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U.S. Commercial Remote Sensing Satellite Industry: An Analysis of Risks

Kevin M. O'Connell, John C. Baker, Beth E. Lachman, Steven Berner, David Frelinger, Kim E. Gavin

National Security Research Division

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Prepared for the U.S. Department of Commerce

National Security Research Division

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PREFACE

This report assesses the key risks facing the emerging U.S. commercial remote sensing satellite firms against the backdrop of trends underlying the larger remote sensing industry and geospatial technology marketplace. These risks are defined broadly to include technical, market, as well as policy and regulatory factors that could affect the prospects for commercial success of the U.S. private remote sensing satellite firms. The report also examines the opportunities and constraints on U.S. imaging satellite firms that must both compete against and seek partnerships with foreign remote sensing enterprises.

The analysis presented in this RAND report should be of interest to U.S. government decisionmakers who deal with policy and regulatory issues concerning the U.S. commercial remote sensing industry, particularly commercial imaging satellite systems, as well as those analysts concerned with understanding the international context for commercial remote sensing. In addition, the report is relevant to the work of corporate managers, planners, and market analysts involved in the commercial remote sensing satellite industry.

The U.S. Department of Commerce supported this research with the aim of better understanding the role that U.S. government policies and regulations play in shaping the prospects for the emerging commercial remote sensing satellite firms. It was specifically sponsored by the National Oceanic and Atmospheric Administration (NOAA), which has licensing and enforcement responsibilities for U.S. private remote sensing satellites, as well as the International Trade Administration (ITA), which is responsible for promoting the growth and international competitiveness of the U.S. remote sensing industry.

This research was conducted for NOAA within the International Security and Defense Policy Center of RAND's National Security Research Division which conducts research and analysis for the Office of the Secretary of Defense, the Joint Staff, the Unified Commands, the defense agencies, the Department of the Navy, allied foreign governments, and foundations.

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SUMMARY

Since the advent of Earth observation satellites nearly four decade ago, governments have been the leading providers and users of satellite imagery data. However, this has recently changed as several U.S. and foreign companies have begun to acquire and launch their own imaging satellite systems. Some American firms are already operating their own imaging satellite systems (e.g., OrbImage's OrbView-2 and Space Imaging's IKONOS). These companies aim to become an important part of the U.S. commercial remote sensing industry, which today largely consists of aerial data providers and the value-added firms that play an important role in converting raw imagery data into the products desired by customers. Success for these new U.S. commercial remote sensing satellite firms heavily depends on both understanding and overcoming various risks (e.g., technical, market, policy and regulatory) that could diminish their prospects in the highly competitive global marketplace for geospatial information products and services. Within this context, U.S. government policies and regulations exert a major influence on the ability of U.S. remote sensing satellite firms to realize their competitive potential in both the domestic and international marketplaces.

COMMERCIAL REMOTE SENSING SATELLITES AND U.S. NATIONAL INTERESTS

U.S. government policy has been instrumental in creating the conditions that have encouraged private firms to start new businesses based on commercial observation satellite systems. Congressional passage of the Land Remote Sensing Policy Act of 1992 set forth the legal conditions for U.S. private firms seeking to own and operate remote sensing satellite systems. The Bush administration issued the first license, which authorized a U.S. commercial imaging satellite that could collect 3-meter (m) resolution imagery, in January 1993. Building on these legislative and executive precedents, the Clinton administration adopted Presidential Decision Directive 23 (PDD-23) in March 1994 as an important enabling document for commercial remote sensing. PDD-23 outlines the U.S. government's guidelines for granting operating licenses to American firms interested in commercial remote sensing satellites, including relatively high-resolution imaging satellites. Since early 1993, the Commerce Department has granted 17 licenses (and numerous amendments) for operating commercial remote sensing satellites to nearly a dozen American firms. PDD-23 also provides guidelines for considering U.S. decisions on requests by American firms to export

sensitive technologies or turn key imaging satellite systems to foreign customers.

U.S. national interests are likely to be affected by whether or not these firms succeed in becoming a viable and productive component of the larger remote sensing industry. U.S. interests go well beyond the commercial success or failure of particular firms. Instead they are rooted in realizing the following broader national benefits from having a robust satellite component to the U.S. commercial remote sensing industry: (1) sustaining the technological leadership of U.S. industry in critical technologies, skills, and know-how associated with both the space and ground segments of imaging satellite systems, (2) enhancing U.S. government access to technological innovation and best practices in the remote sensing marketplace, (3) supplementing U.S. government imaging capabilities during domestic disasters or foreign policy emergencies and (4) reaping larger public benefits from a wide range of civilian and commercial applications of remote sensing data. These benefits include economic development, enhanced environmental monitoring and conservation, improved disaster warning and assessment capabilities, as well as other civilian applications likely to be encouraged by having a robust remote sensing industry.

