Space Industry Study

Industrial College of the Armed Forces

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Abstract

The United States has no current peer in outer space. However, past and present preeminence in space does not guarantee success in the future. Over the past three years, the ICAF Space Industry Study has followed the decline in the industry from the bubble of optimism so prominent in the late 1990s. The collapse of the market for low earth orbit (LEO) telecommunications satellites was followed by a slump in the more traditional geosynchronous (GEO) systems that is projected to continue until the second half of this decade. In this new environment, the whole range of assumptions and policies governing the relationship of the commercial and government sectors require reassessment. Broadly speaking, the government sector has reassumed its traditional role as critical anchor tenant for the industry. The events of the past year—the attack on America and the war that has followed—have reinforced that trend, both by calling more attention to military space requirements, and by further chilling the commercial space sector.

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International Field Studies

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Guest Speakers

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Mr. Damon Wells, Department of State
Ms. Kim Wells, Department of Commerce
Mr. Marc Johansen, Boeing Satellite Systems
Colonel Bob Saxer, EELV Program Manager
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Colonel Ed Bolton, National Security Council
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The Space Industry Defined

Conventionally, national space activities are defined in four sectors: civil, intelligence, military, and commercial. Obviously these sectors overlap and interact in various ways, but they share one common element: they all are derived from, and sustain, the space industrial base. With the collapse of the Soviet Union and the decline of the Russian space program, the United States has enjoyed a dominant position in space capabilities over the past decade. However, other nations have developed significant capabilities, and the space marketplace is increasingly global—both in terms of cooperation, and of competition.

Civil Sector: The civil sector primarily conducts scientific activities and basic R&D. In all national space programs, civil programs provide for technical development and some measure of government support for the industry. The civil sector also provides for multinational programs, free of security concerns that limit cooperation in other sectors of activity. Key players in the civil sector are national and international space organizations, for example:

- National Aeronautics Space Agency (NASA)
- European Space Agency (ESA)
- Japan's National Space Development Agency (NASDA)
- France's Centre National d'Estudes Spatiales (CNES)
- Indian Space Research Organization (ISRO)

Intelligence Sector: The intelligence sector gathers national security related information by conducting reconnaissance and surveillance missions from assets located in outer space. The National Reconnaissance Office (NRO) is the major player in the American space-based intelligence sector, though it operates in close cooperation with a number of "mission partners." Other nations, most notably Russia and China, have their own intelligence organizations devoted to exploiting intelligence from space.

Military Sector**:** The military sector conducts national security missions not included in the intelligence sector. Military communications, missile warning, and navigation/timing are the major functions carried out by military space based assets. America's military space capabilities have established a dominant position globally, a measure of the capability of on-orbit assets and their integration with other forces. Department of Defense provides the policy and direction for military space use. The Unified Space Command and the individual services' space commands execute a variety of military space programs. The US military is now planning upgrades for its existing constellations

and is looking toward new space-based capabilities, including the sensors for missile defense and a space-based radar system.

Commercial Sector: Private companies are the key players in the commercial space sector. However, there is rarely a clean line between the commercial firms and government. Technology normally flows from the government sector into the commercial world; commercial space operations are often closely regulated by governments; firms conducting commercial space operations in many cases are partially sustained by government programs. Our analysis also included the financial and insurance firms essential to the health of functioning of the industry.

Industry Segments

All space operations, regardless of sector, operate through a value chain based on applications—telecommunications, remote sensing, navigation/timing, and so on. The application then establishes a demand for satellite manufacture and for launch. Finally, this whole value chain is fueled by financial resources—provided by government funding for the government sectors, and by a combination of corporate funding and venture capital for commercial services.

Applications & Services: Primary applications include telecommunications, navigation/timing, and remote sensing, with all of these functions performed both commercially and by national security forces. In addition to these "dual use" functions, the government depends on space systems for missile warning.

Space-based applications have become a critical element in the global information architecture, and an essential enabler for American military operations at any scale. Cellular phones, satellite television, bank teller transactions and use of the global positioning system in cars, planes and ships are but a few of the commercial space applications that routinely affect people. Without this support from space, normally entirely transparent to its users, contemporary financial and telecommunications infrastructure could not operate.

Military applications have achieved that same level of transparency and importance. Ongoing operations in Afghanistan and elsewhere have re-emphasized the importance of the oversight, precision navigation, and instant infrastructure provided by satellites.

Satellite Manufacture: Satellite manufacture demands a high degree of engineering and manufacturing expertise, to generate spacecraft capable of operating in the space environment. The demands of design, test, and manufacture create considerable barriers to entry, both in terms of capital and human expertise, and so this is a highly concentrated sector of the industry. As a general rule, satellite technology has flowed from the government sectors into the private sector in both the American and the European space programs.

Launch Vehicles and Services: Launch vehicles provide access to space for all four sectors, and are used for both manned and unmanned missions. Launchers are conventionally considered in classes defined by their payload-to-orbit capability. As a general overview, all areas of the launch world are over-subscribed, by a factor estimated at as much as 500%. This overcapacity reflects the determination of nations to maintain their sovereign access to space, regardless of commercial consequences.

Finance & Insurance: Space operations are expensive because of complex systems that require significant up front capital investment for research, development, facilities and manufacturing. A typical satellite launch can cost over $300 million. Raising the money to launch a satellite is a daunting chore unless you are one of the few corporations or governments with the financial resources to bankroll the project internally. Private companies in the commercial sector and some nations fund their operations by raising money through stocks, bonds and by selling services.

