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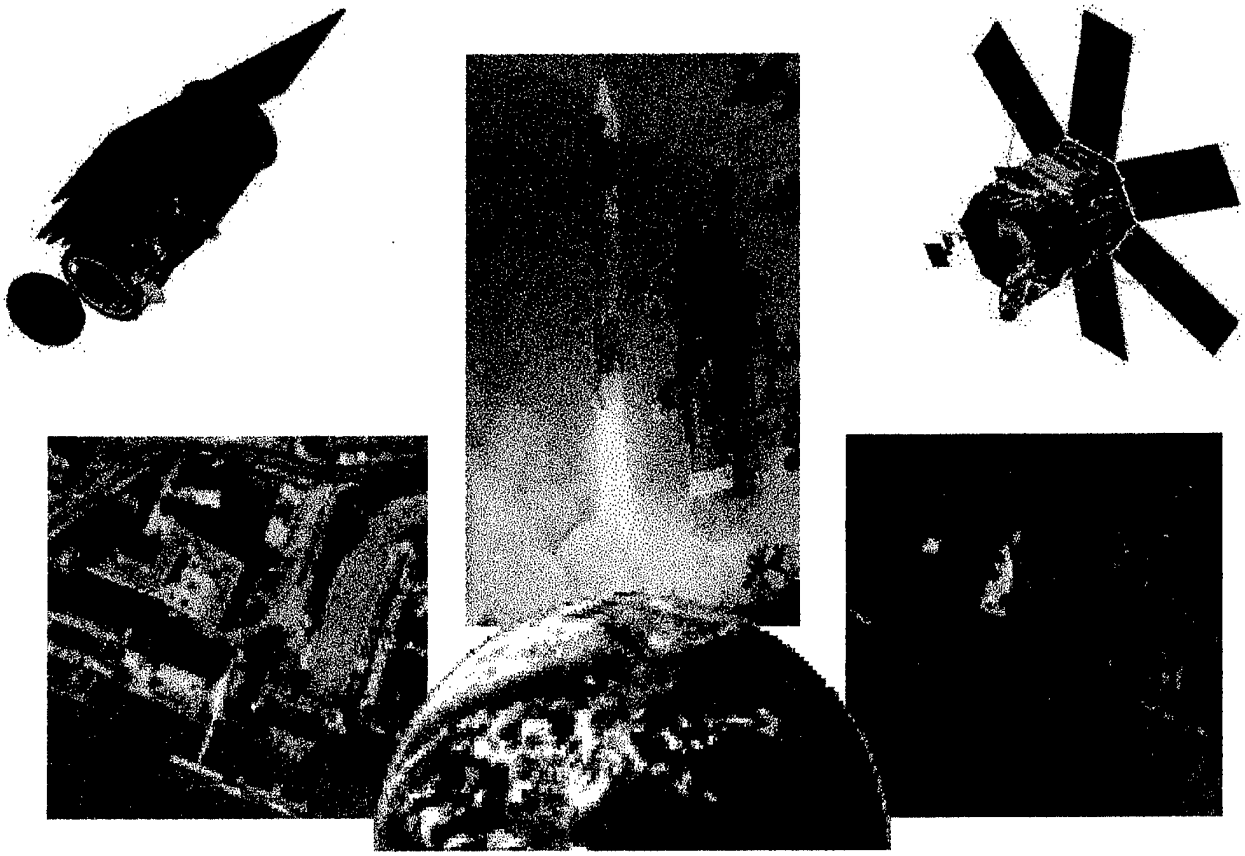

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Having become the ultimate high ground for U.S. military advantage, space is playing an increasingly important role in U.S. national security. To fully understand space and U.S. space assets, it is important to realize that until recently, the U.S. government controlled virtually all aspects of space.[1] Over time, however, the market changed, culminating with the current expansion in commercial space programs. What was once a government-dominated national endeavor based on Cold War imperatives has now become a "vibrant . . . interdependent, international commercial enterprise."[2] The passage of new legislation such as the Land Remote Sensing Policy Act of 1992 and the Commercial Space Act of 1998, combined with the introduction of executive orders such as Presidential Decision Directive 23 (PDD-23), demonstrate the power of this trend toward the free market pursuit of space technology. As the new millenium approaches, the United States will see an even greater increase in the commercialization of key space functions – launch, communication, weather, and imagery. This general trend toward a free market approach within the space industry is significant because it presents potentially serious implications for U.S. security.

The changing nature of space activities has also had a significant impact on the National Reconnaissance Office (NRO), the government agency responsible for developing, launching, and operating U.S. imagery and signals intelligence (SIGINT) satellites.[3] In fact, it has thrust the NRO into a time of transition. In addition to the *internal* changes that occurred as a result of the agency's declassification in 1992, the NRO is also facing a changing *external* environment due

[1] Although the mid-1960s saw the rise of a fledgling commercial sector consisting of a few companies selling communications satellites, space commercialization did not really take off until the early 1990s.
[2] Moorman, Thomas H. General, USAF (Ret.), "Future Military Space Challenges: The Key Dimension of 21st Century Operations," Institute for Foreign Policy Analysis Conference: *United States as a 21st Century Aerospace Power: Strategic Control and National Security*, Cambridge, MA, 18-19 Nov. 1989.

to the evolution of commercial remote sensing satellite systems. Although the NRO has historically maintained exclusive control over the most advanced imagery capabilities, the space market's "opening" will undoubtedly have serious consequences for the NRO and its mission, which is to provide satellite imagery to U.S. intelligence agencies.

It is this market challenge to the NRO – and thus to others in the U.S. national security community – that has led us to write this analytic, prescriptive paper. The NRO needs to explore the implications of employing sources other than the U.S. government for satellite imagery. As General Thomas H. Moorman, USAF (Ret) pointed out, our nation does not yet "understand the full implications [of using commercial satellites] . . . as an augmentation to our reconnaissance capabilities."[4] The purpose of this analysis is to help flush out these implications and provide prescriptive policy recommendations for the NRO.

KEY QUESTIONS, RESEARCH DESIGN, AND METHODOLOGY

The heart of this analysis revolves around one primary question: with the increased commercialization of space, what policy and programmatic options are available to the NRO to ensure the U.S. intelligence community continues to receive reliable, high-quality imagery at a reasonable cost? In trying to answer this question, it is important to look at a number of smaller, more refined questions. For instance, should the NRO explore the possibility of providing the intelligence community with a combination of U.S. government, commercial, and even foreign satellite imagery sources? What are the economic, commercial, and legislative implications of using multiple sources? What should the NRO's relationship be vis-à-vis commercial satellite

[3] Behling, Thomas, and Kenneth McGruther. "Planning Satellite Reconnaissance to Support Future Military Operations." n.p., n.d.: 3.
[4] Moorman, Thomas H., General, USAF (Ret). "Experimentation and Integration Creating the Opportunity to Exploit RAM – An Air Force Perspective." 3 Oct. 1997.

imagery corporations? And lastly, what actions should the NRO take to help ensure its ability to achieve a desirable remote sensing policy?

The best way to go about answering these questions is to conduct a needs-resource assessment by identifying existing satellite capabilities, pinpointing gaps, and defining options (including incentives and disincentives) for action. More specifically, we decided to do the following three things: assess current market capabilities, conduct a feasibility analysis for four possible options for action on the part of the NRO, and analyze other possible actions the NRO might want to take – actions such as using its role in the satellite licensing process to affect regulation in a preferred way.

ROADMAP

The paper begins by setting the stage with a review of contemporary space policy and a historical review of the NRO itself. We examine the changing nature of the commercial space market – a market that has experienced dramatic growth over the past several years. This growth has implications for both the military and commercial sectors. In the next section, we discuss the implications of current and future commercial remote sensing capabilities, as such capabilities have the ability to constrain the policy options available to the NRO. We use open-source documents to define what capabilities exist both domestically and internationally. With this data on the size and shape of the imagery market, we are able to "speculate" about the NRO's current and future capabilities relative to other countries and to the private sector.[5]

Armed with our findings on the current space market, we analyze the following four policy options for action on the part of the NRO.

1. **Maintain status quo operations** where the NRO is the sole provider of satellite imagery to our nation's intelligence community.
2. **Outsource** imagery to private corporations that not only develop, launch, and maintain satellite systems for the NRO, but *also* operate the systems.
3. Establish **government-private sector cooperative projects**.
4. **Adopt a mission niche** in which the NRO alone provides a particular type of satellite imagery and allows the commercial market to fill the remaining demand for other imagery types.

Because these options present significant risks and challenges (as well as opportunities) for the NRO, we conduct a feasibility analysis for each one. For each option, we discuss the NRO's organizational capacity for implementation, the effects on U.S. national security and on the commercial satellite industry, and the option's political feasibility.

Finally, we conclude our analysis with recommendations as to what the NRO should do given recent developments in the imagery market. Our recommendation also includes strategic actions the NRO could urge the U.S. government to undertake, thereby seeking to influence the environment in which it operates.

SETTING THE STAGE FOR GREATER SPACE COMMERCIALIZATION

The Land Remote Sensing Policy Act of 1992, PDD-23, the 1996 National Space Policy, and the 1998 Commercial Space Act provide the framework for the commercialization of the U.S. space industry. The current policy framework sets the stage for an in-depth exploration of the space imagery market, its transformation, and that transformation's effects on the NRO.

Land Remote Sensing Policy Act of 1992

Congress enacted the Land Remote Sensing Policy Act to "enable the United States to maintain its leadership in land remote sensing . . . [and] to establish a new national land remote

[5] The word "speculate" is significant here because so much of what the NRO does (and is capable of doing) is classified. With limited access to information about the NRO and its operations, we have only been able to "speculate" and "predict."

sensing policy."[6] In the Act, Congress declares that it is in the U.S. national interest to do the following three things.

1. Work to maintain leadership in remote sensing.
2. Make commercialization of land remote sensing a long-term policy goal for the United States.
3. Encourage the private sector to become responsible for developing the commercial remote sensing market.

The Act's first three titles provide guidance for achieving these three objectives.