REASSESSING THE RISK FACTORS FOR COMMERCIAL REMOTE SENSING SATELLITES

This report assesses the key risks facing U.S. commercial remote sensing firms. It provides some much-needed perspective on how these risks, or at least our appreciation of them, have changed from the early 1990s when the U.S. government took important steps to encourage the commercialization of satellite remote sensing. A key conclusion is that the various risks were widely underestimated at the time. Consequently, the new U.S. commercial remote sensing satellite firms are encountering somewhat greater-than-expected challenges in achieving technical success and establishing a niche within the highly competitive marketplace for geospatial technologies and derived information products. Thus, despite some promising starts, most U.S. private remote sensing satellite firms face some potentially serious risks to their long-term commercial success, including:

- *Technical risks* in developing and operating technologically sophisticated imaging satellite systems given that new companies are operating with relatively limited resources and systems acquisition experience compared with U.S. government satellite programs;

- *Market risks* intrinsic to the domestic and international marketplaces for geospatial data and information products and services, including stiff competition from well-established aerial imagery data providers and parastatal (government-owned or heavily subsidized) satellite imagery data providers; and

- *Policy and regulatory risks* arising from uncertainties or constraints created by government policies and regulations on U.S. commercial remote sensing satellite firms, which often do not apply to their aerial and non-U.S. satellite imagery data competitors.

Most observers view these risks quite differently today compared with how they were originally perceived in the early 1990s when most of the U.S. commercial imaging satellite businesses were getting started. Table 1 outlines many of the potential risks that are discussed in this report. Our appreciation of the various risks in different areas is probably closer to reality now than in the mid-1990s because of the greater experience and progress of several U.S. commercial remote sensing firms in better defining and dealing with these risks.

To succeed over the long run, these satellite companies need a combination of reliable technologies, government policies that encourage U.S. industry competitiveness, a strong international presence, and, most important, sound business plans to ensure their competitiveness in both the domestic and international marketplaces. Thus, the authors of this report conclude that the greatest risks for the U.S. commercial remote sensing satellite firms come from the challenge of transforming themselves from imagery data providers to strong competitors as information age companies, the need to master the technical risks of building and operating sophisticated imaging satellite systems, and the requirement to operate effectively in a complex international business environment.

However, the U.S. policy and regulatory environment also exerts a substantial influence on the choices available to these new firms, although its influence on the emerging commercial remote sensing firms does not emulate the importance of the market, technical, and international factors. Assessing the net effect of the policy and regulatory factors is obviously complicated by the multiple roles that the U.S. government plays as regulator, customer, patron, and potential competitor vis-à-vis the commercial remote sensing satellite firms. Nonetheless, a key finding of our research is that risks associated with U.S. government policies and regulations are somewhat lower today than

Table 1: Potential Risks Facing U.S. Commercial Remote Sensing Satellite Firms

	Potential Risks for U.S. Firms
Technology area	Launch or spacecraft failures can require added investment and additional insurance expenditures Shortfalls in spacecraft or sensor performance can diminish imagery data quality and market competitiveness Underdeveloped or invalid algorithms and software associated with user technologies for processing, analyzing, and archiving imagery data can discourage potential customers
Market area	Risks that U.S. commercial remote sensing satellite firms will not succeed in: -leveraging the growth of the broader geospatial technology marketplace -adopting new business models that transform the firms from being traditional imagery data providers into information age companies -effectively competing with aerial remote sensing firms in providing overhead imagery products and services -effectively competing with non-U.S. remote sensing (aerial and satellite) firms in supplying imagery products and services in the international marketplace
International competition and cooperation	The risks of competing in the international marketplace with foreign remote sensing enterprises that are fully owned or heavily subsidized by their governments, and thus relatively insensitive to market factors The proliferation of smaller national remote sensing satellites can reduce the foreign demand for U.S. commercial imagery and absorb limited national resources Non-U.S. restrictions on the use of high-resolution satellite imagery can limit U.S. market access
U.S. policy and regulatory area	Protracted and opaque policymaking can complicate future planning and diminish the company's appeal for outside investors Uncertainty over U.S. policy actions can discourage foreign investors and partners Public access to low-cost or free overhead U.S. government imagery can reduce the potential demand for more expensive commercial satellite imagery

they were when PDD-23, a key set of U.S. policy guidelines, was issued in 1994. While negotiating the policy and regulatory regime remains at times challenging and frustrating for U.S. firms, the authors of this report assess that major progress has been achieved over the past seven years in diminishing the policy and regulatory uncertainties that previously had inhibited the development of the U.S. commercial remote sensing satellite systems. Furthermore, U.S. firms are not unique in being subjected to careful government scrutiny and regulation. Canada has imposed explicit regulations on its own commercial remote sensing satellite activities, with U.S. government encouragement, and other countries are believed to have similar regulations even if these national restrictions are not made public.

Nonetheless, substantial improvements are still required for clarifying and bounding the uncertainties that U.S. commercial firms face from policy and regulatory restrictions. The government's policymaking process has yet to achieve the degree of predictability, timeliness, and transparency that commercial remote sensing firms need if they are expected to operate effectively in a highly competitive and rapidly changing global marketplace.

RECOMMENDED ACTIONS FOR THE DEPARTMENT OF COMMERCE

The Department of Commerce (DOC), and its specific agencies, has an essential role to play in strengthening the U.S. government's policymaking process for commercial remote sensing to ensure that the broader national interests will be realized. The authors of report conclude that DOC can best fulfill its responsibilities for promoting the U.S. commercial remote sensing industry and for encouraging the competitiveness of new private imaging satellite firms by adopting the following recommendations:

- *DOC should continue to create a policy and regulatory environment for encouraging U.S. commercial satellite remote sensing firms consistent with the fundamental PDD-23 concept.* DOC must assume a greater leadership role in the interagency process in setting the tone for a responsive policy and regulatory environment based on the assumption that a synergy exists between promoting American industrial competitiveness in remote sensing space capabilities and protecting U.S. national security and foreign policy interests.