Insurance is an absolute necessity in the space industry. The hazardous nature of space operations combined with the high cost of launch vehicles and satellites make commercial insurance very desirable but also very costly. Insurance-related costs already account for 15-20% or more of the cost of a new satellite. The rates for a launch and one year of in orbit operation have gone up 50% higher since 1999, when in-orbit coverage often extended to five years.[1]

These functions are performed in the government sectors as well, but with different players, motives, and processes. Tax dollars feed the civil, military, and intelligence sectors, which are motivated by various mission requirements rather than by the profit motives that drive commercial activity.

Factors Shaping the Industry

The health and composition of today's industry flows from two sources. First, the operating environment and access issues for all space systems shape both the huge advantages, and the equally formidable obstacles to fielding space systems. Beyond these unalterable physical factors, decisions made by policymakers and the industry over the past decade continue to shape today's industrial health and issues.

To begin at the beginning: it is expensive and risky to fly into space. Yet having achieved that, a space system is only arriving at its workplace, and only beginning to face the environmental threats to its success. Launch technology has not fundamentally changed since the beginning of the Space Age, nor is any major advance in propulsion now in sight. The conventionally quoted figure of $10,000 per pound to get to orbit offers at least a broad metric of the buy-in cost of doing business in space. A series of launch failures in the late 1990s led to increased focus on launch reliability, and for the past few years the reliability rates have improved, especially in the government sector. However, the risk will always remain, and the occasional failure can have a devastating effect on a space program and the industry. The need to minimize risk leads to extensive launch

processing campaigns, in turn feeding the cycle of expenses increasing, leading to more conservatism in risk management, leading to more testing, and so on.

That cycle also drives the on-orbit portion of a space system. Even after fifty years of space operations, reliability of on-orbit systems is an issue now, with failures occurring various families of commercial telecommunications satellites. The extremes of the space environment—temperature fluctuations, bombardment by radiation, a near-perfect vacuum, space debris, and so on, provide a rich menu of failure modes. Only extensive testing at all phases of a program can minimize risk, but these tests obviously add to the cost of the system as it matures. Those requirements, in turn, often lead to delays in deployment, cost overruns, and the most common mode of fatality among space programs: budget overruns. In the commercial sector, delays to market can be caused by any element of the value chain, and can be deadly, as competing technologies fill market niches. As technology matures, small satellites have been viewed a partial solution to this cycle, enabling faster programs, less risk per vehicle, and so on; however, they have not found a significant commercial niche.

While the satellite normally gains the most attention, it is only one of three major components to a space system. Tracking, telemetry, and control (TT&C) is necessary to maintain the health of the satellite, and a ground information architecture is necessary to take advantage of the data transmitted down from space. It is often very challenging, whether in the commercial or the government sectors, to harmonize the timing and capabilities of these components.

In the end, then, investments in money and expertise build high barriers to entry in the world of space. As a result, the industry is very confined, with few major participants and few buyers. Historically, most of the buyers have been governmental, with national security or scientific objectives. Practically all of the applications executed in space to this point have had national security implications, and so even commercial operators and builders are subject to careful government regulation in this industry dominated by dual use systems. This characteristic has been a two-edged sword for the industry. It stimulates significant government investment and anchor tenancy; conversely, it drives a government regulatory environment that can be confining and costly to the industry seeking to carve out a role in the greater economy.

What the environment takes away, though, it gives back to some extent with the unique characteristics of space systems. They enjoy overlook and a global perspective, and, depending on constellation configuration, can provide persistent presence over any region desired. For both commercial and national security users, space-based telecommunications offer "instant infrastructure," reaching users that terrestrial systems cannot. Soldiers operating in the valleys of Afghanistan and farmers in remote areas of China alike take advantage of this characteristic. Finally, space systems have enjoyed the right of overflight since the first days of the Space Age, and so can offer information on areas otherwise denied.

These fundamental physical properties of space combine with policy and market choices made over the past few years to shape today's industry. Chief among these include:

- The decline in defense production funding and R&D that followed the Cold War.
- The blossoming of competing information technologies, especially fiber, cable, and cellular communications, which forced space systems away from old market roles and denied entry to others.
- The projected boom in commercial space of the late 1990s, and its collapse with the financial stalemate of the LEO constellations. The excessive optimism on space systems left the industry with vast overcapacity in both launch and satellite manufacture capabilities, and with venture capital far harder to find than had been the case during the boom times. These effects have been magnified by the general slump in telecommunications.
- Decisions governing dual use aspects of space systems have affected both the satellite market, with export control issues, and applications, with the constraints placed on the remote sensing industry by PDD-23.
- The Rumsfeld Commission focused national policymakers' attention on space, and led to a general restructure of the military space bureaucracy. Over time this reorganization may lead to more effective resource allocation and program management for space systems, which in turn might provide for a growth in space capabilities.
- The ongoing war against terrorism has again emphasized the importance of military space systems, and has chilled the commercial sector. Cumulatively these will lead American industry to lean more heavily on the government anchor tenant in the next few years.

The Nature of the Industry

Major factors defining the industry include:

- The number of suppliers and buyers is very small. In economic terms, this is an "oligopoly-oligopsony" relationship. Barriers to entry are extremely high.

- The industry is heavily regulated by governments everywhere, both nationally and in the international arena.

- The natural economic movement toward international cooperation is often thwarted by governments seeking to sustain their domestic capabilities in critical areas, or unwilling to risk technology transfer to unfriendly hands.

- Normal market forces are sometimes overridden by other factors in this industry. As an example, the vast overcapacity in launch vehicles will remain, sustained by governments demanding their own sovereign access to space. The "invisible hand" is not only invisible—it doesn't even exist.

- Useable frequency spectrum is limited and must be coordinated with national and international users. Spectrum shortages can slow or stop satellite projects.

Over the last twenty years the issue of radio frequency management has become a limiting factor in satellite design. This useable portion of the electromagnetic spectrum extends from 3 kilohertz to 300 gigahertz. Prior to 1980, bandwidth was readily available within the useable spectrum and users simply completed paperwork to "stake their claim." Today, users must share the spectrum or not get any at all.

