "Commercial Space Ventures" (April 1990), indicates that there are two major risks in space: market risks and technology risks, both of which are familiar because they apply to most businesses (p. 203). However, the author indicates that another risk factor is far more dangerous to space commerce. Political risks arising from government policies may be the largest barrier to financial investment in the space sector.

The book identifies space markets in such as satellite communications, spacecraft launch, remote sensing, colonization activities, and materials processing. Despite the existence of these markets, newcomers to the space commerce arena have experienced entrance difficulty in the absence of some type of government partnership such as that provided by NASA or Department of Defense contracts. Political risks are generated from this need for this collaboration. Shifts in public policy like that which occurred during the investigation of the Challenger incident can dramatically alter the viability of a small company. Without the necessary capital to sustain itself until policy shifts again, such ventures will likely fold. A new company with novel technology may never be provided the chance to demonstrate what it can do under changing conditions. The author suggests that ongoing shifts in public policy unnerves potential investors and impedes private investment in space commerce.

For large companies such as McDonnell Douglas and General Dynamics, the need to attract seed capital is not as significant an issue as for small start-up organizations. To illustrate this point, the book compares the experience of Qualcomm, a large company, with Geostar, a newcomer to the communications area. Based on the resources owned by the parent company, executives at Qualcomm founded OmniTracks, a company offering a truck tracking service. OmniTracks used satellites owned by their parent company. Geostar, a newcomer to the communications arena, had to finance placement of its own satellites into orbit in order to commerce operations. While additional revenues could be generated from the sale of transponders once the satellites were in orbit, this was insufficient to offset the original costs. The extra capital needed for Goestar dictated that the company had to attract millions of customers in order to generate a return on the investment, while OmniTracks could succeed with far fewer.

Smaller organizations also face dangers arising from changes in the regulatory regime affecting their operations. Many of these organizations have grown accustomed to government protection. Several entities such as British Telecom that had previously been run by their governments were being privatized at the writing of this book. Once privately held, these entities were no longer subject to governance by Intelsat, which stipulated, among other requirements, that such entities had to coordinate new business plans with Intelsat before initiating service that could be competitive with other members of the consortium (p. 43). Free of such regulation, larger entities could overpower smaller rivals in an unfettered market. Regardless of whether one favors government protection or open markets, the author believes that space policy has often been counter productive in the past and must be reevaluated if the U.S. is to be successful in space commerce.

Nathan C. Goldman, Space Commerce. Cambridge, MA: Ballinger Publishing Company, 1985. This early work combines traditional optimism about commercial opportunities with current-sounding skepticism concerning the degree to which government officials are prepared to help make that future occur. The author states that this book is "an alarm to wake the public in this second dawning of the space age" (p. 3). The book seeks to clarify issues pertaining to the emerging field of space commerce, concentrating on transportation, telecommunications, remote sensing, manufacturing, mining, and energy production. Ultimately, the creation of a Department of Space, which would regulate all space activities, is recommended by the author. The current state of "segmentation" or separation of space commerce into different regulatory paths may have been adequate for early commercial efforts but it will retard economic growth once the space industry matures. He favors placing all commercialization support within one organization.

As nations attempt to manage the transition commerce activities into space, Goldman argues, several existing treaties and agreements must be reviewed. For example, the International Telecommunications Satellite Consortium (Intelsat), which was founded in 1964, produced a mechanism for coordinating the activities of nations using satellites for communication. At the time, the agreement was considered a U.S. policy victory. However, U.S. companies making application to the Federal Communication Commission (FCC) for the right to develop space-based communications may find themselves in violation of international agreements. Goldman suggests that a lead agency such as the Department of Space could facilitate regulatory solutions to issues of this nature.

In addition to new international laws and regulations that will emerge, existing domestic statutes must be examined as they too will have an effect on space commerce. Anti-trust laws may have a negative effect as private companies seeking to compete globally attempt to form partnerships to share risks and costs. The author indicates that these laws must be examined carefully as they pertain to the space market so as not to handicap U.S. technology relative to other nations.

Security regulations, as dictated by the Securities and Exchange Commission (SEC), often impede the sale of stock for ventures that are deemed high risk. At the time this book was published, several companies had been denied SEC approval and were therefore unable to raise capital. As space commerce becomes less speculative, this issue may resolve itself, but it will need to be addressed in the early phases of space commercialization.