- *DOC should continue the normalization of the regulatory process for commercial satellite remote sensing systems.* Although we conclude that the U.S. policy and regulatory processes are becoming relatively clearer, they are still less than transparent to all parties nor complete in scope. This situation unnecessarily adds to the uncertainties that are inhibiting U.S. commercial remote sensing

firms and their potential investors from proceeding to the next generation of commercial remote sensing satellite systems. Policy restrictions on U.S. firms should be clarified and well bounded, including the issue of operational controls (i.e., shutter controls).

- *DOC should keep abreast of the changing relationship between aerial and satellite remote sensing firms.* Part of the Department's advocacy role on commercial remote sensing should be to provide, in an open and impartial fashion, a government perspective on how remote sensing markets are evolving. Hence, DOC needs to take a broader perspective on understanding the evolving relationship between the satellite and aerial components of remote sensing to ensure that these dynamics are adequately considered in U.S. policy and regulatory decisions that affect the remote sensing industry.

- *DOC should monitor developments in the broader geospatial and information technology services industries for their relevance to commercial remote sensing.* Beyond understanding trends in remote sensing, DOC must strive to understand how the potential for commercial remote sensing are is affected by trends in the broader geospatial and IT market. The long-term health of the remote sensing industry strongly depends on the future growth of the geospatial and information technology services industries. DOC must ensure that policies and regulations for satellite remote sensing do not unduly constrain the ability of remote sensing firms as they position themselves to capitalize on that growth.

- *DOC should monitor foreign actions that could reflect efforts to restrict market access by U.S. commercial remote sensing firms.* DOC needs to have a good understanding the broader foreign dynamics, including non-U.S. domestic regulations on access to commercial satellite imagery data and services, in order to ensure fair market access for U.S. firms. Whether drawing on its own information sources, or working with the State Department and the Intelligence Community, DOC needs to distinguish between outdated regulations and cases where such domestic regulations are being unfairly exploited to impose trade barriers for protecting national remote sensing programs.

- *Recommendation: DOC should dedicate more resources to undertaking its responsibilities in supporting the licensing and regulation of U.S. commercial remote sensing satellites, as well as should better leverage the broad range of U.S. government resources and expertise that are available in this area.* Although DOC is the lead agency for licensing and regulating U.S. commercial remote sensing satellite firms, it has a relatively small amount of resources devoted to carrying out its multiple responsibilities, including the advocacy and regulatory roles. DOC needs to dedicate more internal resources, as well as take greater advantage of the substantial expertise available within the U.S. government, to ensure that the best assessments are available to policymakers in considering future licensing and regulatory decisions for second generation imaging satellite systems. An important element in these assessments will be to include forward-looking analyses of non-U.S. capabilities, plans, and motives rather than basing U.S. policy decisions only on the current capabilities of operational foreign remote sensing satellite systems.

Along with these recommendations for DOC, this report also offers some complementary recommendations for the commercial remote sensing industry that are presented in detail in the conclusions chapter.

Although the policy and regulatory environment is not the predominant risk factor affecting the long-term viability of the new U.S. commercial remote sensing satellite firms, the U.S. government continues to play important, multiple roles that shape the opportunities and choices available to private companies. Thus, eventually realizing the potential national benefits of having a robust satellite component within the larger commercial remote sensing industry requires the U.S. government to play a proactive role in both promoting and regulating these firms without placing them at a substantial disadvantage compared with their domestic and international competitors.

ACKNOWLEDGMENTS

The authors have benefited from numerous discussions with representatives of U.S. government agencies; managers and experts in the remote sensing industry, including the senior managers at several of the U.S. commercial remote sensing satellite firms; value-added firms and other firms active in the geospatial technology and information market; and with professional organizations with a strong interest in imagery information questions.

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An important part of this study was gaining insights from private firms and nongovernmental organizations concerned with the development and operations of the commercial remote sensing industry. The following commercial firms provided information and insights relevant to our research: EarthData International, DigitalGlobe, ERDAS, Orbital Imaging Corporation, Pixsell, Kodak, and Space Imaging. In addition, we acknowledge the American Society for Photogrammetry and Remote Sensing (ASPRS), the OpenGIS Consortium, and others for offering relevant information and insights on the nature of the remote sensing industry and marketplace.

The final report benefits greatly from input and reviews by RAND staff, including our former colleagues, Scott Pace and Gregory Hilgenberg, and Arthur Brooks, a RAND consultant. Any errors of fact and judgment are those of the authors. The views and recommendations expressed here are not necessarily those of RAND or any of its sponsors.

ABBREVIATIONS

ASP	application service providers
AVHRR	Advanced High-Resolution Radiometer
CCD	Charge-coupled device
CD-ROM	Compact disk-read only memory
CNES	Center National de Etudes Spatial
DEM	Digital elevation model
DMA	Defense Mapping Agency
DOC	Department of Commerce
DOI	Department of Interior
DOD	Department of Defense
DOQ	Digital Orthophotograph Quadrangles
FAA	Federal Aviation Administration
EDC	EROS Data Center
EOSDIS	Earth Observation System Data and Information System
EOSAT	Earth Observing Satellite Corporation
EROS	Earth Resources Observation System
ERS	European Remote Sensing
ERTS	Earth Resources Technology Satellite
ESA	European Space Agency
GIS	Geographic information system
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
HSI	Hyperspectral imagery
IR	Infrared
IRS	Indian Remote Sensing
JERS	Japan Earth Remote Sensing
KOMPSAT	Korean Multipurpose Satellite
MOU	Memorandum of understanding
MSI	Multispectral (color) imagery