Within the U.S., the National Telecommunications and Information Administration answers to the President and manages spectrum for the government. The Federal Communications Commission performs a similar role for U.S. civil and commercial organizations. International spectrum allocations are managed by the United Nations through the International Telecommunications Union.

The number of satellites within the geosynchronous belt is limited due to the potential conflict of radio frequency transmissions. To avoid interference, platforms at this altitude need to maintain an orbital separation of about two degrees for Ka-band systems and even greater separation for lower frequencies. Over the last fifteen years, the geosynchronous band has become saturated. Just within the military sector, the DoD systems at GEO include Milstar, Advanced Extremely High Frequency, Defense Satellite Communications System, UHF Follow-On/wideband Gapfiller satellites, Advanced Wideband System, Global Broadcasting Service, the future Mobile User Objective System, and Space-Based Infrared System High. As of 2001, the number of satellites within the geosynchronous belt exceeded 300.

Technology transfer issues also stretch across the industry, and continue to affect the ability of US manufacturers to export goods and form multinational ventures. Export controls are used to restrict the proliferation of critical technologies and services to actors hostile to US interests. Companies must obtain an export control license from the Department of State before doing business abroad. The process as now executed continues to hamper industry. Strict export controls cost industry because they slow the licensing process, hamper competitiveness, and shelter foreign markets. On the other hand, ineffective controls in the past contributed to loss of advanced technology. Between 1992 and 1998 there were 20 cases of documented export regime violations that enabled China, Iraq, Iran, North Korea, Pakistan, and Russia to obtain controlled technology. It is a real challenge to strike the right balance between protecting the technology and facilitating competition.

The Industry Value Chain: Applications

Military Telecommunications: Shortly after the events of September 11, 2001, the Defense Information Systems Agency (DISA) assessed the bandwidth available from DoD satellites to the military in Afghanistan. It wasn't enough, so DoD had to lease transponders on commercial satellites. This decision was operationally necessary and

followed the pattern established in operations since Desert Storm—but it exposed weaknesses and issues that remain in the military-commercial relationship.

Commercial satcom providers usually will not commit to launching a new satellite until three quarters of the capacity has been "pre-sold" prior to the date of launch.[2] Experts at some of America's leading satcom facilities indicate that an even higher percentage of the satcom capacity is pre-arranged contractually before launch with the remaining amount committed soon thereafter. This doesn't leave significant extra bandwidth for the military to lease spontaneously. As a result, DISA had great difficulties acquiring extra transponders in September 2001. DISA was at a disadvantage for several reasons – DOD was competing with news agencies and other countries in the global market who were willing to sign leasing contracts for multiple years while the DOD only wanted satcom on a monthly basis. Moreover, DISA only had access to 1-year Operations & Maintenance funds and could not legally enter into contracts for months into the new fiscal year without congressional appropriations.

The expense, limited availability, and complication of turning to commercial communications during crisis have led some military leaders to reassess existing policies supporting reliance on commercial sources. However, until the next generation of milsatcom systems enters service, that reliance will remain. The 4-satellite MILSTAR constellation is only capable of transmitting 80 Mbps while a single Global Hawk unmanned aerial vehicle can consume 500 Mbps. Until the future Advanced-EHF replacement to the MILSTAR comes on-line with its capability to transmit 1 Gbps, short-term solutions to the military's bandwidth shortfall will be needed, such as the Wideband Gapfiller, a lesser robust interim solution to AEHF, Global Broadcast System, and leasing options.

Due to an earlier loss of a MILSTAR satellite, DOD committed to the purchase of 4 AEHF satellites plus one spare. DOD considered accelerating AEHF by 18 months but later agreed to have a 3-year gap from last MILSTAR and the first AEHF launch. This will place greater dependency on Wideband Gapfiller, Global Broadcast System, and leases. Wideband Gapfiller will consist of 3 satellites in geosynchronous orbit to provide X-band and Ka-band communications while augmenting the GBS. The first Gapfiller satellite will be launched in 2004 with the other 2 following in 2005.[3]

Commercial Telecommunications: This sector has been the breadwinner for commercial space since its inception in the 1960s, and continues in that role today. The broad category of telecommunications in fact represents the sum of several specific applications, in telephony, mobile services, internet services, and direct to home (DTH) television. On the whole, this sector showed healthy growth, but nothing like the explosion predicted a few years ago. That gap between projections and reality continued to play a role in the industry, slowing the movement toward new space-based applications once expected to energize the market.

With the blossoming of cable and fiber systems, space systems' role in the telecommunications infrastructure has moved into what some have called a niche role.

The long-haul telephony that was once the backbone of the industry has migrated to fiber. However, fiber has its own problems—financial, managerial, and technical. In a sense, space solutions have evolved to complement terrestrial solutions by offering "last mile" connectivity not yet available to fiber users, and filling gaps between the fiber lines. There remain large areas unserved by fiber, and these holes will continue to offer a role to space-based telephony for the foreseeable future. Over the past few years, the largely unforeseen growth in the internet has proven a valuable new market for satellite service providers. And over the past few years, television broadcasts have become the largest and fastest-growing segment of the satellite telecommunications market. Just this year, after a decade-long development effort, the XM Radio digital audio system made its debut. Its competitor, Sirius, has also established service in most of the US.[4]

Bankruptcies and failed Low Earth Orbit (LEO) systems stifled opportunities to create mobile services, internet relays, and broadband networks in LEO-based systems. A roll call of the "constellations of yesteryear" is a melancholy event: Celestri, Ellipso, Teledesic, and so on, all gone. ICO still awaits its launch. Iridium, Orbcomm, and Globalstar all reached orbit, only to declare bankruptcy later. These failures, of course, rippled throughout the industry value chain.