Title I – LANDSAT

Key provisions of this title commit the LANDSAT program to provide users with data "at the cost of fulfilling user requests" – in other words, at the marginal cost.[7] During the Senate debate on the bill, Senator Larry Pressler (R-SD) argued that the original price of $4,400 per frame of LANDSAT data was too high. He asserted that such high costs actually discouraged scientific and academic communities from using LANDSAT data. He argued that the government should provide consumers with LANDSAT 6 data at the marginal cost of photographing each scene, which was, at that time, $1,600.[8]

Title II – Licensing Details

Title II designates the U.S. Secretary of Commerce as the government official responsible for licensing private corporations that want to provide commercial remote sensing systems and mandates that system operations preserve U.S. national security. It also directs private companies to "make available to the government of any country (including the United States) unenhanced data collected by the system . . . of the territory under the jurisdiction of . . . [that particular] government as soon as such data are available and on reasonable terms and

[6] Preamble to the Land Remote Sensing Policy Act of 1992. Taken from the Congressional Research Service, Thomas. http://www.thomas.loc.gov.
[7] Section 105 (a)(1) of the Land Remote Sensing Policy Act of 1992.

conditions."[9] Finally, this title requires private corporations to notify the Secretary of Commerce when they plan to enter into agreements with foreign nations or corporations.

Title III – Technology Demonstration Program and Research & Development Programs

Title III authorizes a "technology demonstration program" to highlight advanced technology beneficial to the development of the remote sensing market. It further directs the President to employ declassified technology derived from the U.S. National Technical Means of intelligence gathering in the technology demonstration program as long as such technology does not adversely affect U.S. national security. This title illustrates the broad trend toward the economic development of space and provides the impetus for advanced technology to move out of the intelligence sector and into the commercial market.

PDD-23

A fundamental shift in U.S. space policy occurred when President Clinton issued Presidential Decision Directive 23 – entitled "Foreign Access to Remote Sensing Space Capabilities" – in March 1994. This directive "leveled the playing field for American firms eager to compete for the multi-billion dollar satellite imagery and value-added market."[10] This directive was an Administration attempt to protect U.S. national security while also enabling U.S. space technology firms to boost profits. The Administration's goal was to bolster U.S. remote sensing firms' ability to capture the majority of the worldwide market – particularly the market composed of nations that do not possess their own satellite systems.

[8] Pages S17140-S17142 of the Congressional Record for the 102d Congress.
[9] Section 202 (b)(2) of the Land Remote Sensing Policy Act of 1992.
[10] Grundhauser, Larry K., Lt. Col., USAF. "Sentinels Rising: Commercial High-Resolution Satellite Imagery And its Implications for National Security." 17 April 1998: vi.

PDD-23 represents a pragmatic approach to the difficult problem posed by the existence of commercial remote sensing programs. Historically, the United States has been the leader in developing, launching, and operating remote sensing systems. Substantial industry regulation in the past, however, served to hinder American firms, thereby enabling European and Russian firms to increase their share of the remote sensing market. Noting this history, Colonel Frank Klotz states in his monograph *Space, Commerce, and National Security* that over time, though, "economic considerations won out over fears that opening up the market for high-resolution imagery might prove militarily useful to nations that would not otherwise have access to satellite reconnaissance."[11] To mitigate the security risks associated with this reality, the U.S. government decided to retain the right to monitor both the end-consumers of satellite data as well as the nature of the data purchased. With PDD-23, the government can "exercise its 'shutter control' option over American-flagged satellites when the collection and/or dissemination of imagery from them threatens U.S. national security."[12] The Secretary of Commerce exercises the shutter control option in consultation with the Secretaries of Defense and State.[13]

National Space Policy

The Clinton Administration unveiled the details of the new National Space Policy on September 19, 1996. The policy outlines the goals of the U.S. space program; provides guidelines for the civilian, national security, and commercial space programs; and provides

[11] Klotz, Frank G., Col, USAF. *Space, Commerce, and National Security*. Council on Foreign Relations, 1998: 43-44.
[12] Grundhauser, vi.
[13] It is important to understand that "shutter control" is far from being a no-cost policy tool. The most obvious problem with the U.S. "shutter control" policy is that the government cannot implement it against foreign providers. Because there *is* foreign competition in the imagery marketplace, customers that become victims of "shutter control" will "be driven away to seek alternative sources of data rather than subject themselves to the whims of American bureaucrats" (Grundhauser 57). Thus, the end result of invoking the "shutter control" policy could be harm to both U.S. firms and U.S. national security.

"intersector guidance" to support national space policy objectives. The goals of the national space policy are to "strengthen and maintain the national security of the United States" and to "enhance the economic competitiveness, and scientific and technical capabilities of the United States."[14] The policy goes on to define the environment the U.S. government ultimately hopes to create with regard to space usage. It declares that the United States is committed to the peaceful use of space by all nations, stating that the "United States considers the space systems of any nation to be national property with the right of passage through and operations in space without interference. Purposeful interference with space systems shall be viewed as an infringement on sovereign rights."[15]

Commercial Space Act of 1998

Congress enacted the Commercial Space Act to "encourage the development of a commercial space industry in the United States" and improve the legal and regulatory framework for commercial space development.[16]

Title I – Development of Commercial Space Opportunities

Title I requires NASA to submit a report to Congress exploring the possibilities for the commercialization of the International Space Station. It authorizes NASA to acquire scientific space data from commercial sources (rather than build new government systems to collect such data) as well as purchase remote sensing data from commercial sources. This title also reaffirms the United States' policy to make the Global Positioning System (GPS) a worldwide navigation standard whose signals can be provided worldwide without direct user fees.

[14] National Space Policy Fact Sheet. 19 Sep 96. http://www.whitehouse.gov/WH/EOP/OSTP/NSTC/html/fs/fs-5.html. Page 1 of 12.
[15] Ibid, 1.
[16] Preamble to the Commercial Space Act of 1998. http://www.thomas.loc.gov.

Title II – Procurement of Federal Space Transportation Services

Title II directs the federal government to use U.S. commercial sources for space transportation services whenever feasible and also directs NASA to prepare for the eventual operations of its space shuttles by the private sector rather than by the government.[17] This semi-private arrangement made possible by last year's Commercial Space Act is significant because it represents a possible future operating model for the NRO. The NASA Administrator has made a conscious strategic decision that the organization's core mission is science, not operations.[18] Using this model, the NRO would shift its focus toward conducting research and development (R&D) while allowing other organizations to conduct satellite operations and maintenance.

THE NATIONAL RECONNAISSANCE OFFICE

A brief review of NRO history will provide the context for the current changes at the NRO. Specifically, this reflection demonstrates the increasingly important role that the NRO played over the course of the Cold War. By understanding this evolution, the implications – both positive and negative – of today's commercial market become more pronounced.

A Historical Review

The National Reconnaissance Office was created almost forty years ago to "meet the unusual intelligence demands of the nuclear age and the Cold War."[19] In the early 1950s, the U.S. faced the grave threat of a surprise nuclear attack by the Soviet Union. In an effort to gain

[17] Report of the Committee on Commerce, Science, and Transportation on the Commercial Space Act of 1997. Summary of Major Provisions. It is interesting to note that the United Space Alliance has already taken over some day-to-day aspects of space shuttle operations – a situation that has left NASA free to focus on conducting research and development (About United States Space Alliance. http://www.unitedspacealliance.com/about/about.html. Page 1 of 2). NASA still retains responsibility, however, for space shuttle safety and high-level management.
[18] Kelman, Steven J. Personal Interview. 8 March 1999.
[19] Hall, R. Cargill. "The National Reconnaissance Office: A Brief History of Its Creation and Evolution." August 1998: 1.

intelligence on the Soviet Union, President Eisenhower authorized the development of the U-2. At the July 1955 Four Powers Summit in Geneva, President Eisenhower proposed the "Open Skies" Agreement which would allow U.S. and Soviet reconnaissance aircraft to overfly each other's territory. Even though the Soviets rejected this proposal in an effort to protect their closed society, the U.S. continued to rely on U-2 flights to gain intelligence the Soviet missile program.[20] As the Eisenhower Administration continued to develop strategic reconnaissance platforms, scientists began working platforms for space.

In early October 1957, the world witnessed the launch of the Soviet-built Sputnik I – a launch that eventually threw the United States and the former Soviet Union into a frantic race for space. Although the Soviet satellite began to decay after only twenty-one days in space, Sputnik 1 had an extraordinary psychological (and even political) impact on the United States. With Congress' urging, the Eisenhower Administration began investing "incredible amounts of money into the developing space-age technology."[21] The Administration had budgeted upwards of $5.25 billion (which today would equal $24.1 billion in real terms) for America's space program. This funding provided the United States with the means to become the first nation to take reconnaissance images of the earth from outer space with Discoverer XIV.[22] While Eisenhower Administration officials knew such strategic reconnaissance was critical to U.S. national security, they did not believe that a single military service or even a single intelligence agency, such as the CIA, should control the United States' new space reconnaissance assets.[23] In response to both the fast-paced ballooning of developments in space technology and the furor

[20] Peebles, Curtis. *High Frontier: The United States Air Force and the Military Space Program.* Air Force History and Museums Program. 1997: 4-5.
[21] Wold, Robert N. "Sputnik's: The Inspiration Launch." *40th Anniversary of Sputnik: Four Decades of Progress.* A Special Sponsored Supplement to *Via Satellite.* n.d.: 4.
[22] On August 18, 1960, the U.S. recovered the capsule from Discoverer XIV that contained the first images of Earth taken from space.
[23] Peebles, 12-13.

caused by the downing of an American U-2 over the U.S.S.R. in 1960, President Eisenhower placed control of reconnaissance satellites in the hands of a new Pentagon office. This new office was the precursor to the National Reconnaissance Office and was headed by the Undersecretary of the Air Force (and later by the Assistant Secretary of the Air Force for Space). Its very existence was classified until the early 1990s.[24]

A New Direction

The NRO functioned well during the Cold War. The end of the Cold War and the office's recent declassification, however, have compelled the NRO to re-examine its role. In an effort to do so, the NRO commissioned a panel in 1996 to help it define its role for the 21st century. The panel – led by Admiral David Jeremiah, USN (Ret), the former Vice Chairman of the Joint Chiefs of Staff – examined the NRO's mission, its relationship with others in the security community, and ways the NRO could change its structure and operation procedures.

The panel concluded that "the future security of the nation depends on its ability to conduct surveillance from space . . . [and] that the NRO continues to be the right organizational answer to the nation's space reconnaissance needs."[25] It stated that the NRO provides the nation with "a preeminent national security advantage with its ability to conduct space surveillance and must continue to do so in the future."[26] It went on to commend the NRO for achieving success through innovative technical achievement and management practices. The panel did provide, however, recommendations for improvement that would streamline the NRO, making it more efficient and thus more effective.[27]

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[24] Hall, R. Cargill, 2,3.
[25] The Jeremiah Panel. "Executive Summary." *Defining the Future of the NRO for the 21st Century.* UNCLASSIFIED Report to the Director, National Reconnaissance Office. http://www.fas.org/irp/nro/jeremiah.html. Page 4 of 14.
[26] Ibid, 4.
[27] Ibid, 4-5.