MSS	Multispectral scanner
NAPP	National Aerial Photography Program
NASA	National Aeronautics and Space Administration
NGO	Nongovernmental organization
NIMA	National Imagery and Mapping Agency
NOAA	National Oceanic and Atmospheric Administration
NRO	National Reconnaissance Office
PAN	Panchromatic (black and white) imagery
PDD	Presidential Decision Directive
OTA	Office of Technology Assessment
RSI	RADARSAT International
SAR	Synthetic aperture radar
SEP	Societe European de Propulsion
SOP	Satellite Operating Partner
SPOT	Satellite Pour l'Observation de la Terre
TIR	Thermal infrared
TLM	Topographic line map
TM	Thematic mapper
UN	United Nations
USC	United States Code
USGS	United States Geological Survey
VNIR/SWIR	Visible near-infrared/shortwave infrared
WIS	West Indies Space

1. INTRODUCTION

Since the advent of Earth observation satellites nearly four decade ago, governments have been the leading providers and users of satellite imagery data. However, this has recently changed with several U.S. companies (e.g., DigitalGlobe, Orbital Imaging Corp., Space Imaging, and others) proceeding with plans to acquire and launch their own imaging satellite systems.[1] These companies seek to become an important part of the U.S. commercial remote sensing industry that today largely consists of aerial data providers and value-added firms. Their success depends on both understanding and overcoming various risks (e.g., technical, market, and policy/regulatory) that could diminish their prospects for commercial success in the highly competitive global marketplace for geospatial information products and services. In this context, U.S. government policies and regulations play an important role in helping create the conditions that will enable U.S. commercial remote sensing satellite firms to realize their competitive potential in both the domestic and international marketplaces.

This report assesses the various types of risks facing U.S. commercial remote sensing firms. It provides some much-needed perspective on how these perceived risks have changed from the early 1990s when the U.S. government took major steps to encourage the commercialization of satellite remote sensing.

BACKGROUND

To succeed, the new U.S. commercial remote sensing firms must deal with a broad range of risks, including technological, market, and policy and regulatory factors. In addition, these risks must be managed within an increasingly complex global marketplace for geospatial technologies that places a premium on international partnerships while encouraging fierce competition.

Risk Factors Facing U.S. Commercial Remote Sensing Satellite Firms

Technological improvements in space systems and ground equipment are main drivers behind growing commercial interest in imaging satellites. Advances in spacecraft and sensor technologies make it possible to build imaging satellites that are substantially smaller,

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[1] See Appendix A for more details on specific U.S. commercial remote sensing satellite firms.

cheaper, and more agile compared with the relatively large and expensive observation satellites, such as Landsat, that have set the standard to date. The new commercial observation satellites can produce high-resolution (i.e., less than 1 meter) panchromatic images and somewhat lower-resolution multispectral images.[2] Future commercial satellites are planned that will collect radar or hyperspectral imagery data. Equally important are continuing advances in ground-based technologies that substantially reduce the costs and complexity of the equipment used for working with satellite imagery. These technologies include less expensive but more capable desktop computers and workstations, user-friendly software for imagery processing and display, and economical data-storage systems. Finally, the growing use of geographic information systems (GIS) and the Internet are also rapidly increasing the ease of access to satellite imagery data and information products for potential customers.

Although technology is an important enabling factor, there are risks of technical setbacks associated with producing and operating commercial imaging satellite systems, particularly given the limited resources available to private firms when compared with government acquisition programs. For example, the successful IKONOS launch in September 1999 was preceded by the earlier launch failure of IKONOS-1 in April of the same year. Similarly, the DigitalGlobe's EarlyBird-1 imaging satellite suffered an in-orbit failure shortly after its launch in December 1997. These initial setbacks reflect the intrinsic risks of producing and launching modern satellite systems despite the extensive U.S. experience with civilian and military imaging satellite systems and operations.

U.S. government policy has been instrumental in creating the conditions that have encouraged private firms to start new businesses based on commercial observation satellite systems. The Land Remote Sensing Policy Act of 1992 played an important part in encouraging the private sector to develop and operate satellite remote sensing systems.[3] Presidential Decision Directive 23 (PDD-23), which was signed in March

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[2] Resolution is used in this report to refer to the spatial dimensions of the smallest object that can be distinguished in an image from its surroundings. High-resolution images provide sufficient detail to enable imagery analysts to detect and possibly identify smaller objects, including vehicles and small buildings.

[3] Title II of the Land Remote Sensing Policy Act of 1992 (P.L. 102-555) authorizes the Secretary of Commerce to license private sector remote sensing space systems. The text of Title II can be found in Appendix B.

1994, was an important enabling document because it further specified the U.S. government's conditions for granting operating licenses to American firms interested in commercial remote sensing satellites, including relatively high-resolution imaging satellites.[4] Since January 1993, the Department of Commerce has granted 17 operating licenses (and numerous amendments to licenses) for commercial remote sensing satellites to various American firms. In July 2000, the Commerce Department's National Oceanic and Atmospheric Administration (NOAA) issued the interim final U.S. regulations for private remote sensing space systems, which specify the legal obligations of U.S. commercial firms that receive government licenses to operate their own imaging satellites.