The United States and Europe compete vigorously for business in this industry. There are some signs that the commercial sector is going through a metamorphosis with some departures, joint ventures, mergers, and partnering. In addition to the recent bankruptcies, some companies are simply abandoning the sector. Lockheed Martin announced that it will be selling two business units associated the telecommunications sector. Part of this deal will include its stake in Intelsat.[5] This year, Lockheed announced its plans to divest its holdings in Inmarsat, New Skies NV, Lockheed Martin Global Telecommunications, and Comsat.[6]

The U.S. Federal Communications Commission halted a review of the merger between Echostar Communications Corporation and Hughes Electronics Corporation.[7] Both DirectTV and Echostar are only now becoming profitable, even with the high number of subscribers. There are more than 100,000 subscribers per month signing on to DirectTV.[8] There seem to have been dramatic improvements in the performance of local cable companies perhaps due to the competition from DTH providers. If so, it may be possible that the Department of Justice will allow a merger as long as there is competition between DTH and cable for the same customers.

The industry's top story during 2001 occurred when Societe Europenne des Satellites (SES Astra), of Luxembourg, acquired New Jersey based GE Americom for $5B.[9] SES Global now owns SES Astra, a 12-satellite operator serving Europe, thereby creating the world's largest satellite operator, ahead of Intelsat and PanAmSat Corporation.

Satellite Navigation: The U.S. Department of Defense originally created the Global Positioning System (GPS) for military satellite navigation. However, it is now widely used by companies and private citizens alike. "The aviation market grew around 10

percent, the land market grew just over 24 percent, the marine market grew 11 percent, the military and timing markets grew just under 25 percent. The land market comprised almost 62 percent of the total North American GPS revenues."[10] The U.S. GPS system is free to anyone who can purchase a receiver. Rockwell Corporation, now Boeing, designed and built the original system; Lockheed Martin is currently engaged in building replacement satellites with additional features. DOD is looking toward the next-generation GPS III system that is expected to have about 500 times the transmitter power of the current system, multiplying its resistance to jamming.[11]

Over the past year, after long deliberation the European Union and European Space Agency agreed to establish the Galileo satellite navigation system. The European community would partially fund the system through licensing fees, but the primary impetus for the Galileo program is to establish a navigation/timing capability independent of the United States. The Galileo will also provide the European space industry some equivalent of the anchor tenancy offered by US government systems to American industry. The US and Europe will have to work out issues of compatibility, signal interference, use by adversaries, and so on as the system matures.[12]

Remote Sensing: Satellite remote sensing--once the exclusive realm of the United States (U.S.) and Soviet Union--has in recent years moved from the exclusive, highly secret domain of defense and intelligence into the public and commercial mainstream.

Although defense and intelligence applications receive the most attention, there are many civil and commercial remote sensing applications. These range from urban planning, to environmental monitoring, to humanitarian response. However, the reality for the U.S. commercial remote sensing satellite industry is that its primary revenue stream comes from DoD. Developing new markets is not easy. For example, attempts to promote the use of satellite remote sensing as a useful homeland defense tool for state and local governments has drawn little interest. State and local budgets are tight and spending priorities are focused on first responders leaving few dollars for expensive satellite imagery products.[13] Similar considerations have slowed acceptance of space-based imagery in other possible markets; in addition, long-established aerial imagery firms have a strong foothold in this market and offer advantages over space solutions in many circumstances.

Beyond these market issues, the industry has been constrained by US policy in several regards. These include: license conditions, no sales to "nations of concern"; 24-hour data delay after acquisition of certain types of data; further restrictions on radar and hyper spectral licenses; case-by-case decisions on selling turnkey observation system to a foreign customer; export of sensitive technologies, and, of course, shutter control.

The Government retains the right to impose restrictions or "shutter control" as a measure of last resort on commercial imaging systems during periods when national security or foreign policy may be compromised as defined by the Department of Defense (DoD) or the State Department. Ultimately, the Department of Commerce issues shutter control decisions based on DoD and/or State Department input.[14]

After the events of 9/11, NIMA and Space Imaging entered into an "Assured Access" agreement in October shortly after the U.S. began the war against terrorism in Afghanistan. Essentially, NIMA bought all time on orbit for $1.9M per month with discount pricing for individual images it decided to purchase. Some critics considered "Assured access" shutter control. The agreement lasted two months and was not extended due to non-U.S. customer pressure on Space Imaging.

In 2001, the Defense Science Board suggested that the commercial observation satellite market would evolve rapidly with four or five suppliers with better than 1 m capability.[15] The U.S. has three firms that offer or will offer high-resolution satellite imagery: Space Imaging, DigitalGlobe, and OrbImage. All have suffered technical and financial setbacks. Global competition is now the rule. France's SPOT Image, India's IRS, and Canada's RADARSAT are international commercial satellite imagery providers. Future systems are being discussed in Germany, Japan, Israel, Russia, China, the UAE and Italy. Competition for market leadership could be intense.

The industry faces myriad problems: investment, start-up costs, funding, education, analytical capability and training. Lack of basic consumer awareness currently limits the commercial imagery satellite industry's ability to broaden its market beyond the federal government.

The Government has a long-term interest in the success of commercial imagery providers. From a direct user perspective, the commercial sector offers many capabilities that the US government and security forces could find very useful as a complement to national systems—imaging, value added analysis, and geospatial data among them. Furthermore, if the U.S. industry is not successful then foreign firms will fill the void. Proliferation of foreign competition will limit U.S. influence over the release of high-resolution data.[16] A robust U.S. industry may deter new entrants and slow development of new remote sensing capabilities by other nations. After all, with entry cost estimates of 97M$ to 497M$ (including satellite, ground segment, launch and insurance costs), the market has significant entry barriers.[17]

The industry must demonstrate more marketing savvy. The firms cannot rely solely on the U.S. and foreign governments for revenue. The industry must demonstrate the ability to produce and deliver affordable, analyzed and integrated products that have civil and commercial applicability. Producing accurate and useful information from imagery is an arena in which the U.S. enjoys a significant competitive advantage. The US has more advanced processing software, better-trained analysts and photo-interpreters than any other nation. We must allow our firms to use this advantage.