In analyzing the NRO's mission, the Jeremiah panel carefully studied the NRO's ability to revolutionize space reconnaissance and to increase the level of intelligence support so as to strengthen U.S. national security. It recommended that the NRO adopt a new mission statement that would read, ". . . enable the U.S. Government and military information superiority, during peace through war." The wording is highly appropriate given that the NRO is responsible for providing "unique and innovative technology, large scale systems engineering, development and acquisition, and operation of space reconnaissance systems and related intelligence activities needed to support global information superiority." [28]

The Jeremiah panel also explored some of the NRO's business practices to ascertain whether they remain appropriate for the current environment. When the NRO was still classified, it was able to use "special" business practices. During the Cold War, other organizations used similar special business practices for the development and operation of top-secret programs such as Polaris and the F-117. These practices worked because they increased the likelihood and speed of success. The 1996 panel noted, however, that:

> In recent years, there has been an erosion of the benefits of special business practices. Management is far less streamlined with many new players in the process who can say "no" but not "yes." The [acquisitions] program manager has far less latitude to make decisions . . . To press on despite 11 failures before a first success – as the NRO did on the CORONA program – would be unthinkable today . . . The decrease in the use and effectiveness of special NRO business practices results, either directly or indirectly, in many of the shortcomings of the NRO evident today: reduced technical innovation, limitation to evolutionary vice revolutionary architectures, significant increase in staff and Contract Advisory and Assistance Services (CAAS), overly detailed specifications, proliferation of engineering change proposals (ECPs), increased costs, and erosion of confidence . . . Business practices in the program specification phase tend to focus on "how" not "what." This focus generally leads to design refinement and constrained proposals to fit existing architectures.[29]

This environment, the panel asserted, has forced change at the NRO to be evolutionary rather than revolutionary. The panel went on to intimate that what the NRO needs most to fulfill its new mission is revolutionary change.

[28] Ibid, 6.

To fulfill the requirements of the Department of Defense (DoD) *Joint Vision 2010*, the NRO is aiming to provide global information superiority – an aim that has resulted in a redirection of NRO priorities. The NRO has started focusing more on treating the military services as its primary customer. Before the Gulf War, the CIA and the State Department were the office's primary customers.[30] Critics argue that this redirection in "customer clientele" is dangerous because it has caused the NRO to focus more on tactical intelligence and less on strategic intelligence. They point to the surprise of India's nuclear weapons testing on May 11 and 13, 1998, as evidence of this dangerous shortcoming in strategic intelligence. They acknowledge that the Jeremiah panel's recommendation that the NRO "guarantee 'global information superiority to NRO data users'" will help remedy this problem.[31]

But the NRO's problems have not stopped there. It now faces the problem of a constrained budget. Mr. Keith Hall, the current NRO Director, expressed his concern about the budget in a recent speech:

> The reality is that our budgetary resources are limited. Someone once said – 'It's hard to reach for the stars, when you are clutching your wallet!' We must now make choices about which capabilities we will pursue – long gone are the days of buying whatever capabilities the state of technology will permit.[32]

Mr. Hall admits that the NRO must now concentrate on being more cost-effective in accomplishing its critical mission. The emerging commercial remote sensing market may provide the NRO with the opportunity to achieve this objective.

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[29] Ibid, 8.
[30] *Aviation Week & Space Technology*. 9 Feb. 1999. 26.
[31] Covault, Craig. "Eavesdropping Satellite Parked Over Crisis Zone." *Aviation Week and Space Technology*. 18 May 1998. 30-31.
[32] Hall, Keith. "Remarks to the National Network of Electro-Optical Manufacturing Technologies Conference." 9 Feb. 1998. http://www/fas/org/irp/nro/hall9802.html. Page 1 of 5.

THE CHANGING NATURE OF SPACE

Details on the Market's Growth

Commercial space is a growing field. The number of annual commercial space launches and the revenue generated from commercial space activities has increased dramatically. Forecasts indicate that between 1998 and 2007, 1,700 satellites will be launched into space. Of that number, 1,200 to 1,300 of the systems will be commercial assets.[33]

On the other side of the ledger is the economic impact of commercial satellite projects. The year 1997 was a key year for the commercial space industry. It was the "crossover year" – the year in which commercial payloads exceeded government payloads for the first time in history. Figures for the end of 1998 show that the growth of commercial space is now twenty percent while that of the government is only two percent, and it is estimated that these figures will continue to hold true over time.[34] The growth of the telecommunications industry and its need for communications satellites is likely to be the largest contributing factor to this growth in commercial space. Companies and agencies needing remote sensing technology for tasks such as urban planning, cartography, geology, farming, and environmental planning will fuel the projected growth in the imagery segment of the commercial space market.

Analysts' predictions for the size of the imagery market vary widely, ranging from approximately $600 million by 2004 (28.6 percent compound annual growth rate starting with 1998 revenues of $139.3 million)[35] to over $1.2 billion by the year 2000.[36] In 1992, the Center for Space Policy, a space policy consulting group (now called CSP Associates), estimated that the space market's remote sensing sector would reach as high as $2 billion by the end of the

[33] Berry, Robert and Donald L. Croner. "The Global Relevance of Space: Civil, Commercial, and Military." *1998 National Space Symposium*, Colorado Springs, CO. 8-9 April 1998.
[34] Moorman, from his speech, "Future Military Space Challenges: The Key Dimension of 21st Century Operations."
[35] Frost & Sullivan. *World Commercial Remote Sensing Markets*. Report #5619-22. Feb. 1998. 1-4.

decade – a figure that author Nathan Goldman has called highly "unattainable."[37] Goldman argues in his book, *Space Policy: An Introduction*, that "any private or public remote sensing operation will be competing increasingly with European and Japanese programs, while unsettled legal and political issues still complicate the status of remote sensing."[38] Industry watchers predicted that in order to attain such a high market value by mid-2001, "over 30 satellites . . . [would have to] be in orbit around the Earth using affordable technologies to provide volumes of imagery to an international clientele with fidelity previously unobtainable by the general public."[39] More recent predictions, however, say that this situation is indeed possible. The Office of Air and Space Commercialization in the Department of Commerce has estimated that the imagery market will be worth $15 billion by the end of this decade.[40]

Space Technology and the Military

The military application of space technology is also growing. The military employed a significant number of space assets during *Desert Shield* and *Desert Storm* – so much so that some now refer to the operation as the world's first "space war." These space assets enhanced the U.S. advantage in the Persian Gulf and facilitated the rapid victory against Saddam Hussein and the Iraqi military, thereby making clear the importance of information dominance.

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[36] KPMG. *The Satellite Remote Sensing Industry: A Global Review*. June 1998: 37.
[37] Goldman, Nathan C. *Space Policy: An Introduction*. Ames, IA: Iowa State University Press, 1992. 175. Some government officials like the Commerce Department's Undersecretary for Oceans and Atmosphere – Dr. D. James Baker – disagree with Mr. Goldman. Dr. Baker has cited some satellite systems licensees as forecasting the emergence of a $2 billion global commercial imagery market by 2000 (Testimony of Dr. D. James Baker, Under Secretary for Oceans and Atmosphere, U.S. Department of Commerce. Given before the Subcommittee on Space and Aeronautics, Committee on Science. U.S. House of Representatives. 4 June 1997).
[38] Ibid, 175.
[39] Grundhauser, 2.
[40] Testimony of Dr. D. James Baker, Under Secretary for Oceans and Atmosphere, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, before the Committee on Science, Space, and Technology and Permanent Select Committee on Intelligence. 9 Feb. 1994. Accessed from Lexis-Nexis Academic Universe.

Having seen the future potential, the U.S. military continues to improve its ability to use information warfare. The current Revolution in Military Affairs (RMA) seeks to leverage information and advanced technology to achieve battlefield success. As the RMA continues, the U.S. military will grow more dependent upon space assets, as space assets make possible the information operations required by this revolution.

The growth in military space applications, however, is not keeping pace with the growth in commercial space applications. In 1992, Nathan Goldman argued that "since 75 percent of all satellites are military in their designation . . . space policy is predominantly military policy."[41] The recent growth in the commercial space market renders this statement outdated, though. Colonel Klotz notes that "even as military uses of space grows, its share of the 'action' – and ultimately its ability to dominate the space policy process – is being overtaken by the commercial sector."[42] The Assistant Secretary of the Air Force's (Space) prediction that by 2007 commercial investment in space ($170+ billion) will outpace DoD space investment ($13-14 billion) by more than ten-fold simply drives home the reality of this trend.[43]

By seeking to utilize information technology, a significant implication of the RMA is that it will increase the interconnection between the military and commercial sectors. The RMA depends on advanced information systems, many of which the commercial sector produces. A large connection between the two sectors already exists, with many commercial products having military applications. Colonel Klotz argues that "the U.S. military and other government agencies (and their counterparts in other countries) could become major customers for the even more detailed commercial satellite imagery that will soon be available."[44] Telecommunications

[41] Goldman, 226.
[42] Klotz, 10.
[43] Assistant Secretary of the Air Force (Space). "Welcome to HQ USAF!" Briefing.
[44] Klotz, 14.

is an example of a commercial system that has military potential. Countries with poor communications infrastructures such as China, India, or Brazil could use commercial communications satellites to improve their military communications capability.[45]

The Secretary of Defense's 1998 annual report notes the increasing importance of the relationship between space technology and the military. Last year's report asserts that space power is as important to the United States as land, sea, and air power. General Estes, the former Commander of U.S. Space Command, echoed this assessment when he said, "because of this tremendous investment, [space has] now become . . . an economic center of gravity for the U.S. . . . it is not the military development in space, it is not the civil development of space, it is the commercial development of space that is driving the U.S. interests, the U.S. lines of communications, and the U.S. lines of commerce to space."[46] Drawing on the growing importance of commercial space programs, many analysts see the current commercial developments in space as analogous to the development of sea-based commerce. In previous centuries, nations had to develop large navies in order to protect their trade as well as their sea lines of communication. According to this analogy, the flag followed the trade – the military evolved to protect commercial interests. Those who use this comparison argue that nations are now establishing space lines of communication and that governments will soon face pressure to protect these lines along with their other space-based capabilities.