Formulating U.S. policy guidelines for commercial remote sensing satellites is complicated by the dual-purpose nature of imaging satellites, particularly those that produce high-resolution imagery data, which have both civilian and military applications. The national security heritage of high-resolution imaging satellites further complicates U.S. policymaking in this area. Licensing decisions on commercial observation satellites must be broadly reviewed within the U.S. government to ensure full consideration of the national interests in encouraging American industrial competitiveness while also safeguarding U.S. national security, international obligations, and foreign policy interests. The challenge of reconciling these differing national objectives has sometimes resulted in protracted consideration of license proposals and has drawn criticism from some U.S. firms of particular licensing provisions, such as "shutter controls," which they argue place their firms at a disadvantage compared with their foreign competition.

One of the greatest challenges for the new imaging satellite firms is to devise viable business plans that will enable them to become an integral component of the rapidly evolving U.S. commercial remote sensing industry. This industry currently consists of a broad range of private firms involved in developing and manufacturing the essential technologies (e.g., sensors, platforms, workstations) and software products related to aerial and satellite imaging collection systems. However, much of the real market value of commercial remote sensing industry resides in the diverse value-added service providers that apply

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[4] In addition, PDD-23 provides guidelines for considering U.S. decision on requests by American firms to export sensitive technologies or turnkey imaging satellite systems to foreign customers. See Appendix

their particular expertise to transforming imagery and geospatial data into the distinctive types of information products and services desired by various market segments. New types of value-added resellers of information derived from imagery data are also emerging to address the rapidly evolving needs of the information economy.

The market prospects for the new commercial remote sensing satellite firms are uncertain. These new companies face stiff competition at both home and abroad from other data providers that can supply the type of precision geospatial data desired by most customers. Although the new commercial observation satellites have attracted substantial attention in recent years, much of the imagery data produced by the commercial remote sensing industry still comes from aerial platforms, which have been the mainstay of the commercial remote sensing industry in the United States for more than 50 years. Aerial data providers still offer the highest resolution imagery that is commercially available.

U.S. commercial remote sensing satellite firms also must compete with imaging satellite systems that are fully or substantially funded by foreign governments. Until the IKONOS launch, the emerging global marketplace for satellite imagery data was dominated by non-U.S. civilian observations satellites, including France's SPOT, the European Space Agency's (ESA) ERS radar imaging satellites, Canada's RADARSAT-1, Japan's JERS-1, and India's IRS-1C and -1D satellites.[5] These national governments have broad interests in supporting satellite remote sensing to address their continuing needs for resource management, environmental assessments, maritime safety and security, and technology development. Most of these governments permit their civilian satellite imagery to be sold on the international market for limited cost-recovery reasons rather than any expectation that the full costs of these government programs will be covered. U.S. commercial remote sensing satellite firms therefore must not only compete against other private firms to establish a market niche but also must compete with parastatal (i.e., government-owned or heavily supported) imaging satellites that receive direct or indirect subsidies from their governments.

C for the March 1994 White House fact sheet statement on "Foreign Access to Remote Sensing Space Capabilities."

[5] Along with these well-established, large civilian observation satellite program, a steady growth in the number of national imaging satellites is expected as other governments (e.g., Brazil, Taiwan, South Korea) take advantage of technology advances that are making much smaller and less expensive imaging satellites feasible.

Risk Factors and the Commercial Remote Sensing Satellite Industry

Despite having made a generally promising start, U.S. commercial remote sensing satellite firms face various risks to their long-term success, including:

- *Technical risks* associated with the challenges facing commercial firms in developing and operating technologically sophisticated imaging satellite systems;

- *Market risks* arising from highly competitive domestic and international markets for geospatial data and information products and services; and

- *Policy and regulatory risks* arising from uncertainties or constraints created by government policies and regulations on U.S. commercial remote sensing satellite firms.

These risks are generally viewed quite differently today from how they were originally viewed in the early 1990s, when most of the U.S. commercial imaging satellite businesses were getting started. To succeed over the long-run, these firms will require a combination of reliable technologies, encouraging government policies, a strong international presence, and, most important, sound business plans to ensure their competitiveness in both the domestic and international marketplaces.

Report Motivation

The main reason to assess the risk factors facing the U.S. commercial remote sensing satellite firms is that several important U.S. national interests are likely to be affected by whether or not these firms succeed in becoming a viable and productive component of the larger U.S. remote sensing industry. U.S. interests go well beyond the commercial success or failure of particular firms. Instead they are rooted in realizing the following broader national benefits from having a robust satellite component to the U.S. commercial remote sensing industry. These include (1) sustaining the technological leadership of U.S. industry in critical technologies, skills, and know-how associated with both the space and ground segment of imaging satellite systems, (2)enhancing U.S. government access to technological innovation and best practices in the commercial remote sensing marketplace, (3) supplementing U.S. government imaging capabilities to provide additional capabilities to deal with domestic (e.g., natural disasters) and foreign

policy emergencies; and (4) reaping broader public benefits from a wide range of civilian and commercial applications of remote sensing data. These benefits include economic development, environmental monitoring and conservation, disaster warning and assessment, as well as other civilian applications likely to be encouraged by a robust remote sensing industry.

REPORT PURPOSE

What are the main factors that pose a risk to the success and competitiveness of the U.S. commercial remote sensing industry? What role do U.S. government policies and regulations play in minimizing or exacerbating these risks, particularly for the new U.S. firms that are pursuing commercial remote sensing satellite programs? This report's basic objective is to assess the risks facing the development of the emerging U.S. private remote sensing satellite companies with respect to their opportunities to become a commercially viable component of the larger commercial remote sensing industry. These risks are defined broadly to include technical, market, and policy and regulatory factors that could affect the competitiveness of the U.S. commercial remote sensing satellite firms.