For this sector to mature, the government must reassess its policies toward commercial users, and find the funds to exploit commercial capabilities. The policies established in PDD-23 have been tested and have reached the edge of the map; it is time for a general review of national commercial imaging policy.

The Industry Value Chain: Satellite Manufacturing

The commercial satellite market continues to slump, and most people predict the slump will continue until at least 2005. The collapse of the LEO market, downturn in the U.S. economy and the terrorist attacks on September 11, 2001 have turned investors away from satellite ventures. New financing will be difficult to obtain either for new companies looking to build satellites, or existing companies looking to expand. The only companies currently making a profit are the satellite ground service providers. There is a reluctance to build new satellites, as the industry is waiting to see how consumer demand evolves.

Only a few years ago, commercial enterprises such as Iridium, Globalstar, and Orbcomm were willing to risk billions of dollars on huge multi-satellite systems before they had an established market. Those days are over. Today, no one will invest in an unproven business model involving satellites. That reluctance translated into another year's delay in the advent of long-anticipated broadband systems, and to the gradual attrition of some of these concepts—most notably Astrolink, which had appeared to be maturing technically and with a sound business case.[18]

Three U.S. satellite companies (Boeing Satellite Systems, Loral, and Lockheed Martin) have historically dominated the commercial communications satellite industry. Their European competitors are Astrium and Alcatel Space. Of these five major manufacturers, Boeing is the market share leader, with a current backlog in commercial satellites of 27 satellites, about 32% of the global total.[19] In 2000, Alcatel and Astrium received 16 orders for satellites while the U.S. firms received 22 orders. In 2001, the European companies sold just 4 satellites out of a total order for 24. While the balance of yearly contract awards has swung widely over the past three years, overall the European manufacturers have become much more formidable competitors to the US firms during this time. The export control regime established in 1998 has played some role in this swing; other factors include the weak Euro, effective marketing by the European manufacturers, and the leveling technological playing field between US and European commercial satellite industries.[20]

During the 1990s, these five prime contractors invested in production facilities to respond to customer demands for faster delivery of bigger satellites. Collectively, they can deliver approximately fifty satellites per year.[21] This number does not include the manufacturing capacity for military satellites by the U.S. industry, or the Russian, Chinese, Japanese, Indian, or Israeli vendors. Overall demand is forecast at about 200 satellites over the years from 2001–2010. The five main manufacturers have the capacity to build more than twice as many satellites as are likely to be needed during the decade. Unless new applications come along to eat up this excess capacity, we can expect to see some companies merge or even exit the industry entirely. Lockheed Martin and Loral are actively pursuing a merger. But, the European governments do not appear to support a consolidation of Astrium and Alcatel. Neither the U.S. nor any of the European governments appear to support a transatlantic merger. In short, at the moment there does not appear to exist the combination of buyer, seller, and willing government necessary to create a significant merger. Over time, though, economic pressures on the industry will place more and more pressure on its participants to seek greater efficiency.

Most of the demand is for geostationary communications satellites. The past few years have seen a general trend toward larger satellites, and to satellites with longer lives on orbit. Longer life and greater capacity translate into lower demand. On the other hand, several systems have developed systemic failure modes that have affected on-orbit lifetime and reliability. These have had serious impact on insurance costs and availability, as we will discuss shortly.[22]

In the 1st quarter of 2002, 6 new telecommunications satellites were ordered. Only 3 geostationary satellites were launched. Currently about 100 satellites are under construction with an estimated value of $11B. This is down from the peak in 2000. Projected demands for telecommunication satellites indicate that transponder demand will continue to grow from current 6,240 to 11,129 transponders in 2010. DTH Television will remain the principal application using approximately 50% of the available transponders. This will require about 175 – 200 new satellites to either replace current satellites or augment the current capacity.[23]

In summary, then, the best projections indicate that the current flat market for commercial satellites will remain until about 2005, with more systems reaching orbit during the latter half of this decade. These systems will primarily provide television, telephony, and internet services.

While the commercial telecommunications satellite market stands still, the government sectors grow more prominent in their role as anchor tenant. In both the intelligence and the military sectors, the US is undertaking modernization of nearly every constellation now on orbit. Further, as the missile defense architecture matures, the SBIRS Low constellation will provide another sizeable LEO constellation to be built, tested, and launched (assuming cost and technical issues can be overcome).[24]

Over the past year, the military space acquisition community has been shaken by the problems developing in the AEHF and SBIRS High systems.[25] Explanations for the overruns and slips in those systems range from the acquisition strategy employed, to more fundamental issues with the capability of the industrial management and workforce. In any case, both programs have survived but will remain under close watch. Cost growth in these programs has had a chilling effect on prospects for growth in military space capabilities, as funds that might have been available for new mission areas has been sunk into these programs' recovery profiles.

The study also examined smaller satellites. Advances in computer, sensing and propulsion systems have combined to shrink the size of satellite components to a previously unheard of extent. These miniaturized components have found their way into both large and small satellites. In the case of larger satellites, smaller components mean that more capacity can be built into a payload, thereby increasing cost-effectiveness and raising the reliability of the satellite by the addition of redundant transponders, etc.