Critics of this line of argument assert that the legal framework governing space is different from the one that existed during the age of naval exploration. They argue that the potential for naval conflict had always existed because the framework for resolving territorial or rights disputes was not *established*, but rather *evolved with time*. With space, they assert, the

[45] Mahnken, Thomas G. "Why Third World Space Systems Matter." *Orbis*. Fall 1991. 566.
[46] Estes, Hugh, General, USAF. "Space as an Area of Vital National Interest." 3 Nov. 1997.

legal framework has already been *established.* The central premise is that space is an area open to all nations to be used for peaceful purposes.[47]

Before the Soviet Union launched Sputnik I, American scientists urged President Eisenhower to have the U.S. launch a small, scientific satellite to establish the "freedom of space" precedent, allowing satellites to freely overfly foreign countries. These scientists hoped that by using a scientific satellite to establish this precedent, the U.S. could then deploy reconnaissance satellites and that the Soviet Union would be barred from attempting to destroy these U.S. satellites. To make their argument, the scientists used the existing "freedom of the seas" legal principle, which allowed ships of all nations free passage on the high seas outside a nation's territorial waters. Ultimately, the Soviet Union effectively established the "freedom of space" precedent with its surprise launching of Sputnik I, because Soviet officials never requested permission for Sputnik to overfly the U.S.[48]

A series of U.N. resolutions culminated in the 1967 Outer Space Treaty, which codified the principles of unimpeded access to space for all nations as well as outlined the terms of noninterference with space systems. More than ninety nations have ratified this treaty, which provides the basic legal framework for international space law. The treaty designates the use of space for peaceful purposes to benefit of all humanity, further declaring that all nations may explore and use outer space, the Moon, and other celestial bodies and that no nation may claim sovereignty over celestial bodies. While this treaty does not categorically prohibit the military use of space, other agreements contain such limitations. The 1967 Outer Space Treaty prohibits the placement of weapons of mass destruction (WMD) in space, and the 1963 Limited Test Ban Treaty forbids the detonation of nuclear weapons in space. The 1972 Anti-Ballistic Missile

[47] Klotz, 15-20.
[48] Peebles, 8.

Treaty proscribes the deployment of space-based ABM system components. While a framework exists for space, it is not comprehensive. So, as Colonel Klotz argues, "in the absence of a well-established and widely accepted legal regime in space, the historical analogy of the need to protect lines of communication in the traditional sense may not be all that far fetched."[49]

CURRENT AND FUTURE COMMERCIAL SYSTEMS: TRENDS & IMPLICATIONS

It is within this historical and political context that we examine the capabilities of commercial remote sensing systems in order to answer the primary question. The review in Appendix 1 describes key system aspects, such as resolution and imagery type.

Future Trends

As future generations of satellites provide sharper resolutions, the U.S. government will face an increasing number of security problems. The industry capability appears to be rapidly approaching a resolution of 2 meters or less – evidenced by the fact that the government granted one-meter resolution licenses to four companies in 1994.[50] In a recent statement to Congress, the NRO Director acknowledged the current availability of 2 to 5-meter imagery in the commercial marketplace.[51] This detail is significant because nowadays, analysts can glean important intelligence information from pictures with a resolution of 10-meters or less. The Carnegie Endowment for International Peace conducted a study in the late 1980s regarding the resolution

[49] Klotz, 8.
[50] Stoney, William E. "The Pecora Legacy – Land Observation Satellites in the Next Century." *Pecora 13 Symposium,* Sioux Falls, SD, 22 Aug. 1996. http://geo.arc.nasa.gov/esdstaff/landsat/wes.html. Page 4 of 7.
[51] Hall, Keith R. "Statement by Assistant Secretary of the Air Force (Space) and Director, National Reconnaissance Office Keith R. Hall before the House Science Committee Space and Aeronautics Subcommittee, House National Security Committee, Military Research and Development Subcommittee, and House National Security Committee

level necessary to detect, identify, and quantitatively measure various military targets. According to Lt. Col. Grundhauser, the study suggested that "substantial military information can be derived even from sensors known to have poor spatial resolution, such as LANDSAT's multispectral scanner and thematic mapper. Surprisingly, the imagery analysts discovered that using SPOT's 10-meter GSD imagery – resolution that will soon be considered mediocre – enabled them to easily satisfy nearly all the targeting-associated tasks contained in the study's target list."[52] The consequences of improving imagery resolution are potentially more threatening to U.S. national security than one might have originally thought.

Implications

This new generation of domestic and international commercial, high-resolution imaging satellites will have national security applications. These commercial satellites will enable countries without advanced space programs to verify treaties and conduct threat assessments. The U.S. and the former Soviet Union have used satellites to verify international agreements for many years. The multilateral negotiations on treaties, such as the Comprehensive Nuclear Test Ban Treaty and the Nuclear Non-Proliferation Treaty, have dramatically increased the number of nations involved in international treaty verification. The commercial satellites will also enable these nations to monitor the force structure and disposition of neighbors and regional adversaries. Commercial systems could enable nations to highlight treaty violations. Vipin Gupta notes that in instances where collected information has raised questions on compliance, "commercial imagery could be readily used as evidence for wider dissemination. Since the technological capabilities of commercial satellites are essentially public knowledge, commercial high-

Military Procurement Subcommittee Hearing on U.S. Spacepower in the 21st Century." 29 Sept. 1998. http://208.240.89.171/speeches/29SepSFR.html. Page 3 of 4.

[52] Grundhauser, 22.

resolution imagery will be inherently more suitable for release than classified data."[53] Commercial high-resolution imagery will also reduce the threat of surprise first strikes by increasing regional transparency.

While the development of commercial, high-resolution remote sensing satellites will have some positive aspects, it will also has the potential to cause problems between nations. Some analysts argue that the development of commercial, high-resolution remote sensing satellites could be as destabilizing as the proliferation of nuclear, chemical, and biological weapons. High-resolution images have the potential to disrupt regional balances of power by creating asymmetries. The remote sensing images will be distributed on a commercial basis, enabling some states to acquire images while rival states may not be able to acquire any. Commercial distribution of capabilities could result in economically and militarily powerful nations acquiring the premier remote sensing capabilities, while less powerful nations are left with degraded or no imagery capabilities at all. Furthermore, some states that object to commercial satellites taking pictures of their territory may attempt to find countermeasures to protect themselves, thereby prompting an anti-satellite (ASAT) arms race.[54]

STRATEGIC CONSIDERATIONS

The development of commercial, high-resolution remote sensing systems presents the NRO with new opportunities as well as new threats. Commercial remote sensing systems with 1-meter resolution provide capabilities that were once found only in the intelligence community. The deployment of these systems may enable the NRO to supplement its capabilities by purchasing imagery from the commercial sector. The option of purchasing images from a

[53] Gupta, Vipin. "New Satellite Images for Sale: The Opportunities and Risks Ahead." *International Security*. http://www.llnl.gov/csts/publications/gupta/oppor.html. Page 2 of 6.

private corporation or the option of working in conjunction with one or more companies both have implications that the NRO should consider.

Porter's Competitive Forces

As it continues to operate in a transitioning environment, the NRO should take a step back to assess its core tasks and how these tasks compare with private sector capabilities. Although the NRO is not in direct competition for profits or market share with private remote sensing companies, it does endeavor to maintain the technological advantage in imaging capabilities necessary to support U.S. national security. Ideally, it is in the NRO's interest to make sure other countries – which are often the commercial providers' customers – have inferior imagery while DoD retains exclusive access to the best imagery and information available. The NRO is essentially in competition with commercial industry to most effectively utilize R&D funds to maintain its technological lead over current commercial capabilities.

In light of this "competition," the NRO must plan strategically. Michael Porter, a professor at Harvard University's Business School, offers useful advice on "making choices about how to position [an organization] in its competitive environment."[55] According to Professor Porter, there are five forces that drive competitive environments. They are as follows:

1. Character of the Rivalry: is the competition subdued or is it cutthroat?
2. Threat of New Entrants: how high are barriers to entry, and how many regulations exist?
3. Threat of Substitute Products or Services: how many alternatives to the products exist?
4. Bargaining Power of Suppliers: do suppliers control prices because of a unique product?
5. Bargaining Power of Buyers: do buyers purchase enough in quantity to affect the price?

Professor Porter goes on to present five common, fatal flaws lurking in such an environment – pieces of advice the NRO needs to consider.

[54] Gupta, Vipin. http://www.llnl.gov/csts/publications/gupta/risks.html. Pages 1-2 of 6.
[55] Porter, Michael E. "Know Your Place." *Inc.* Sept. 1991. 90.

1. Misreading Industry Attractiveness: more glamorous industries are attractive but draw more competition.
2. Possessing No True Competitive Advantage: imitation is not really a strategy.
3. Pursuing an Unsustainable Competitive Advantage: easily imitated produces will not be very successful.
4. Compromising Strategy for Rapid Growth: it is unwise to expand the competitive scope at the expense of the original strategy.
5. Unclear Strategy/Not Communicating with Employees: hidden or unexpressed agendas do not promote unity or harmony among team members.[56]

The NRO must consider all of these forces and be wary of these fatal flaws as it pursues a goal of finding its competitive advantage. The competitive, commercial remote sensing market currently has several unique characteristics. On the national level, the imagery market is very competitive because the stakes involved are very large. The U.S. government would prefer that American corporations dominate the international remote sensing market because the licensing process enables it to use shutter control to regulate the products sold by American corporations. While many new entrants are threatening to enter the market, it remains to be seen how successful these ventures will be. The barriers to entry are quite high – satellites systems are extremely capital intensive. Furthermore, the market is highly regulated by governments. In the U.S., firms must obtain a government license to operate. This license regulates the imagery quality and the customers to whom the product may be sold. Some buyers, such as national governments, could purchase high enough quantities to affect the price of imagery.

These forces will influence the firms engaged in the developing commercial imagery market. As Professor Porter says, the best strategy will ultimately "make a certain group of customers very, very happy, and that is the logic. You target all your efforts on those customers, and you achieve either lower costs or uniqueness in meeting their needs. Best of all, the big boys cannot easily move in on your turf."[57]

[56] Ibid, 90-91.
[57] Ibid, 91.

According to Professor Porter, the critical idea of competitive advantage "comes in only two basic varieties. You can have consistently lower costs than your rivals . . . [or] you can differentiate your product or service from your competitors', in effect making yourself unique at delivering something your customers think is important."[58] Since the NRO does not have a cost advantage due to the economies of scale inherent in commercial production, *it should focus on product differentiation.* More specifically, as Professor Porter articulates, "A sustainable competitive advantage comes from choosing an appropriate strategy and appropriate scope."[59] Since the commercial sector will focus on providing imagery that typical clients will demand, *the NRO can focus its resources instead on providing imagery that is both custom-tailored for its customers and lacking in practical application for other users.* Thus, free market competition could be a blessing in disguise – the NRO can narrow its scope to suit the U.S. intelligence agencies' specific needs, which the commercial market tends to find unprofitable anyway.