NASA has supported regulations that ensure inventors the right to receive patents for technologies developed in conjunction with the agency. This is an important issue in the attraction of private business to the space sector. The author states that careful attention will need to be paid to patent issues so as to ensure that representatives from the private sector feel secure in entering joint space development agreements with government agencies.

As more work is done in space, new issues will emerge involving domestic regulation. For example, how will pharmaceuticals manufactured in space be regulated? Will the Food and Drug Administration have jurisdiction, or should this jurisdiction be transferred to an agency such as the proposed Department of Space?

As commercial firms make the transition to space, countless new issues will evolve. The author seeks to create a framework so these issues can be quickly addressed as new challenges emerge.

Roger Handberg, The Future of the Space Industry: Private Enterprise and Public Policy. Westport, CN: Quorum Books, 1995. Handberg, a professor of political science, provides an opinionated introduction to the state of commercial space activities worldwide in which he argues that "the private sector's growth in space has been unduly stunted because the field has remained effectively the domain of the public sector," (p. 154), especially in the United States.

In some ways, the book is better read backwards, from the latter chapters to the earlier ones. In the next-to-last chapter, Handberg examines opportunities in space commerce. He reviews the potential for commercial growth in launch services, telecommunications, global position technologies, remote sensing, microgravity and vacuum-based research and manufacturing, space tourism, and energy production. In the preceding chapter, he assesses the efforts of Russia, Japan, France, Germany, and China to enter the global space market. Like other analysts, he believes that the greatest potential for space commerce lies in using space to improve conditions in global regions not yet able "to fully participate in the world economy" (p. 124) and suggests that no factor would do more to promote this growth than "sustained investment in new, more cost efficient launch technologies" (p. 149). The tone of this section is optimistic, especially his discussion of the manner in which competitors to the United States are pursuing commercial opportunities such as solar power satellites (Japan) and alternative launchers (China).

The overall tone of the book, emanating from the first half, remains less than optimistic. Handberg charges that government space policies have produced a "psychological subordination" within potential space industries, thereby retarding private sector growth. The crippling effect operates in two ways. First, the system that developed rewarded companies that met the needs of the government bureaucracy, meaning they became bureaucratic and cautious, mirroring their economic mentors. Second, the participants began to believe that nothing was truly possible without the government, either its money (mostly) or its symbolic support. (p. 44)

Handberg is especially critical of NASA's role in space commercialization. "NASA's fixation on the Space Shuttle has done the most damage to space commercialization by hampering even crippling the search for a new more cost effective launch system," he reports in one place (p. 102). The agency's interest in space commercialization, he argues, "has been lukewarm at best," observing that "commercialization requires a very different mind set than currently exists within the agency" (p. 49). Not surprisingly, his plans for the expansion of space commerce lie outside America's civil space agency. He points with interest to Japanese experience with two government space agencies – a commercially oriented one in the National Space Development Agency and the scientific programs operated by the Institute of Space and Astronautical Science. Handberg suggests a similar (though not identical) arrangement for the United States. He recommends the creation of an independent Space Business Agency, outside the Commerce or any other established department, and a refocusing of NASA's energies on basic research and development. He also expresses interest in the

proposal offered by Representative Joel Hefley for a public corporation, modeled after Comsat, devoted to the task of developing more efficient launchers.

While providing an interesting overview of the commercial space sector, the book often allows facts to follow conclusions rather than the other way. The Iridium experience with low-Earth orbit communication satellites, to which the author refers twice, can hardly be characterized as cautious. Handberg's characterization of government subsidies as a means for "maintaining obsolete technologies" ignores the role that government subsidies have played to advancing new technologies in areas including space (p. 27). Nonetheless, the book contains useful information and a provocative point of view.

Lou Dobbs, Space: The Next Business Frontier. New York, NY: Pocket Books, 2001. Lou Dobbs, well know for his endeavors as a financial journalist, wrote this book in order to publicize what he believes to be the next business frontier – investment in space. In 2001, when he wrote this book, revenues from the industry he labels "space business" had grown to more than $100 billion per year. He predicts that space activities will propel business growth in the 21st century to the same degree that Internet start-ups did in the 1990s. As a consequence of this growth, governmental roles will change dramatically. NASA backed research and development will give way to privately-backed ventures.

Government is not suited for development of space commerce, he argues. In the early stages of space commercialization, government assistance was critical. Now it interferes with commercial development because people in government, no matter how well meaning, do not think like business executives. He decries government assistance as "a dead end, however you choose to view it" (p. 140). Organizations engaged in space commerce must be free to develop through use of any model that generates profits, regardless of their social value.