Smaller propulsion and guidance systems will likely enable small satellites to find and rendezvous with other satellites to carry out repair and refueling missions. This

ability to find and locate other satellites can be readily adapted to an anti-satellite, force application mission. Future miniature anti-satellite space vehicles will not need large launchers and expensive infrastructures to reach orbit—particularly if existing aircraft can be adapted to function as a first stage. Or, they can ride as parasites on larger payloads. Likewise, the combination of small payloads with existing aircraft and missile technology means that development times for such devices may be greatly accelerated. This raises the possibility that in the very near future non-space-faring nations hostile to the United States may be able to put miniature ASATS into space thereby threatening vital, but vulnerable national security assets.

It seems most likely that these small satellites will remain in a limited economic niche in the world of space: research, some national security applications, and so on. Larger systems will continue to carry the weight of the industry for the foreseeable future.

The Industry Value Chain: Launch Vehicles and Services

Launch activity is inherently cyclical. However, 2001 was a stagnant year beyond any expectations based on business cycles, with only 16 commercial launches compared to 36 in 2000 and a global total of 60 launches. That global launch rate was the lowest since 1963. A modest recovery to a total of 75 launches, with 20 commercial launches, is projected for 2002.[26] Demand for commercial launch will remain at roughly 15-20 launches per year through 2003. US launch providers shared in the slow rate; the four US commercial launches in 2001 represented the lowest level since the Challenger disaster. A modest improvement is projected for 2002, to 8 launches.[27]

This decrease in demand has placed intense competitive stress on all players in the market, and the stress will increase in the near future, as more contenders enter an already-overcrowded field. The market forces that might have been expected to thin out these competitors will be stymied by the national requirements that will in nearly all cases keep these programs alive—however limited the launch rates.

Arianespace has successfully captured over 60 percent of the global commercial launch market and more than 50 percent of the international GEO market. Ninety percent of Arianespace revenue is derived from commercial business, and they performed 8 launches that carried 11 of the 16 commercial satellites orbited during 2001. Arianespace captured another 13 out of 25 contracts open to competition in 2001, and have 42 other orders on backlog. In short, over the past years and at present, the lion's share of revenues for commercial launch goes to the Europeans.[28]

However, Arianespace gets very little government business, which accounts for the lion's share of the launch market. From 1996 to 2001 the US launched 190 times, Russia 169, and Europe 65. The difference is that of Europe's 65 launches just 8 were non-commercial, whereas the US had 114 non-commercial and Russia 124. Clearly government business is the bedrock of the space launch industry.

That lack of a significant government anchor tenant has left Arianespace very vulnerable at a time of commercial slump. Arianespace must also contend with a multinational production process, and with a complex organizational and industrial support structure. These increase the Ariane V's price to the point where dual launches become necessary to create some equivalent pricing with the world market. However, that strategy, however ably executed, imposes its own issues in terms of timing, technical complexity, and risk. Arianespace announced its financial results for 2001 with a reported a loss of $193 million euros on sales of $807 million euros. They attribute this loss to the rapidly deteriorating commercial conditions in global launch services and the impact of the company standing down Ariane 5 flights after the incident that occurred last July on its 10th mission.[29]

China has effectively pulled its Long March rocket off the commercial market while it concentrates on manned space flight initiatives. The Ariane 4 is phasing out; the last flight will be in 2003, and Ariane 5 is taking over its position. The Titan series is all but gone. Even so, the space launch market is very crowded and getting more crowded all the time. Two new American systems, the Evolved Expendable Launch Vehicles (EELV) from Boeing and Lockheed-Martin, will enter the field within a few months and will provide extremely keen price pressures on an already-stressed market.

EELV and its Successors: Lockheed-Martin and Boeing present their rival EELV launch vehicles as the next step in affordable space transportation. A unique DOD/industry partnership, the program is structured to buy commercial launch services rather than launch vehicle hardware. The government would only be one customer among many. Lockheed Martin and Boeing are the prime contractors with both providing a family of launchers, each built around a common core vehicle. DOD provided $500M to each company; the companies were expected to pay the rest of the development costs themselves in exchange for full rights and control of both EELV systems.[30]

This strategy was predicated on the market projections of the late 1990s, which anticipated about 60 launches to GEO per year. The collapse of that market, with launch projections sunk to about a third that level, has forced a re-evaluation of the relationship between DOD and the contractors. Decreased demand for launch services has led the Undersecretary of the Air Force to plan to inject an additional $200M per year into the FY04 budget to keep both companies afloat for the life of the program.[31]

Both the Lockheed-Martin and the Boeing systems are scheduled to undergo their first launches this summer. Much will be riding on them: in such a crowded market, any sign of unreliability will have disastrous consequences in the commercial sector.

The Space Launch Initiative (SLI) is intended to produce a complete space transportation architecture. It will encourage a variety of Reusable Launch Vehicle (RLV) technologies rather than a single concept. NASA envisions a space shuttle replacement that is fully reusable, two-stage system that launches cargo and crew separately.[32] NASA hopes to have at least two viable designs by 2006. A lot of SLI's budget will be spent developing a new propulsion system that is safer and more reliable.

SLI is taking a closer look at kerosene propelled first stages versus cryogenic fuels. (This is not exactly new technology. The Atlas V uses a Russian made R-180 engine that burns kerosene and liquid oxygen).

Recently the AF and NASA conducted a joint study of their reusable launch needs to examine the pros and cons of conducting a joint flight demonstration this decade. Current discussions involve the potential for the AF and NASA to develop a Joint Strike Fighter like program for RLV. Top AF and NASA officials say they will continue to evaluate the possibility of jointly building a prototype RLV as proposed in a recently completed review of the agencies' requirements for an operational reusable launcher.[33]

The debate continues on the merits of investing in technology that produces a second generation RLV, or design enhancements for the EELV that will lead to an unmanned RLV. Skipping a generation in technology development is one option. Should the government spend $15M to get to 2nd Generation technology or $30M to get 3rd? And, can we keep the current shuttle going until 2030 while we wait on the new technology? In any case, the country cannot afford two separate RLV development programs.