Lessons from a Previous Case

Toward the end of the 1970s, Congress held hearings on the future of the LANDSAT system. During the deliberations, Congress considered the following four options: sell LANDSAT to a private corporation; create a private corporation, like COMSAT, that could take over LANDSAT operations; continue governmental operation with the eventual goal of transferring LANDSAT to a private industry; or operate LANDSAT as a permanent federal program. Part of the problem was deciding which government agency should control LANDSAT, as NASA, NOAA, the Department of Agriculture and other agencies had competing claims to the system. The government decided the most economical option would be to continue

[58] Ibid, 91.
[59] Ibid, 91.

government operation with the eventual goal of privatizing. The transition began in November 1979 when President Carter shifted LANDSAT's control from NASA to NOAA. While NOAA was assigned operational control, NASA retained research and launch responsibilities.

A few years later, the Reagan Administration reassessed the situation. With a penchant for private industry control, President Reagan accelerated the privatization schedule by five years, which meant private industry would take over LANDSAT's operation in 1984. The decision was controversial and raised concerns among LANDSAT users, many of which were state and local governments. The users were concerned that a private company would not be capable of providing continuous data and the high-quality management, technology, and assistance that they had come to expect under government operation. Critics questioned whether economies of scale and private sector efficiencies were the best way to develop commercial remote sensing systems. By 1983, several companies had combined efforts to produce a competitor to LANDSAT. They hoped this new satellite would also provide communications and navigation capabilities to compete with Geostar and Navstar. The end of the worldwide oil crisis and the ensuing drop in oil prices, however, put a stop to this venture into commercial remote sensing.[60]

These initial steps in the privatization of the LANDSAT system provide some cautionary lessons. First, the companies' failure to produce a competitor to LANDSAT shows that the *barriers to entry are high* – particularly given that the development process for such a system is long and arduous, not to mention expensive. Development, launch, and operation of a remote sensing satellite can cost millions (even billions) of dollars.

Second, commercial firms planning to develop remote sensing satellites to compete with

[60] Goldman, 181-182.

LANDSAT *misread the attractiveness of the industry.* World economic and political events can often create barriers to raising the capital necessary to build satellite systems. Before the companies could develop and field their system, external events conspired to remove the need for the system altogether. The drop in oil prices reduced the need to develop new oil fields, and thus reduced the need for remote sensing imagery.

It appeared that LANDSAT competitors would emerge in the 1980s to develop a commercial remote sensing market. This did not occur because the barriers to entry constrained the competitors, and the competitors misread the attractiveness of the industry. As the current commercial remote sensing market develops, it appears that companies have been able to overcome the costly barriers to entry that constrained earlier development, but *it remains to be seen whether the industry can sustain itself.*

INTERNAL POLICY OPTIONS

Option 1: Status Quo Operations

The first option is for the NRO to continue current operations in which it serves as the principal provider of all high-resolution imagery to the U.S. intelligence community.[61] In other words, the NRO would continue doing what it has done since its inception during the Cold War.

Organizational Capacity for Implementation

If the NRO is going to continue providing the U.S. intelligence community with the best satellite imagery possible, it must take advantage of the Revolution in Business Affairs (RBA) principles as well as implement the recommendations of the Jeremiah Panel. In particular, it

[61] The NRO is responsible for the design, development, and operation of space reconnaissance systems and associated intelligence activities (Jeremiah Panel. http://www.fas.org/irp/nro/jeremiah.htm. Page 6 of 14.).

needs to concentrate on removing management inefficiencies by streamlining its organizational capability in order to achieve cost savings and revolutionary systems development.

If the NRO chooses to maintain the status quo, it is imperative that the NRO return power to its program managers so as to streamline the acquisitions process – a move that is likely to require legislation. Once the appropriate legislation is enacted, the NRO will have to be judicious in selecting the systems it wants to develop and deploy. Of course, the NRO's budget constraints will restrict its choice of systems.

Effects on U.S. National Security

The status quo has serious implications for U.S. national security. The biggest threat is the un-monitored development of commercial remote sensing systems abroad. An example of this security threat is the current situation with regard to RADARSAT 2. The U.S. is concerned that the images provided by Canada's RADARSAT 2 have the potential to endanger U.S. national security. The U.S. is working to negotiate an agreement, however, to require the Canadian government to notify the U.S. when it is planning to sell data with resolution better than 5 meters to another party.[62] Even with such an agreement though, the U.S. government can expect to have little control over Canadian (or any other country's) satellites. It will, however, still have the ability to protect U.S. national security through the licensing process for U.S. firms and through its ability to use shutter control.

Effects on the Commercial Satellite Industry

Status quo operations have the potential to offer great benefits to the NRO. One possible benefit is increased efficiency. To achieve a high level of efficiency, though, the satellite industry must first transition "from [its current state as] a craft industry to a manufacturing

industry that can deploy national security space systems better, cheaper, and faster."[63] Such a transition would benefit the NRO because it would improve (even speed-up) the manufacturing processes used by NRO contractors, thereby decreasing the total cost of satellite systems. The problem is that it is difficult for the NRO as an organization to instigate the industry's transition from that of a craft industry to a manufacturing one.

The status quo may also provide the NRO with economic benefits. As the market for commercial remote sensing systems develops, market pressures will move companies to develop systems with characteristics similar to those used by our nation's intelligence agencies. As this trend occurs, *the NRO would be wise to try and influence the designing of features on the American systems so as to make them more useful for the U.S. military.* As the market develops, it may become feasible for the NRO to purchase a commercial-off-the-shelf system rather than developing its own customized system.[64]

One glaring drawback to the status quo option, though, is its effect on the U.S. space industrial base. If the NRO focuses too much on operations and maintenance – two portions of the budget that have increased for existing systems – and does little to support the development of the commercial space market, commercial companies may decide to focus their efforts elsewhere. Companies like Orbital Sciences and Itek could engage in a large-scale production shift in which they concentrate on dual-use products that can be used by the civilian sector as well. Such a shift has the potential to damage the U.S. industrial base for high-technology remote sensing products.[65]

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[62] Galloway, Page 2 of 2.
[63] Hall, Keith R. Statement made at the Hearing on U.S. Spacepower in the 21st Century. 29 Sep 1998. Page 4 of 4.
[64] Caballero, Julian and Keith Hazard. "Reconnaissance and Battlefield Awareness." *New World Vistas Air and Space Powers for the 21st Century.* Space Applications. vol. 45.
[65] Gutmanis, Ivars. "Technology and the Industrial Base." *Air and Space Power in the New Millennium.* Ed. by Daniel Goure and Christopher Szara. 1997. 146.

Political Feasibility

This option is politically feasible given the current status of the commercial market. The NRO would need to work with Congress, however, to gain permission to use streamlined business practices. Incorporating such practices would simply enable the NRO to do more. It is worth noting, however, that this option could become increasingly politically infeasible if the escalating costs of increased capabilities collide with the NRO's budget limitations.

Option 2: Outsourcing

A second option for the NRO is to consider outsourcing the development and operation of remote sensing satellites. Traditionally, government agencies have used contracting for their acquisitions process. When a government agency "contracts out," it is essentially paying a contractor to develop the system, and in some cases, maintain it. In all cases, though, government personnel *operate* the system. When a government agency outsources, it pays non-governmental personnel to operate the product, which would be, in this case, a satellite system.[66] If the NRO were to outsource a remote sensing satellite system, a chosen contractor would be responsible for developing, launching, maintaining, and operating the satellite system.

To more fully understand outsourcing, it is useful to look at the experiences of American businesses in the 1980s, when they faced intense competition from global competitors. In order for American firms to survive, they had to fundamentally change the way they did business. While reengineering their business processes, American firms focused on the their core competencies and started outsourcing their non-core functions to other companies that

[66] Kelman, Steven J. Personal Interview. 8 March 1999.

specialized in these particular functions. This practice ultimately helped firms achieve greater business efficiency.[67]

DoD has learned from the experiences of American businesses and is beginning to focus more on its core competency – joint military operations – while making an effort to outsource its non-core functions. In his testimony to the Senate Armed Services Committee, the former Deputy Secretary of Defense, Dr. John White, asserted that DoD "ought to focus on . . . [its] core competencies; that is . . . [its] ability to conduct military operations in the interest of the United States. This is where . . . [DoD's] focus ought to be, not on the ancillary efforts that have to be done to provide the services and goods . . . [DoD needs] to do that [military operations], but effectively on . . . [its] mission."[68] Given DoD's public stewardship, it has an enormous number of responsibilities – some of which can be outsourced.

It is important to note that there are criteria for determining the appropriateness of outsourcing functions. According to Professor Steven Kelman, former Office of Federal Procurement Policy Administrator, an institution should only outsource a particular function when certain criteria are met.

1. The function is not a core mission for the institution.
2. A commercial market place to provide the service already exists.
3. Performance criteria for the function can be easily established.
4. Outsourcing the function achieves cost savings as well as better performance.
5. The function is not inherently governmental.

If a function violates any one of these criteria, it should not be outsourced.

[67] Kelman, Steven J., Michael J. Lippitz, and John P. White. *Reforming the Department of Defense: The Revolution in Business Affairs.* Report of a Conference Sponsored by the Stanford-Harvard Preventative Defense Project. Harvard University. April 30 – May 1, 1998. 9.

[68] White, John P. "Statement of [the] Honorable John P. White, Deputy Secretary of Defense." Dr. White made this statement at the Hearing of the Readiness Subcommittee of the Senate Armed Services Committee on Privatization of Certain Defense Activities. 17 April 1996.

Organizational Capacity for Implementation

Unfortunately, given these criteria, remote sensing is not an ideal candidate for outsourcing. First of all, since the commercial remote sensing market is in its nascent stage, it is not clear that the NRO could necessarily achieve significant cost savings by outsourcing its remote sensing function, violating the fourth criterion. Furthermore, providing remote sensing imagery to the intelligence community is a function inherent to the U.S. government, violating the fifth criterion. Thus, outsourcing its remote sensing responsibilities may not be the wisest path for the NRO to choose.

Effects on U.S. National Security

Outsourcing poses significant risks to U.S. national security. First of all, outsourcing the production of remote sensing imagery could threaten DoD's ability to have unfettered access to such imagery in the future. It would also divest the U.S. government of the capability to independently provide remote sensing imagery. Clearly, the type of dependence upon the commercial industry that outsourcing requires poses substantial security concerns.

Effects on the Commercial Satellite Industry

Outsourcing would greatly benefit the commercial satellite industry, however. The market would mature as private corporations competed to obtain NRO contracts. Commercial companies operating these systems for the government would gain the technological experience necessary for successfully competing in the commercial market.