Private venture capital firms such as SpaceVest will lead the way, according to Dobbs. SpaceVest is a fund with twenty portfolio companies whose activities range from remote sensing to satellite services to Space.com. Managers of this fund indicate that the first step to success involves creating a pool of educated investors who understand the risks and benefits associated with investments in space. Once Wall Street develops an understanding of the types of investments being made, more investors will flock to the sector. The author also mentions Kleiner, Perkins, Caufield & Byer as a firm that has engaged in space commerce investment. Investment in WildBlue, a start-up company that utilizes satellites to offer high-speed Internet access to its customers, brought the well known venture capital firm into the space commerce sector and lent credibility to future space ventures.

Start-up companies are reviewed by Dobbs. He feels that these companies have a strong chance for success because "in new and emerging industries, there are no ground rules and start-ups can forge their own paths" (p. 145). Dobbs believes that large companies such as Lockheed and Boeing have no incentive to generate new ideas. These companies have strong histories of developing products based strictly on client specifications, notably the government. They have few incentives to cut costs or development new products, certainly not as much as start-up companies trying to parley good ideas into profitable ventures.

In 1993, Walter Kistler founded Kistler Aerospace, a company that designs launch vehicles based on the same landing principles that were used for the Mars Pathfinder mission. Dobbs refers to this business as "the vanguard for how space business is sure to evolve." He predicts that the use of Kistler's K-1 rocket could drastically reduce the launch costs for commercial space. By 2001, the company had raised one-half billion dollars and was in need of several million more. A surprise investor, NASA, was attracted to the concept after learning of its potential success. Kistler was awarded $135 million to provide a demonstration of the concept. Dobbs mentions several other noteworthy start-ups including Kelly Space & Technology, Inc., Spacehab, Bigelow, Beal Aerospace, SpaceDev, X-Prixe, Celestis, and Startcraft Boosters.

Dobbs concludes by providing a summary of future space commerce developments such as microgravity research and manufacturing, microgravity proteins and pharmaceuticals, microgravity fluid dynamics and combustion, space based solar power, space mining, technology applications in space (MEMS), and nanotechnology. He provides a list of companies that provide additional information. This book is a well organized source of information for the reader interested in investigating the possible future of space commerce.

Space Commerce: Specific lessons and applications

D. V. Smitherman, ed., "New Space Industries for the Next Millennium." NASA/CP – 1988 – 209006. NASA Marshall Space Flight Center, December, 1998. This report, though brief, contains one of the most comprehensive summaries of potential space markets and the specific activities that would expedite their development. Participants in the 1998 workshop who produced this report identified six new space industries and a wish list consisting of some 60 recommendations that could be undertaken by government, industry, and academia.

Participants suggested that future growth in space commerce could occur through travel and entertainment, the generation of solar electric power for terrestrial use, on-orbit satellite assembly and repair, research in orbital laboratories, orbital manufacturing of materials for use on Earth and in space, and the recovery of space resources such as water and precious metals. New commercial opportunities will also exist for firms developing space infrastructures such as transportation vehicles, business parks, space utilities (such as power generation), and commercially led exploration. Potential products that might emerge from these areas range from super-pure exotic-material semiconductors manufactured in orbiting factories to space jewelry and high-fidelity telepresence devices that would allow humans to experience space while still on Earth, plus others too numerous to list.

The heart of the report consists of what the participants termed "key issues" – specific proposals that would expedite the creation of new space industries and products. Some are technological. As workshop participants observe, a key technological requirement is "affordable, dependable, and reasonably safe transportation" (p. 1). Many of the proposals are aimed at industry, such as the suggestion for a Space Chamber of Commerce, while others require joint industry-government action, such as the development of industry standards for building codes, passenger training, and crew

licensing. The most comprehensive set of recommendations are directed at government. If implemented, they would result in new institutions, new procedures, and new government policies.

Participants suggest the creation of a federally-chartered space development bank to provide financial backing, guaranteed loans, and limited liability insurance. They suggest a large number of policy incentives, including tax credits, tax holidays, tax leveraging (whereby firms could invest tax liabilities from profitable space ventures in new undertakings), anchor tenancy (government use of private space facilities), extension of patent rights (from 17 to 50 years) for products created in space, and solicitation of scientific missions from private firms.