Meanwhile, DARPA is addressing the military's need for a responsive small launch vehicle in the near term. The Responsive Access, Small Cargo and Affordable Launch (RASCAL) is a small RLV designed to lift a 75 kg payload into 500 km orbit. Two contactors have been been chosen to develop design concepts. In FY04 a single team will be selected to build and demonstrate RASCAL for test flights in 2006.[34]

The Industry Value Chain: Financing and Insurance

Designing, developing, producing, integrating, launching, and operating satellite systems is a tremendously expensive venture. Few operators can afford to fund their own satellites. Generally speaking, at least some of the funds will have to come from external sources--most likely private equity, bonds, debt, and infrequently, public equity. In 1999 there was much less venture capital available than previous years. Operators borrowed to make up the difference. In 2000, known financing of satellites was approximately $9.5 billion. In 2000, Merrill Lynch's SatCom Index fell by 55% followed by another 12% loss in 2001. These losses drove investors from the market and contributed to the failure of many initial public offerings at very early stages. Ultimately, this "drive from the market" caused a severe shortfall of funds just when most firms were in need of those resources to support operations.[35]

The commercial satellite telecommunications industry, while not in a state of crisis, is relatively illiquid. Financial institutions are much less enthused with the industry than in years past and will continue to be extremely cautious with future requests for additional loans. According to Fitch IBCA, more than 5% of all telecommunications issuers defaulted on their debt in 2000, leaving banks with $5.2 billion in defaults. A similar analysis by the Federal Reserve showed that the proportion of "bad or potentially bad telecommunications' loans" increased to 14% in 2001. Communications satellites are generally lumped in with the telecomm industry.

High failure rates and early on-orbit anomalies, especially with the Boeing 601/702 and Loral's FS-1300 satellite buses, are cutting deeply into commercial profits. Insurance providers have been hit especially hard over recent years raising calls for rate restructuring. There are several large claims still pending from 2001, but even so the space insurance industry has already paid $830 million in claims against $490 million in premiums.[36] As an indicator for the rest of the insurance industry, Munich Re is calling for an increase of 50% for launch rate insurance and a 70% increase in on orbit rates. For a $250M satellite, this would increase launch insurance to $27.5M and on orbit insurance to nearly $9M *annually*.[37] In an effort to reduce losses and maintain profitability the insurance industry is trending towards a more direct and active level of involvement with the manufacturers. Specifically, satellite owners and booster manufacturers are now being asked to accept more of the risk for new design improvements and unproven boosters.

People: As in previous studies, this year's survey repeatedly revealed concerns with the entry and retention of qualified people in the industry. While the crisis of a few years ago has abated with the decline of the dot-coms, this remains a central long-term issue for the health of the industry and the ability to expand current capabilities.

First, the current workforce is aging and retiring. According to a study led by USAF (Ret.) General Thomas S. Moorman, Jr., "Fifty-four percent…of the (aerospace) workforce is 45 years old or older."[38] As noted in earlier studies, there remains a demographic slump behind the generation now approaching retirement, leaving a bimodal distribution in the management and workforce. Second, fewer students are graduating with technical degrees than in the past. Third, the number of people coming into the workforce is also shrinking. The current workforce of "baby boomers" totals roughly 78 million people; the next generation, Xers, has only 58 million. Even with the Net Generation of 60 million workers there will not be enough to fill all the jobs available.[39]

Many incentives, scholarships and other patchwork efforts have been tried to overcome these problems; however, there has been little impact. The challenges will be magnified as the wave of layoffs continues to roll through the American space industry; at a time when the major satellite manufacturers are cutting their workforce, persuading newly trained engineers to enter the profession becomes even more difficult.

General Analysis

Our analysis of the space industry reveals stagnation, uncertainty and lack of direction. Overcapacity--partially due to a government subsidized launch capability expansion, the economic downturn, blown projects (Iridium, et al) and decreased research and development (R&D) has led to lethargy in virtually all segments of the industry.

Currently each sector has its own vision or visions for future space applications. However, there are high costs and technological challenges associated with accessing and operating in space. Overcoming these costs and challenges requires integration among industry sectors. The Rumsfeld Commission addressed this issue, recommending a series

of steps to create more effective focus and coordination on space issues at the national level. These have not been implemented, and as a general observation, space issues have taken a back seat at the national level to more pressing concerns.

Today the United States is the world's sole space superpower, with capabilities that others only dream of. This nation invests about ten times as much in space as its nearest competitors, and has done that for years. It has built up a vast core of expertise among thousands of trained people. However, building on this legacy is the task facing today's policymakers, and that is a difficult challenge given the array of conflicting priorities facing the nation.

In the civil sector, for example, the International Space Station now stands in peril of finishing its days as a truncated descendant of the system that had been envisioned for decades. Were this to occur, the original purpose and capabilities of the station would be lost, and with it, most likely, any hope of ever again engaging international partners in a major space initiative. Given the expense of space operations, it is likely that any major future program will demand multinational partnership. That will rest on the demonstrated reliability of the US as a partner.

The military sector has moved rapidly to implement the reorganizations recommended by the Rumsfeld Commission, and is now consolidating the new organizations. It will take time for the newly structured organizations to hit their stride and demonstrate whether the reforms can actually yield more effective space capabilities for the nation. At the moment, the focus of policymakers is more on conquering the problems of ongoing programs, than on looking toward new capabilities.

The commercial sector continues to seek its path, with the evolving market case for telecommunications, the slow growth in demand for remote sensing, and the overcapacity in both launch and satellite manufacturing. The assumptions and policies of a few years ago, when it was expected that the space industry would largely cut its ties from the government anchor tenants, have proven premature at best.