Political Feasibility

A major downside, though, is that this option is not politically feasible. It is important to note that the U.S. Congress is often reluctant to approve outsourcing measures for DoD military

functions; it is unwilling to even allow DoD functions that are clearly *support* in nature to be outsourced. For example, in 1996, Congress was reluctant to outsource more depot maintenance – a function that is important, but clearly just support in nature. Given this tendency, *it is unlikely Congress will support outsourcing something as important to national security as satellite imagery.*

Option 3: Government-Private Sector Cooperation

A third option is for the NRO to enter into a cooperative arrangement with commercial remote sensing companies. This option could take on a number of different possibilities. One such possibility is for the NRO to negotiate an agreement with a commercial firm for permission to attach a high-resolution camera to the company's remote sensing satellite. A second possibility is for the U.S. government to allow an American remote sensing firm to develop a system with a resolution sharper than 1 meter, and then purchase this high-end imagery while requiring the company to sell degraded imagery to other buyers. A third possibility would be for the NRO to purchase a commercial off-the-shelf (COTS) system, as COTS would offer the NRO efficiency and value.

Organizational Capacity for Implementation

The reason why the NRO might want to enter into a cooperative agreement with a private company is so that it can achieve cost savings. The NRO is well organized and thus able to negotiate the necessary agreements to implement any cooperative project it chooses. With regard to the camera-attachment possibility, however, Dr. Robert Hermann, former NRO Director, is very skeptical. He believes that the system impact of such an add-on would be substantial and affect launch parameters, system weight, thermal balance, and sensor interaction

in design and in operation. He believes this impact to be sufficient to drive the cost for equivalent performance high enough so that it would likely be cheaper for the NRO and their potential partner to launch separate satellites.[69]

Effects on U.S. National Security

There are also security hurdles associated with this particular option. Satellite control is the major concern. If an NRO camera were placed on a commercial satellite, it is not clear who would have priority in the case of competing targeting requirements. If the U.S. government wanted imagery on one target while concomitantly a commercial buyer wanted imagery on another target, contractual issues and market share would determine which customer received priority – something to which the U.S. government would be unwilling to be subjected.

With regard to the second arrangement, if a commercial company were to develop a high-resolution satellite and sell its best imagery to the U.S. government and its degraded imagery to commercial sources, it could eventually face market pressures that would force it to sell the better imagery to other customers. In response to such a chain of events, the U.S. government could conceivably impose restrictions on commercial companies through the licensing process or through its right to impose shutter control on commercial U.S. remote sensing satellites.

Another hurdle is that the commercial company's operations personnel would have to obtain security clearances, as the NRO's target list would be highly classified. These targets would also have to be removed from all public listings of targets for the commercial satellite.

Effects on the Commercial Satellite Industry

Government-private sector cooperation would benefit the U.S. commercial satellite industry, as commercial companies would have the opportunity to work with advanced

[69] Hermann, Robert J., Dr. Telephone Interview. 16 March 1999.

technologies that may benefit their own systems. This option would also provide commercial companies with a guaranteed source of income from the NRO.

Political Feasibility

For this option to be politically feasible, the NRO would need to assure Congress that U.S. national security would be protected. With recent reports of possibly detrimental advanced technology transfers, however, Congress is likely to be skeptical of at least the first two cooperative proposals.

Option 4: Staking out a Niche and Utilizing Commercial Systems

The fourth option is for the NRO to stake out an operational niche in space reconnaissance and utilize commercial systems to augment government remote sensing systems. An operational niche would allow the NRO to provide a unique capability to the national intelligence community.

Organizational Capacity for Implementation

If the NRO were to occupy a particular niche within the remote sensing realm, then it would be the sole provider of that particular capability. It would purchase images not accounted for in its niche, and provide them to the U.S. intelligence community. By allowing the NRO to take advantage of commercial products, this policy option would reduce the number of areas in which the NRO would have to focus its R&D money. Under this option, the NRO could enter into a "service purchase agreement with one or several of these commercial ventures [to] provides [sic] products for use in the more mundane applications of overhead imagery – mapping, for example – and reduce the tasking conflicts on the more capable military and NRO

systems."[70] This "service purchase agreement" would also allow the NRO to purchase (or lease) a commercial system during crises so as to improve its coverage of the area in question.[71]

In pure economic terms, an operational niche represents a monopoly on a certain segment of the market. The identification of possible mission niches for the NRO arises from the identification of a gap between current commercial remote sensing capabilities and NRO mission requirements. Occupying a particular niche would allow the NRO to focus more of its R&D and procurement funds on a particular segment rather than on the full spectrum of intelligence satellites. For example, two current NRO operational niches include SIGINT and ballistic missile early warning satellites, because commercial satellites with these two capabilities are nonexistent. By developing and operating satellites that perform these functions, the NRO provides a unique capability for the national intelligence community.[72]

Possible operational niches for the NRO exist in the area of high-resolution imagery. Current commercial high-resolution satellite systems can provide imagery with resolution up to 1 meter and a best revisit rate of approximately four days. Thus, the gap that needs to be filled is the provision of imagery with a resolution greater than 1 meter and a revisit rate that is faster

[70] Caballero and Hazard, 45.

[71] The National Imagery and Mapping Agency (NIMA) is already moving in this direction. NIMA's current strategic plan states that making good use of commercial imagery is now a high priority objective. The agency has four principle reasons for wanting to employ available commercial imagery: it is unclassified; it has improved spatial resolution and geopositional capabilities; it covers a broader range of the spectrum; and it has utility as a backup for national systems (Grundhauser, 50-51). At the end of 1998, NIMA awarded fifteen contracts for imaging in three general areas: surveying; mapping and charting; and intelligence and photogrammetic services. It awarded these contracts in an effort to be more responsive to military and government customer requirements. NIMA believes these contracts signal a "carefully planned effort between government and industry to build long term commercial partnerships and expand technology transfers" (NIMA Press Release 990113-1. "National Imagery and Mapping Agency Awards Omnibys Contracts." http://164.214.2.59/general. Page 1 of 2.).

[72] The use of SIGINT and ballistic missile early warning systems is for illustrative purposes. SIGINT and ballistic missile early warning systems are classic examples of a core government function. A need for these types of systems does not exist in the commercial world, so the government must provide these capabilities for them to be accomplished.

than four days.[73] Customers in the commercial market, however, have little demand for such a relatively expensive capability, as mineral deposits, crops, and topographical features do not change states rapidly enough to require frequent satellite revisits.

One way to provide this capability is to develop geosynchronous systems. While engineers have successfully simulated such a system, contractors have been reluctant to develop a prototype.[74] Another way to provide rapid revisit rates is to have a constellation of satellites in low earth orbit. As it stands, Resource 21's R21A, B, C, and D satellites are scheduled for launch in 2000 (see Appendix 2) – a constellation of four satellites that will provide the most rapid revisit time to date, which is about four days. Extrapolation implies that a constellation of 16 satellites would provide a one-day revisit rate. The GPS constellation provides worldwide coverage with 24 satellites.[75] Consequently, the NRO could probably field a constellation of 16 to 24 satellites in low earth orbit to provide high-resolution imagery with almost real-time, worldwide coverage.

By staking out such a niche in the spectrum of imagery functions, the NRO will be able to incorporate Professor Porter's ideas of scope and competitive advantage. In essence, it will demonstrate its recognition "that our foes and friends will all have useful military space imagery available to them and that [the NRO] should capitalize on that same availability and reserve [its] investments for the margin: for those capabilities too esoteric for commercially profitable investment but still of importance to the American warrior."[76]

[73] Satellites with rapid revisit rates are necessary to provide global information superiority to the warfighter. This particular type of satellite reconnaissance is vital for DoD operations in terms of assessing how certain areas are changing in real- or at least near real-time (e.g., aircraft movements, force buildups, etc.).
[74] Caballero and Hazard, 43.
[75] Kruczynski, Leonard R. "Global Positioning System." *Microsoft Encarta 97.*
[76] Caballero and Hazard, 33.

Effects on U.S. National Security

The Land Remote Sensing Policy Act of 1992 places constraints on the niche option by requiring commercial corporations to provide unenhanced data of a foreign nation to that particular nation, thereby enabling the nation to know the chief areas of U.S. interest. Given this situation, the NRO will have to work with the Secretaries of Defense, State, and Commerce to ensure that this requirement of providing other nations with imagery of their own territory would not apply to NRO purchases.

Although foreign sources of commercial remote sensing imagery offer good possibilities, the NRO must be prudent in its use of foreign remote sensing products. Ivars Gutmanis warns, "Buying abroad increases the supplier market and may lower costs, but it can undercut domestic vendors, erode the U.S. industrial base, and result in the unexpected denial of critical components because of political and/or economic changes in the source country."[77] The NRO must protect itself from relying solely on a foreign source that could be cut-off at a critical juncture.

Effects on the Commercial Space Industry

The niche option, like the outsourcing and government-private sector cooperation options, would enhance the U.S. commercial space industry by stimulating further commercial development. Analogies from the development of naval and air power are appropriate to mention in this context of space power development. According to Colonel Klotz, Alfred Thayer Mahan and General Henry "Hap" Arnold asserted that the ability to operate at sea and in the air "meant wider access to markets and the ability to bring economic and military power to bear where national interests were at stake. A robust technological industrial infrastructure was

[77] Gutmanis, 147.

considered essential not only to sustain a worldwide presence, but also to provide the intellectual know-how and material capacity to produce and employ large fleets of naval and air forces in the event of armed conflict."[78] Similarly, the development of intellectual know-how and material capacity for space will be essential for the future.

Political Feasibility

We believe the fourth option is politically feasible, as the U.S. is already purchasing commercial remote sensing products for military applications. This option would simply make this process of purchasing commercial produce systematic.

Because the Land Remote Sensing Policy Act of 1992 presents some problems with regard to this option, the NRO will have to work within the existing framework to exempt its purchases from disclosure requirements or else influence Congress in such a way that it will grant a statutory exemption.

There are political consequences associated with this option. Since the government will undoubtedly ensure that it gets a good price on the products it purchases, some individuals are concerned. One expert summarized this concern with the following statement: "Government entry into the market inevitably distorts the market and undermines incentives to lower costs or improve capabilities, encouraging firms instead to pursue government contracts and to polish their lobbying expertise. This sort of environment is destructive to efficiency, and to the political system itself."[79]

[78] Klotz, 47.
[79] Grundhauser, 4. Grundhauser quotes Glenn Harlan Reynolds, Chairman of National Space Society, in a letter to the Chairman of the House Subcommittee on Science, Space, and Technology. 9 Feb 1994.