An extensive set of recommendations are aimed at the regulatory framework affecting space commerce. "The lack of regulations, standards, and guidelines hobbles potential new commercial space activities," the report suggests. "Some standards do exist, but they are almost always in reaction to situations that have already occurred. Government policy should be proactive, creating a framework in which companies can grow and expand" (p. 12).

Among the specific regulatory reforms suggested are proposals for government regulations that limit the exposure of space firms to lawsuits, allocate proper bandwidth for power transmission, provide reasonable regulations for reentry and passenger transport, legislation that provides clear property rights and mining claims for industries developing space resources, a simplified process for licensing commercially developed launch vehicles, greater protection for proprietary information, consistent access and pricing policies for the use of government space assets, and reasonable governance, zoning, and security procedures for facilities like the International Space Station.

At the present time, participants in the workshop finally note, commercial space policies in the U.S. are carried out by at least two federal departments (Transportation and Commerce) and one independent agency (NASA). "No single Government agency has overall leadership responsibilities for developing new space industries," they observe. Perhaps new legislation is needed, they venture to say, in order to provide "an overall coordinated effort" (p. 12).

U.S. Department of Transportation and Federal Aviation Administration, "Liability Risk Sharing Regime for U.S. Commercial Space Transportation: Study and Analysis," April 2002. In the year 2000, Congress directed the Secretary of Transportation to complete a study of the manner in which commercial firms might protect themselves against liability claims arising from the risks involved in launching rockets and spacecraft. Overall, the report deals with the challenge of insuring an activity still treated as hazardous and somewhat unpredictable by insurance providers.

The general risk sharing regime for firms operating in space, in place at the time of the study, combined privately purchased insurance with government support. Under the Commercial Space Launch Act of 1988 (CSLA), commercial firms seeking a launch or reentry license were obliged to obtain insurance sufficient to cover what the Federal Aviation Administration deemed to be the maximum probable loss likely to occur from third-party liability and property damage in the event of an accident. The U.S. government assumed the liability for successful claims in excess of the maximum

probable loss, up to a set limit. Beyond that limit, the licensee or legally liable party reassumed financial responsibility.

The voluminous report analyzes a number of issues related to the process of insuring private space transportation companies, anticipating the manner in which the current system might change as launch rates increase. These include alternatives to the current risk sharing arrangement, practices in other countries with launch companies that compete with U.S. firms, and the insurance issues affecting the desire of states to license commercial spaceports. The authors of the report also assess the effect that reclassification of space launches as "ultra-hazardous" as opposed to the current designation as "hazardous" might have on the various legal precedents affecting liability.

In general, the authors of the report conclude that some sort of government-business partnership will be required to resolve liability issues for commercial launchers. The persons writing the report considered a large number of options, such as the system used by the nuclear power industry in which companies contribute to a risk pool and the system of privately obtained insurance used within the airline industry. They also examined devices such as catastrophe bonds and the use of tax credits to subsidize the cost of insurance. In general, the authors found options borrowed from other industries to be inappropriate to the business of launching spacecraft. The relatively small number of launches would render a financial pool insufficient to cover losses. Commercial airline liability emphasizes risk to passengers rather than falling debris and the involvement of foreign governments in indemnifying their space transportation carriers would place a wholly private system in the U.S. at a competitive disadvantage. The central issue in the U.S., the authors conclude, is "how much government involvement would be appropriate" (sec. 1, p. 8).

At the time the report was written, liability insurance for space launches was available at a cost that, in the view of people writing the report, did not appear to significantly diminish the profitability of the business. However, experts would not characterize the market as stable. The cost of obtaining insurance for payloads (not for liability, the subject of this report) soared from about 5 to 30 percent of insured value following a series of losses in 1986 and the amount insurers were willing to cover fell by nearly half from $100 to $60 million per launch. As in other markets, insurance premiums are subject to potentially large fluctuations. Current insurance availability for space transportation is premised upon a public-private risk sharing arrangement that could be jeopardized by the withdrawal of government support. The authors conclude that the need for government involvement is not likely to change given the small number of projected launches nor the manner in which the hazards associated with space launches are classified. In addition to presenting information and analyzing options, the report demonstrates how complex the issues associated with insuring commercial launch activities can be.