Key Observations

• The US has become dependent upon space capabilities to meet its national security strategy. Accordingly, our nation will take required actions to ensure access to space. Currently this challenge is being met by providing significant subsidies to the EELV development contractors for the life of the program. This effort provides multiple pathways to space for the US.

• The military and intelligence sectors form the backbone of requirements and customer demand for the US space industry. New technologies and developments will be derived from needs within these sectors. The commercial space sector is not the key technology driver for the US space industry with the possible exception of some communications technologies. Companies that support government sectors have been using internal R&D funding to meet short-term priorities instead of investing in technologies for future

capabilities. The overall median R&D expenditure rate for the commercial sector is one to three percent of total revenues.

• The US has the most advanced and capable military and intelligence space sectors in the world. However, dual-use technologies with both military/intelligence and commercial applications, including international capabilities such as high-resolution remote sensing satellites and radar satellites are closing this comparative advantage of US systems. Therefore, future potential adversaries will have access to space-derived battlefield surveillance and reconnaissance products that will change the planning strategy of US and coalition military forces.

• The space launch segment has a tremendous overcapacity. Today, the existing launch capacity meets 500% of the existing US and world demand. A major portion of this over capacity resulted from failed demand within the SATCOM-based digital phone and Internet access markets.

• Over capacity also exists in the satellite-manufacturing segment. The commercial sector is overbuilt. In terms of geosynchronous satellites alone, the top five companies within this sector can build 50 satellites per year, which is 200% of the existing market. Satellite manufacturers can adequately meet the needs of all three government sectors.

• Despite years of study and debate, the export control system remains cumbersome and time-consuming for space products. While there is much room for improvement, as a general observation, it seemed that the industry had grown accustomed to the existing processes and is more able to work within them than seemed the case in previous studies. Estimates of the cost to the industry range as high as $1.5B/year, but so high a cost seems to be a high estimate at this point. The larger costs in terms of international partnering, coalition operations, and transatlantic relations are harder to quantify and are as significant as the strictly economic effects.

• The space industry can meet current national mobilization requirements for space capabilities. Mobilization in the space industry includes leasing existing capabilities from the commercial sector, repositioning on-orbit assets, launching existing spares or smaller satellites with some capabilities, and building new large satellites over the long term.

• The supply chain for critical components within launch and satellite manufacturing may have to cross international borders in the future. Some elements have a single US vendor and some vendors have narrow profitability margins.

• The US lacks an overarching space vision to motivate the US public and future generations as was experienced during the 1960's space program to place a man on the moon. All space sectors would benefit from an overarching vision to use as a baseline for their respective visions, goals and objectives.

• A potential growth market for networks of small satellites is possible within the space control arena and specialized scientific observation constellations. The markets for small

satellites seems more promising for new market segments as opposed to replacing existing capabilities now resident on large satellites.

• Insurance costs for space launch and payloads are increasing due to higher risks and an increase in failure rates. During 2001 the industry saw twice as many payouts as compared to premiums.

• The US government is working toward the so-called "core complete" version of the International Space Station. That concept would provide for a 3-person crew and would only permit a few hours a week for scientific experimentation. It represents a fundamental shift in the orientation and capabilities of the ISS, and essentially backs away from the commitments made over decades to national partners in the system.

• The most significant technology to develop for the space industry is cheaper access to space. If users can reach space at significantly lower costs, new industries will have an opportunity to develop such as space tourism and power generation in space. Any significant breakthrough in the foreseeable future will demand government investment, as industry R&D remains at a low level given competitive pressures, and is focused on near-term requirements.

• The European Union and ESA have agreed to develop the Galileo system, after years of uncertainty. As the system matures, it will be critical for the US and European participants to work out issues of interoperability, access, and deconfliction.

Policy Recommendations

• The US government must continue to lead R&D efforts for the space industry and establish a stable funding profile to develop key enabling technologies for the industry. Government efforts should focus on developing a reusable launch vehicle; space control advancements; and breakthrough technologies that would enable a next generation "leap-ahead" launch capability. It will be important to create effective partnering between NASA and DOD to fund these critical breakthroughs.

• The President's Space Policy Coordinating Committee should lead efforts to establish a national vision for space that will mobilize the national will of the US public to pursue a bold pathway for space initiatives in order for the US to maintain its leadership in space. One of the key objectives of establishing and promoting a national vision for space is to motivate and attract the next generation of talented space pioneers and entrepreneurs.

• In order to mitigate our nation's dependence on space, the government space sectors should develop or maintain redundant capabilities for communications, navigation, launch and remote sensing capabilities. The industry should also identify easy-to-target vulnerabilities and take actions protect against their exploitation. In order to enable future leadership in space control, the military and intelligence sectors should take steps to enable a comprehensive real-time situational awareness of the space environment. This development includes a higher fidelity space surveillance capability as well as a space

environment monitoring and forecasting capability that includes continuous observations of the sun and prediction of long-period objects that may intersect with the earth. The entire industry needs to continue efforts to protect future on-orbit assets through hardening or maneuvering techniques.

• The US should spend additional funds to expand the final configuration of the ISS to a 7-person crew. This move would enhance our nation's willingness to cooperate with international partners for the continued peaceful exploitation of near-earth space. Additionally, this step would help provide a basis for continued cost sharing for the future operation of the ISS. This cooperation would serve as a model for other more daring efforts in the future.

• The US Government should develop a policy that states the degree to which the US shall maintain sovereign capabilities to design, develop, manufacture, integrate, test, deploy, and operate critical weapon systems and their components.

• Europe's Galileo navigation system can prove either a divisive issue for trans-Atlantic relations, or an opportunity for the US and Europe to develop mutually supporting systems. Given that the EU and ESA have decided to proceed with this project, the US should engage with the Europeans to address issues of interoperability, access, and de-confliction.

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