The report gives particular attention to the U.S. firms that are attempting to break into the geospatial information marketplace by developing and operating their own commercial remote sensing satellite systems. Three reasons underlie this focus. First, these private firms are the newest players in the commercial remote sensing field; they reflect an important change as companies seek to become primary providers of satellite imagery data for the first time. Second, these commercial remote sensing satellite firms are subject to rather substantial U.S. government policies and licensing regulations compared to aerial imagery firms or ground-based data producers. Third, U.S. government satellite imaging programs can potentially benefit from technology innovations and best practices associated with the development of a robust commercial remote sensing satellite industry. Thus, it is important to gain a better understanding of how U.S. policies and regulations can affect the business opportunities and risks these companies collectively face.

Defining Risk for the Purposes of this Report

Throughout this report, we discuss the risks to the commercial space remote sensing industry. Risk can be thought of as simply the

probability of something going wrong.[6] Technologies may fail, markets may not materialize as expected, or international competition may be fiercer than anticipated when projects were begun, all with a positive probability and all with an associated penalty. Any of these factors might diminish the commercial viability of a single company or perhaps of the entire industry. Some risks can be characterized and the level of uncertainty decreased by gathering more information or through classic risk-reduction techniques used in business and engineering. Other risks can only be described and understood (but not affected), such that appropriate business decisions-given the risk-can be made to limit the risk or to mitigate its likely effects.

In describing risk, assessing either the probability or the net cost to an outcome's occurrence can be difficult and subjective. Such is usually the case in commercial space remote sensing, for two reasons. First, decisionmakers have little or no historical precedent on which to rely (making probability assessment problematic at best). Second, depending on how the space-based commercial remote sensing industry is defined, a factor might be interpreted either as positive or negative. For example, a factor that severely impacts the raw data market may hurt some companies, while others in the data exploitation side of the business may benefit.

REPORT APPROACH

Our approach focuses on identifying and assessing the key factors underlying the risks facing the U.S. commercial remote sensing firms as they compete in the domestic and international marketplaces for geospatial information products and services. Several salient questions guided our research:

Technical factors. What are the major technical risks for commercial remote sensing satellite firms? What are the levels of risks associated with each area? How do programmatic factors, such as resource constraints, affect the risks that the new commercial firms confront in developing and integrating new remote sensing technologies?

Market factors. Where do the commercial remote sensing satellite firms fit within the larger U.S. remote sensing industry? How do aerial

[6] More formally, risk is the expected cost of a negative outcome, which has two discrete elements: the measured consequences of an undesirable outcome (x) and a probability that the outcome might occur (p). Thus, a higher value px would denote a higher level of risk.

and satellite data providers compare as competitors in the commercial market for geospatial data, information products, and services? What challenges do remote sensing satellite firms face in securing a significant niche in the complex and highly competitive geospatial technology marketplace?

International factors. How are foreign remote sensing satellites expected to grow over the near term? What risks do U.S. commercial remote sensing firms face in competing with foreign firms that are government controlled or heavily subsidized? Alternatively, what opportunities and constraints exist on U.S. commercial firms seeking business partnerships with foreign enterprises and private firms? And what types of domestic constraints exist within foreign countries that could limit the access of U.S. commercial firms for selling their satellite imagery data, products, and servies?

Policy and regulatory factors. How are government policies and regulations affecting the competitiveness of the emerging U.S. commercial remote sensing satellite firms? What types of risks do government policies and regulations pose for U.S. commercial remote sensing satellite firms vis-à-vis their domestic and international competitors? What role can the U.S. government play in facilitating the access of these remote sensing firms to foreign markets?

We conducted separate analyses to answer these questions and to analyze the particular risks associated with these distinct areas associated with the commercial remote sensing industry. In assessing the technical factors, we analyzed four key segments: space, launch, ground, and the user technologies.[7] In considering how market developments are likely to affect the prospects for commercial remote sensing satellite firms, we analyzed trends within the broader remote sensing industry, as well as developments affecting both aerial and satellite imaging firms. In assessing the policy and regulatory environment, we focused mainly on the specific U.S. government policies and regulations that govern the development and operations of commercial remote sensing satellite firms. Finally, our assessment of international factors analyzed the key trends for foreign imaging satellite systems expected to produce imagery data that will be sold on the international marketplace.

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[7] The risk assessments provided in this report are solely those of the authors based on their research and experience in working on these issues, except as otherwise noted.

HOW THE REPORT IS ORGANIZED

The next three sections of this report present our analysis and findings in the key areas that affect the development of the U.S. commercial remote sensing industry. Section 2 reviews the technical trends and risks associated with remote sensing with particular attention to imaging satellite systems. Section 3 presents our analysis of the complex and rapidly changing marketplace for geospatial technology that is the focus of the commercial remote sensing industry. Section 4 outlines the broader international context for remote sensing with attention to both foreign competition and cooperation. Section 5 examines the U.S. government policies and regulations that shape the opportunities and risks for the private firms pursuing commercial remote sensing satellite systems. Finally, our conclusions and recommendations are presented in Section 6.

2. TECHNICAL FACTORS

Today's remote sensing satellites draw on a 40-year heritage of space technology. Optical imagery satellites have been flown since the 1960s. The first civil electro-optical remote sensing satellite, Landsat, was placed into orbit in 1972; while the first civil synthetic aperture radar (SAR) satellite, Seasat, was orbited in 1978. Commercial remote sensing satellites generally do not require fundamental advances in technology to meet their performance objectives; they can largely take advantage of technology that already is developed and in hand.