Richard M. Obermann and Ray A. Williamson, "Implications of previous space commercialization experiences for the reusable launch vehicle." Space Policy 14 (1998) 17-25. Many space enthusiasts have predicted a bullish future for space commerce. Frequently such predictions have turned out to be excessively optimistic. Obermann and Williamson, space analysts from Washington, D.C., examine the history of two space

commercialization efforts – remote sensing and expendable launch vehicles (ELVs) – in order to identify factors that impede and advance space commercialization.

For their major finding, Obermann and Williamson emphasize the degree to which opposing government policies compete to frustrate support for commercial development. Experience with privately-financed ELVs illustrates this point. During the Reagan administration, government officials transferred development rights to the Delta, Atlas, and Titan launch vehicles to private industry and Congress passed the Commercial Space Act of 1984, which provided a mechanism for licensing commercial launchers. Federal policy required NASA to purchase expendable launchers from U.S. industries and, in a move reminiscent of cabotage laws designed to protect the U.S. merchant marine, required domestic satellite manufacturers to launch a certain proportion of their payloads on U.S. launchers.

At the same time, federal officials adopted other launch policies that diluted the effect of these commercial promotion policies. Officials designated NASA's space shuttle as the nation's "primary launch vehicle" and offered launches at prices that competed directly with commercial ELVs. Under pressure from the domestic satellite industry, federal officials allowed domestic satellite makers to use Chinese, Russian and European rockets, in spite of fears expressed by leaders of the domestic launch industry that those countries would "compete unfairly on price" (p. 21).

Development of commercial remote sensing was likewise frustrated by competing government policies and one additional factor over which government officials had little control. In 1984, Congress passed the Land Remote-Sensing Commercialization Act. Federal officials turned operation of the Landsat system to EOSAT, a privately owned company, provided a subsidy, and allowed the licensing of other companies wishing to generate Earth resource data. Efforts at commercialization, according to the authors, were frustrated nonetheless. Obermann and Williamson blame the unwillingness of the government, for reasons of national security, to license satellites capable of providing high resolution images and the absence of a mature infrastructure for selling and distributing data.

The authors conclude with a series of lessons that emphasize the limitations of federal support for commercial space initiatives, especially the effort to promote a commercially derived second-generation reusable space launcher like the Lockheed Martin VentureStar. They characterize financial mechanisms such as tax incentives, government purchase orders that provide "anchor tenancy," and regulatory protection as potentially necessary but probably insufficient to spur a reusable launch industry and note that relatively uncontrollable factors such as the worldwide demand for launch services may prove decisive. In the end, the authors wonder whether commercial development might be better served by having NASA revert to its traditional role of providing research support. In any case, they warn against the dangers of having the federal government pick commercial winners before the outcome of competing commercial approaches has become clear.

Scotty Scottoline and Rich Coleman, "Effectiveness of Loan Guarantees vs. Tax Incentives for Space Launch Initiatives," a paper presented at the meeting on space technology of the American Institute of Aeronautics and Astronautics, Albuquerque, New Mexico, 28-30 September 1999, material dated August 1, 1999. Although this paper

appears in transparency form (with a two page written abstract), the issues with which it deals are so significant as to warrant inclusion on the list of essential readings. The authors deal with the challenges involved in raising funds through financial markets for new commercial space initiatives, especially privately-financed launch vehicles.

Most of the financing for private launchers will require debt – up to 80 percent of the capital requirements to design and construct workable successors to the space shuttle and smaller launch vehicles. People working in private financial markets are accustomed to providing capital for telecommunication and direct broadcasting satellites. According to the authors, these commercial applications represent "the current limit of acceptable risk for Space businesses on Wall Street" (p. 1). The downfall of the Iridium venture (established to create a telecommunication system based on low-Earth orbit satellites) has restricted the availability of private financing for satellite projects that go beyond the two commercial proven undertakings and – as the authors insist – the perceptions of financial risk for reusable launch vehicles "far exceed the risk aversion limit for commercial satellites" (p. 1). As a consequence, corporations considering new launch vehicles – especially recently-created small enterprises, face an insurmountable financial barrier. The authors report that small start-ups like Rotary Rocket were able to raise only 5 percent of the combined capital they needed to launch their designs.

Without government help, business entrepreneurs who wish to obtain loans with which to complete work on more effective launchers would have to pay 14 to 17 percent interest or higher. Even at those rates, financing might not be available because of the external perception of the risks involved. To help entrepreneurs gain access to financial markets, lawmakers have considered granting loan guarantees. However, this approach would require the government to review the business plans of potential launch providers before issuing the needed support. As a consequence, other persons have argued for a system of tax incentives wherein the government would essentially leave the companies alone.