National Security Implications for Any Policy Option

Despite which policy the NRO chooses to pursue, commercial remote sensing satellite systems will continue to have a dramatic impact on U.S. national security. The data provided by these commercial systems have obvious strategic implications, as they have the resolution necessary for detecting military installations and troop movements. These systems also have other implications. For instance, one country could use these systems to determine if an agricultural competitor was having a poor harvest. If so, the imaging country could use this information to its advantage in negotiations on grain purchases. A similar scenario could happen in various other markets, such as oil or gas exploration.[80]

The existence of commercial remote sensing systems will also have a tremendous national security impact in the arms control arena. Nations that previously could not verify arms control treaties because they lacked National Technical Means will be able to purchase commercial imagery to perform this function. Commercial imagery could also have implications for nations trying to circumvent arms control treaties. These nations could use commercial imagery in an attempt to gauge what U.S. national technical means can verify. This knowledge would allow these nations to develop better schemes to avoid detection, thereby increasing the likelihood that nations will try to cheat on arms control agreements.[81]

In a conflict situation, the adversary may employ commercial remote sensing systems to collect data on U.S. forces. In the past, the U.S. military would neutralize the adversary's capacity to collect reconnaissance information on U.S. forces. However, this will not be an option for the United States if it is an allied nation operating these systems. Furthermore, these systems may continue to provide information to nations uninvolved in the conflict. Therefore,

[80] Goldman, 185.
[81] Grundhauser, vii.

the military needs options other than those that stress neutralizing these assets by destroying them.[82] However, the availability of commercial data to an adversary may not provide as much an advantage as it may initially appear. It has taken the United States over thirty years to develop the necessary analytic capability necessary to interpret the data. Other nations will lack this capability, at least in the near term. As some analysts argue, the intelligence "advantage will be with the U.S. for many years."[83]

EXTERNAL POLICY CONSIDERATIONS

Beyond its internal management of resources and funds, the NRO can pursue its strategy by taking steps to shape events external to its organization. Specifically, by looking at a desired end-state for the U.S. commercial imagery market, the organization can seek to influence those who have the authority to make the decisions that affect this end-state. Understanding that the United States currently has an advantage in imagery capabilities and that it has declared policies to strengthen commercial development, the government can seek to either maximize profits or monopolize the global commercial imagery market.

Due to limited competition and the fact that systems are very costly, the United States need only set its price equal to the marginal cost of the closest competitor if it wants to maximize profits. Such a pricing strategy keeps domestic companies competitive while allowing them to sell at prices high enough to cover their costs. The drawback to this option is that the United States has no regulatory (i.e., shutter control) power over its foreign competitors.

If the U.S. goal is to dominate the market, then domestic producers can dump their imagery at low prices to customers (even perhaps adversarial ones, under the theory that "if we

[82] Caballero and Hazard, 38.
[83] Ibid, 45.

don't sell it, then somebody else will"), thereby driving out the foreign competition. Obviously, some foreign systems funded by their own governments will still operate. This option is not as economically appealing in the short run because of the low prices that the firms would have to initially endure. Over time, thought, producers could raise prices at least until the threat of competition reemerges. Nonetheless, it does provide the United States greater leverage in enhancing its national security by subjecting virtually all imaging satellites to the U.S. government's licensing process and its corresponding regulations. This goal is thus the more appealing alternative for the NRO, since it has an advisory role within the intelligence community regarding the licensing of satellite launches.

A way to get the best of both worlds is quiet diplomacy. By making both the threat of low-priced competition and the potential for dumping apparent to foreign competitors, such as CNES and its SPOT system, the government can bargain with other countries regarding adversary access and a pricing strategy. Striking an agreement as such could both ensure a globally competitive market and minimize the threat to U.S. national security presented by the profit-maximizing strategy described above.

RECOMMENDATIONS AND CONCLUSIONS

Based on our needs-resource assessment, we have concluded that the most efficient objective for the NRO is to pursue a niche of high-resolution remote sensing systems augmented by commercial sector capabilities. As Ms. Cheryl Roby, Principal Director for Intelligence in the Office of the Deputy Assistant Secretary of Defense (Intelligence & Security), recently asserted, "The question is not 'if' commercial imagery will be purchased. The question is only

when, and under what circumstances."[84] Planned and licensed commercial systems are capable of providing imagery with resolution up to one meter and with a revisit rate of four days. The NRO should focus its efforts to provide systems with technical capabilities greater than that of the commercial market. The NRO should exploit existing commercial remote sensing systems to supplement government remote sensing systems. In so doing, it should consider developing a system similar to the Civil Reserve Air Fleet (CRAF). The CRAF allows the U.S. government to supplement its airlift capability by utilizing commercial airlines to transport troops and equipment during times of national emergencies. To provide an incentive for commercial airlines to participate in this system, the government provides financial compensation.[85] A similar remote sensing arrangement during national emergencies would enable the NRO to augment its own niche systems with the capabilities of commercial remote sensing satellites.

The analogy between the CRAF and the use of commercial satellites has an important difference, however, that must be understood. The aircraft used in the CRAF program are used for support missions and are in relatively little danger. The NRO would be using commercial systems for actual operations – an environment that would increase the threat to these satellites. As the NRO relies more heavily on commercial systems, it will face greater claims from the commercial companies to protect, or harden, their satellites. Hardening satellites adds weight to the system, which, in turn, increases the total cost of launching them. Commercial companies would be less willing to add this weight while they do not see the current threat to their systems.

The continuing commercialization of space poses great challenges and opportunities. It is in the national interest for the United States to remain a leader in space despite the growing

[84] Statement for the Record of Ms. Cheryl Roby, Principal Director for Intelligence, Office of Deputy Assistant Secretary of Defense (Intelligence & Security), Office of the Assistant Secretary of Defense (Command, Control, Communications and Intelligence). Subcommittee on Space and Aeronautics, House Committee on Science, Hearing on H.R. 1702. 4 June 1997. http://www.house.gov/science/roby_5-4.html. Page 5 of 9.

challenges. In many circumstances, economic interests conflict with security interests in this burgeoning field. As Colonel Klotz argues, "Striking a balance between economic and national security interests in the sale of advanced technology has always entailed a judgment about relative risks and the establishment of safeguards that serve both interests. The danger is that well-intentioned efforts to maximize one interest could cause the other to suffer. In striking this balance, it is probably best at the moment to *err of the side of promoting the development and competitiveness* of the American space industry" [emphasis added].[86] These recommendations should help the NRO strike this balance and ensure that the NRO can provide the proper information to tomorrow's warfighter as well as ensure global information superiority.

[85] Civil Reserve Air Fleet Fact Sheet. United States Air Force. http://www.af.mil. Page 1 of 4.
[86] Klotz, 53.

APPENDIX 1: COMMERCIAL REMOTE SENSING SYSTEMS

United States

Program/Company	Attributes

LANDSAT	• U.S. Department of Interior initially developed the idea for LANDSAT in the mid-1960s.
	• NASA launched the first LANDSAT in 1972.
	• Original LANDSAT provided multispectral imagery with resolution around 80 meters.[87]
	• LANDSAT 7 is scheduled for an April 15, 1999, launch.
	• LANDSAT 7 will carry an Enhanced Thematic Mapper Plus (ETM+). This eight-band instrument is capable of:
	  • 15-meter ground resolution in the panchromatic band
	  • 30-meter resolution in the short-wave infrared, near-infrared, and visible bands
	  • 60-meter resolution in the thermal infrared.[88]

WorldView	• WorldView plans to deploy two remote sensing satellites in the near future that will both have a multispectral sensor and a high-resolution sensor. • The multispectral sensor will operate in the green, red, and near infrared bands to provide 15-meter resolution. • The high-resolution sensor will provide panchromatic images with 3-meter resolution. • Operates like a camera, taking one picture as it passes over the target area. • The sensor can be tilted in such a way that it can provide a "stereo" view. • This system will also report the satellite's position and orientation so that the user can determine the location of features within the image without having to use ground references. • WorldView satellites will have on-board data storage and will download data when a WorldView ground station comes into range.
Lewis and Clark	• This is a project NASA has undertaken within its Small Spacecraft Technology Initiative. • Lewis was launched in July 1997, but has yet to begin working. • The Clark satellite employs an EarthWatch EarlyBird satellite as its platform. • 3-meter resolution panchromatic sensor. • 15-meter multispectral sensor. • Other scientific instruments include an X-ray spectrometer and a sensor to perform atmospheric tomography.[89]

[87] Multispectral Scanner LANDSAT Data. http://edcwww.cr.usgs.gov/glish/hyper/guide/landsat.
[88] *Landsat 7 Facts.* http://geo.arc.nasa.gov/sge/landsat/17.html. Page 1-2 of 3.
[89] Grundhauser, 12.

United States (continued)

Program/Company	Attributes
Space Imaging	• This is a product of Lockheed-Martin's Space Imaging Incorporated. • Panchromatic sensor will produce images with 1-meter resolution. • Multispectral sensor will operate in four spectral bands with 4-meter resolution. • SIS will use the "pushbroom" method to acquire images.[90] • The satellite has the option of downloading images in real time if a ground station is in range or storing them on-board until a station comes into range. • Space Imaging Incorporated will use regional franchises to handle data reception, distribution, and archiving. These franchises will have the capability to program the image target and the acquisition schedule to the satellite without going through the satellite's maker.[91]
Orbimage	• Orbimage's plans include the 4-satellite Orbview system. • Orbview-1 takes weather images. • Orbview-2 takes images of the earth's surface features. • Orbview-3 and 4 will have panchromatic 1-meter resolution and multispectral 4-meter resolution. • Orbview-4 will be the first ever hyperspectral satellite (8-meter resolution).[92]
Earth Watch	• EarlyBird 1 was launched in December 1997. • EarlyBird 1 provides 3-meter resolution and is the world's first commercial high-resolution satellite ever successfully launched. Four days after its launching, however, the system failed due to an on-board power system problem. • QuickBird is EarthWatch's next generation of satellites. • QuickBird will carry a panchromatic sensor with 1-meter resolution and a multispectral sensor with 4-meter resolution.[93] • QuickBird 1, scheduled for launch later this year, will be the only system launched in a non-sun-synchronous, non-polar orbit - a characteristic giving it the unique ability to observe locations on the earth at different times of day under different lighting conditions.[94] • Once the satellite collects the image, then it will be relayed through a network of two ground stations (one in Norway, the other in Alaska) linked to Mission Control, which is located at EarthWatch Headquarters in Colorado.