This is not to say that remote sensing systems do not entail technical risks. Space remains a severe operating environment, and key components and subsystems must operate to the highest levels of reliability under extreme operating conditions. Government satellite programs have attempted to meet this requirement, in part, through rigorous testing, redundancy, and extensive documentation of components. While this has resulted in the successful launch and operation of many remote sensing satellites, failures still occur.[8] Owners of commercial remote sensing systems will procure those systems under commercial models where cost and schedule may be more critical than they have been in government procurements. This may entail new risks.

As Figure 2.1 illustrates, commercial remote sensing systems consist of four segments: the space, launch, ground, and user segments. Each segment involves different technologies and entails different types of risks. We explore the technical risks attendant to each of these areas below. This is preceded by a brief discussion of what we mean by technical risk in the context of this analysis.

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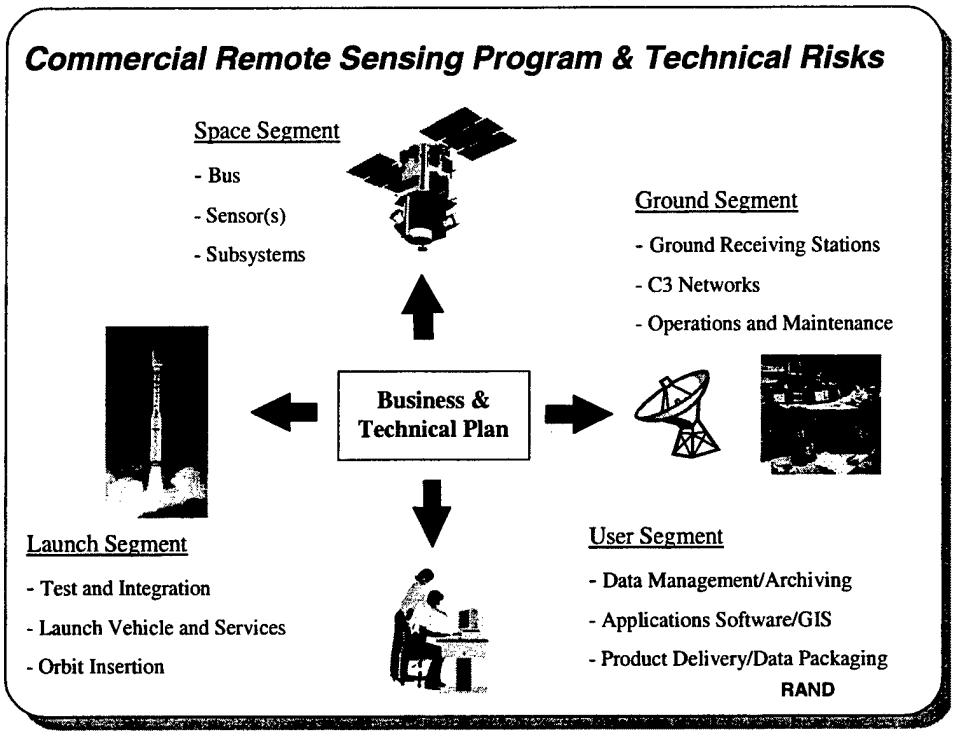
[8] Landsat 6, for example, was lost in a launch failure in October 1993, France's SPOT 3 failed prematurely on orbit in 1996, and NASA's

Figure 2.1: Commercial Remote Sensing Programs and Technical Risk



DEFINING TECHNICAL RISK

For the purpose of this analysis we divide technical risk into two categories: technology risk and programmatic risk. Technology risk relates to the availability and maturity of the key technologies needed for a commercial remote sensing system, while programmatic risks are those associated with a particular commercial remote sensing program that increase the technical risk beyond what is inherent in the technology itself.

Table 2.1 presents a hierarchy of the risk levels associated with a technology, where lower entries on the table correspond to decreasing technology risk.[9] For an electro-optical remote sensing system, for example, these risk levels would apply to such technologies

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Lewis satellite carrying a hyperspectral sensor that failed in orbit in 1997.

[9] NASA has a similar, albeit more detailed, hierarchy of technology readiness levels. See, for example, Liam Sarsfield, *The Cosmos on a Shoestring: Small Spacecraft for Space and Earth Science,* Santa Monica, Calif., RAND, MR-864-OSTP, 1998.

as charge-coupled devices (CCDs), optics, attitude sensors, control actuators, and on-board storage. Technologies or systems in the first two categories would generally be considered high risk, those in the second two categories would be considered medium risk, and those in the last two categories would be considered low risk. A separate technology challenge is associated with system integration, the ability to combine the key technologies and subsystems into a working system. System integration risk increases with increasing system complexity and with increasingly tight design tolerances.

Table 2.1: Technology Risk Levels

	Characteristics
Descending Levels of Technology Risk	Fundamental feasibility not demonstrated
	Feasibility demonstrated at laboratory or controlled demonstration level
	Operational feasibility demonstrated in a different operating environment
	Operational feasibility demonstrated in same operating environment, but reliability not demonstrated or low
	Modification of an existing, reliable design
	Use of an existing, reliable design

In comparison with technological risks, programmatic risks largely involve issues related to program management. Programmatic risks include:

- Inadequate funding
- Overly aggressive schedule

- Lack of experience in performing similar projects by the organization or key personnel
- Frequent turnover of key management or technical staff

To the extent that commercial remote sensing firms may be small start-up companies with limited capital resources, these programmatic risks can be quite significant. For this assessment, we assume that the existence of one or more of the programmatic risks increases the overall technical risk one to two levels above what it would otherwise be based on the technology risk alone. Thus, programmatic risk elements might raise the technical risk of what would otherwise be a low-risk system to a medium technical risk, or change a medium-risk system to high technical risk.