The authors compare the relative advantages of loan guarantees versus tax incentives for a hypothetical new medium-to-heavy launch vehicle with development costs of $6.5 billion over five years. Under the loan guarantee program, the instigating industry would obtain 80 percent of its capital requirements from loans with federal guarantees covering 80 percent of the value of the loans. For tax incentives, the authors examine two types of tax credits (by which the corporation could reduce its tax payments by 20 percent) and an alternative by which the corporation would pay no taxes at all for ten years (a tax holiday).

Loan guarantees are superior to tax incentives in all cases. They are clearly superior from the point of view of the business and they are probably better for the government, depending upon the assumptions made about the likelihood of default, in the sense that they could cost the Treasury less money. Loan guarantees have the immediate effect of lowering interest rates for the instigating corporations to about 7 percent. They are the only alternative that provides an expected rate of return that exceeds the minimum set by financial markets for this type of undertaking. The 10-year tax holiday provides a slightly better return on investor equity, but that effect does not appear until well into the operational phase of the project, with the consequence that the company's cash outflow during the development phase (with a prospective tax holiday and no loan guarantee) is significantly higher.

Loan guarantees, the authors conclude, are best way to go. They help rocket companies immediately, they satisfy Wall Street lending requirements, they cost the federal government nothing if the venture succeeds, and they cost less than tax incentives so long as the probability of default remains at 30 percent or below.

U.S. National Aeronautics and Space Administration, (D. O'Neill, compiler), "General Public Space Travel and Tourism," vol. 1, Executive Summary. NP-1998-3-11-MSFC, NASA Center for AeroSpace Information, Linthicum Heights, Maryland, March, 1998. This report summarizes the findings of a two-year Space Act Agreement study sponsored by NASA and the Space Transportation Association. The study recommends that the U.S. focus attention on the development of a space travel and tourism sector and that government agencies, particularly the Departments of Commerce and Transportation, work closely with NASA to facilitate this effort. As stated by various panels and groups, such as the 1994 Commercial Space and Transportation Study and the Japanese Rocket Society, millions of people are ready to travel as tourists in space if costs can be reduced and safety and reliability assured. The authors of the report recommend how this can occur, overcoming the psychological, technological and institutional barriers that stand in the way of a healthy space tourism industry.

Study participants recommend leaders in this field begin by thoroughly evaluating the market. Many estimates have been made, several of which are mentioned in the report. As these estimates provide a basis for business design and development, they must be validated before work can begin. The report indicates that specialists may encounter difficulties achieving the needed level of validation in the presence of current launch vehicles. Obviously, vehicles capable of transporting large number of passengers will be necessary to make travel and tourism feasible. Once the market is successfully identified and adequate vehicles developed, the gradual build-out of the business can proceed. The report points out that this process is somewhat circular in that financing depends on market expansion and vice versa.

The study identifies many of the policy issues that government agencies and corporate executives must address before general space travel and tourism can actually begin. These issues are categorized as long term and short term. Short term issues include corporate formation along with government licensing and regulation. The manner in which space travel companies are organized, licensed, and regulated will be a major concern. The report looks to other extreme activities such as sky diving for ways to create a safe and streamlined regulatory process. Long term issues may involve subjects such as property rights, environmental monitoring (to check atmospheric pollutants from launch vehicles), and various business claims established by frequent use.

The findings of the two-year study, including a workshop held in 1997, are included in the report. The report provides a good summary of the barriers to a thriving space travel and tourism industry and provides specific recommendations. It recommends that governmental bodies encourage entrepreneurial activities involving space travel and tourism and that a new not-for-profit organization be created to facilitate communication between the private and public sectors. Universities that offer educational programs on travel and tourism could include space in the curriculum. Theme parks could encourage space travel by providing virtual reality opportunities. Government agencies could work closely with the private sector to reduce the risk and

cost associated with the technologies required for safe public flight. NASA program managers working to develop new launch vehicles, as well as private firms such as Boeing and Lockheed Martin, could include space travel and tourism as a possible use for the products they create.

Notes

[1] Lou Dobbs with HP Newquist, Space: the Next Business Frontier. New York: Pocket Books, 2001, p. 2.
[2] Christine Y. Chen, "Iridium: From Punch Line to Profit?" Fortune. September 2, 2002.
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