[90] With the "pushbroom" method, the satellite tilts forward as it approaches the target area. Once it is over the target area, the satellite looks straight down. After passing the target area, the satellite tilts back to its original position.
[91] Gupta, Vipin. "New Satellite Images for Sale: The Opportunities and Risks Ahead." *International Security*. http://www.llnl.gov/csts/publications/gupta/sat.html. Pages 1-17 of 17.
[92] Orbimage web-pages. "Orbview-3: High-Resolution Imagery in Real Time." http://www.orbimage.com/satellite/orbview3/orbview3.html and "Orbview-4: High-Resolution Imagery and Hyperspectral Data." http://www.orbimage.com/satellite/orbview4/orbview4.html.
[93] EarthWatch webpage. http://www.digitalglobe.com/company/spacecraft/.
[94] This characteristic is remarkable in that the industry standard for such systems is to work in a sun-synchronous near polar orbit.

United States (continued)

Program/Company	Attributes
GER	• With the launch of its first satellite scheduled for 2001, the Geophysical & Environmental Research Corporation (GER) will focus on the agricultural market with its 4-day revisit imagery.[95] • Each of GER's six satellites will feature a better than 5-meter panchromatic sensor coupled with 10-meter multispectral sensor.[96]
Eyeglass	• This satellite is the result of three companies – Orbital Sciences, Itek, and GDE Systems – involved in the production remote sensing products for the U.S. intelligence community. • The high-resolution sensor will be able to provide panchromatic images at 1-meter resolution. • The system will have the capability to produce regular images that are 120-by-120 kilometers and stereo images that are 70-by-70 kilometers. The standard image will be 15-by-15 meters. • The satellite will have a GPS receiver, an Earth sensor, and a sun sensor to calculate the satellite's position, thereby improving the system's accuracy. • Eyeglass will also use a series of regional ground stations to download data, and images not downloaded will be stored on-board the satellite. • The producers of Eyeglass are planning to offer two types of licenses – Gold and Platinum. • Gold agreements will grant distribution rights to the user within that user's state • Platinum agreements will be issued for a geographic region with a radius of 2,600 miles.
ERSI	• Earth Resource Surveys Incorporated is developing the highly capable IKONOS system. • Boasting "a level of detail that is far superior to any currently operational commercial satellite," the first IKONOS (of two) satellite is scheduled for a spring 1999 launch and capable of 1-meter panchromatic/4-meter multispectral resolution.[97] • Revisit times have been calculated at 11 days per satellite.[98]

Europe

Program/Company	Attributes
ERS Series	• The European Space Agency operates this series of remote sensing satellites. • Use synthetic aperture radar systems with a resolution ranging from 10 to 30 meters.[99]

[95] "GEROS." http://www.ger.com/geros.htm. page 1 of 2.
[96] KPMG, 26.
[97] "IKONOS Image Products." http://www.ersi.bc.ca/ikonos.html. pages 1 and 2 of 3.
[98] KPMG, 22.

France

Program/Company	Attributes
SPOT	• The French national space agency – Centre Nationale d'Etudes Spatiales (CNES) – owns and operates the SPOT program. • Images from this program are distributed worldwide through private companies – even to the United States. • During the Gulf War, the U.S. Air Force became "the single largest consumer of SPOT imagery, which was particularly useful because of its wide-area coverage and utility in feeding the Air Force mission rehearsal and planning systems."[100] • Multispectral images taken in the green, red, and near infrared (IR) ranges have a resolution of 20 meters. • Panchromatic images are black and white and provide 10-meter resolution.[101] • SPOT 4 will continue to provide the same imagery as its predecessors with new additional features, such as a middle IR band and a Vegetation Monitoring Instrument with 1-kilometer GSD for daily global coverage. • SPOT 5 – with its sophisticated post-processing technique whereby "two separate 5-meter GSD images are blended to yield 2.5 to 3-meter GSD panchromatic images . . . without sacrificing the standard 60 square kilometer area of earlier SPOT systems"[102] – will produce images for non-military consumers. • SPOT 5 marks a significant policy reversal for the French, as in the past, the French government reserved imagery with a resolution better than 5 meters for its own military.

Russia

Program/Company	Attributes
KVR-1000	• This satellite produces panchromatic images degraded to two-meter resolution. • It uses ejected canisters to return its film to earth. • The system's full capabilities are not fully known, because the Russian intelligence community still uses the KVR-1000 system to gather intelligence. • It is difficult to gauge the time needed to fill an image order because the process is still covert. • Provides greater resolution than any other commercial system.
System TK	• Follow-on system to KVR-1000, which Russia plans to launch late next year. • It has 1-meter panchromatic imagery, 4-meter multispectral imagery, and 2-meter synthetic aperture radar imagery.[103]

[99] Ibid, 16.
[100] Grundhauser, 16.
[101] SPOT High Resolution Visible Data. http://edcwww.cr.usgs.gov/glis/hyper/guide/spot.
[102] Grundhauser, 16.
[103] Ibid, 12.

South Africa

Program/Company	Attributes
Greensat	• It has a multispectral camera that operates in the red and near infrared bands, providing 16-meter resolution. • The high-resolution camera provides panchromatic images at 1.8-meter resolution while operating in the green, red, and near infrared bands. • This system has a longer "dwell time" than other sensors, thereby increasing the signal-to-noise ratio to provide a sharper image. With the maximum dwell time, the system can produce an image that covers 8-by-5.5 kilometers. • It operates using the "pushbroom" method to enable the satellite to produce stereo images of a particular target. • It does not store images on-board, but rather transmits the digital images to ground stations in real time. This set-up implies that Greensat's global coverage capability depends upon the distribution of regional ground stations. • On future satellites, the company plans to place a synthetic aperture radar (SAR) system on-board that will provide 3-meter resolution. The SAR will enable the satellite to penetrate cloud cover and take images at night.

Canada

Program/Company	Attributes
RADARSAT	• It was first launched in October 1995 • It has synthetic aperture radar that operates in various modes, allowing for the creation of images with resolutions from 10 meters to 100 meters. • It can penetrate clouds, haze, smoke, and darkness to produce imagery.[104]
RADARSAT 2	• The planned launch is November 2001. • Its synthetic aperture radar will provide resolution of 3 meters. • The Canadian government is funding its development, but a private corporation, Macdonald Dettwiler, will operate the system.[105]

India

Program/Company	Attributes
IRS Series	• IRS-1C and IRS-1D satellites produce imagery with a 5-meter resolution. • The two-satellite constellation makes for a revisit rate that is between three and five days.[106]

[104] Ibid, 14.
[105] Galloway, Gloria. "U.S. Reluctant to Launch Canadian Satellite." *National Post Online*. http://www.nationalpost.com/news.asp?f=990219/2293081. February 19, 1999: Pages 1-2 of 2.
[106] Grundhauser, 16.

Australia

Program/Company	Attributes
ARIES	• ARIES is the Australian Resource Information and Environmental Satellite. • It produces 10-meter panchromatic imagery for agriculture applications such as measuring crops, soil conditions, and vegetation status. • It can produce 30-meter resolution hyperspectral imagery.[107]

Israel

Program/Company	Attributes
EROS	• This is a joint venture between Israel Aircraft Industries and CORE Software Technology of California. • This joint venture, West Indian Space, Ltd., is incorporated in the Cayman Islands, thereby allowing the company to avoid U.S. licensing restrictions for commercial imagery satellites. • EROS-A will provide 1.5-meter imagery with its panchromatic sensor with a three-day revisit rate. • The panchromatic sensor on the next generation satellite will provide 0.82-meter imagery. • West Indian Space is marketing EROS as a turn-key national imagery satellite program priced to sell for $10 million annually.[108]

China and Brazil

Program/Company	Attributes
CBERS	• The China-Brazil Earth Resources Satellite (CBERS) is preparing to launch the five satellites, each of which can collect 20-meter imagery.[109] • The first satellite was to go up in 1998, with the next three satellites scheduled for 1999, 2000, and 2001.[110]

[107] Ibid, 17.
[108] Ibid, 17.
[109] "CBERS." http://www.nma.embrapa.br/satellite/cbers.html. pages 1 and 3 of 4.
[110] KPMG, 33.

APPENDIX 2: LAND IMAGING SATELLITES PLANNED TO BE OPERATIONAL BY 2000

Source: Mitretek, 16 February 1998

System	Owner	Sensor	Launch Date	Spatial Resolution (meters)									Stereo Type	Swath (km)	Global Revisit (days)
				Pan	Thematic Upper Bands							Radar			
					Visible & Near IR				Short Wave IR		Thermal IR				
					1	2	3	4	5	7	6				
Multispectral															
IRS-1C,D	India	M & P	95,97	6		23	23	23	70				C/T	70,142	48,24
IRS-P5, IRS-2A	India	M	98,99			6, 23	6, 23	6, 23	23				C/T	25,142	125,22
SPOT 4	France	M & P	97	10		20	20	20	20				C/T	120*	26
CBERS	China/Brazil	M & P	98,99	-.8	20	20	20	20	80	80	160		C/T	120	26
Landsat 7	U.S.	M & P	98	15	30	30	30	30	30	30	60			185	16
EOS AM-1	U.S./Japan	M	98			15	15	15	6 bands @ 30		5 bands @ 90		F/A	60	49
R21A,B,C,D	Resource 21	M	00		10	10	10	10	20					200*	4[t]
High-Resolution															
EarlyBird 2	EarthWatch	M & P	98	3		15	15	15					F/A	36	120
IKONOS 1,2	Space Imaging EOSAT	M & P	98,99	1	4	4	4	4					F/A	12	247
Quickbird 1,2	EarthWatch	M & P	98	1	4	4	4	4					F/A	20	148
Orbview 3	ORBIMAGE	M & P	98,99	1&2	8	8	8	8					F/A	4 & 8	740,370
SPIN-2	Russia[+]	P	96,97	2,10									F/A	180,200	
Eros-A	West Indian Space	P	98	1.5									F/A	14	211
Eros-B	West Indian Space	P	99	1									F/A	20	148
IPS-P6	India	P	99	2.5									F/A	10	298
Hyperspectral															
EO-1	U.S.	H & M	99		128 bands @ 30				256 bands @ 30					15	200
HRST	U.S.	H	00	5	210 bands @ 30									30	100
ARIES	Australia	H	00	10	32 bands @ 30				32 @ 30					15	200
Radar															
RADARSAT	Canada	SAR	95									10 C-band		50-500	
ERS	ESA	SAR	98									25 C-band		100	

KEY: P=Panchromatic M=Multispectral H=Hyperspectral F/A=Fore/Aft stereo C/T=side-side stereo SAR=Synthetic Aperture Radar

* Swath is achieved by two side-by-side instruments

[t] Four (4) satellites planned to provide 3.5-4 day global repeat coverage

[+] Photographic film return system

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