SPACE SEGMENT TECHNICAL RISK

The space segment of a remote sensing system is composed of the spacecraft and the imagery sensor or sensors carried by the spacecraft. Three types of sensors have been used, or are planned, for commercial imagery systems: electro-optical, synthetic aperture radar (SAR), and hyperspectral sensors. (Other types of sensors, such as LIDAR[10] or LADAR, which use laser illumination, or thermal infrared (TIR) sensors, are not currently planned for commercial imaging satellite systems.) Electro-optical (EO) sensors, the most common of the three, have been used in civil remote sensing systems since the early 1970s. These sensors are functionally similar to consumer electronic cameras and camcorders. Indeed, they share such common critical technologies as charge-coupled devices (CCDs), which are used instead of film to sense the images. Panchromatic electro-optical sensors take the equivalent of black-and-white pictures, while multispectral cameras provide the equivalent of color pictures.

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[10] LIDAR (light detection and ranging) offers an active remote sensing technique that can be used for making very accurate measurements of terrain elevations, as well as measure the elevation of tree canopies. Airborne laser mapping is currently a leading-edge remote sensing application for aircraft of helicopter platforms. In comparison, NASA has plans for an experimental satellite system, the Vegetation Canopy Lidar (VCL), which will employ multiple lasers to

While electro-optical sensors generally rely on sunlight as the source of illumination, SAR sensors provide their own illumination in the form of radio waves emitted by the radar. These radio waves also have the ability to penetrate clouds, much as television signals transmitted by satellite do. The result is that, unlike electro-optical sensors that must image during daylight and can be obscured by clouds, SAR sensors can collect imagery during day or night and are much less affected by cloud cover.

Hyperspectral sensors are a special type of electro-optical sensor. Unlike panchromatic sensors that provide information in only one spectral band, or multispectral sensors that provide information in 3 or 4 bands, hyperspectral sensors provide information in dozens or even hundreds of narrow spectral bands. The resulting spatial and spectral data provides what is frequently called a "hypercube" of data; that is, a two-dimensional geospatial image with a third dimension consisting of the spectral data associated with each image pixel. The hypercube then may be used to analyze such things as what types of material are present in each pixel in the image.

Table 2.2 presents the technical risk for the space segment of commercial remote sensing systems. We separately consider the three types of sensors: electro-optical, SAR, and hyperspectral. For each type of sensor we consider the technical risks for current-generation sensors and for future sensors with enhanced performance.

Current-generation electro-optical sensors are taken to be those with resolution of 1 meter or coarser. These sensors use technologies that are well understood and, generally, commercially available. They are hence evaluated as being of low technology risk. Future-generation electro-optical systems with improved spatial resolution do not require new technology. However, alignment tolerances and stability requirements for these sensors will be more demanding, thus increasing the system-integration risk. We therefore evaluate these sensors as having medium technology risk. When programmatic risks apply, the overall technical risks for current and future electro-optical sensors could rise to medium and high, respectively.

SAR Sensors

Current-generation civilian SAR sensors produce data with resolutions between about 5 meters and 30 meters or coarser. Again

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measure the vertical distribution of vegetation canopy on a worldwide basis.

these use mature technology. NASA flew the first space-based civil SAR, Seasat, over two decades ago, and NASA has continued to fly SAR sensors on the space shuttle. In addition to the United States, the European Space Agency (ERS-1, ERS-2,), Canada (RADARSAT), Russia (Almaz) and Japan (JERS) have also successfully placed SAR systems into orbit.

Table 2.2: Space Segment Technical Risk

	Electro-Optical Sensors		SAR Sensors		Hyperspectral Sensors		Space-craft
	Current	Future	Current	Future	Current	Future	
Technology Risk	Low	Medium	Low	High	Medium	High	Medium
Risk with Programmatic Factors Present	Medium	High	Medium	High	High	High	Medium-High

Several alternative design options are available for current-generation SARs. While active-aperture, phased-array antennas may be used, they are not required; passive antennas can be used. Similarly, although transmit/receive (T/R) modules may be used, tubes or solid-state amplifiers provide an alternative.

Based on the demonstrated ability of a number of countries to successfully deploy SAR sensors with 5 to 30 meter resolution and the availability of several alternative technologies for building the SAR, we judge current-generation SAR sensors to be of low technology risk. When significant programmatic risks exist, the overall technical risk of current-generation SAR sensors increases to medium risk.

The situation changes when SAR resolution is significantly improved. Power requirements increase, putting greater demands on the transmitter technology and increasing the complexity of the thermal design of the sensor and spacecraft. To keep power levels in check, a spotlight mode may be incorporated, but this requires a phased-array or

a mechanically scanned antenna, either of which increases antenna complexity, cost, and risk. Bandwidth must be increased to improve the range resolution.[11] This increases the complexity of the signal-generation for the radar and the downlink for the system. Taken together, we judge that these factors result in high technology risk for future-generation SAR sensors with resolution in the 1-meter range.

Hyperspectral Sensors

First-generation space-based hyperspectral sensors are taken to be those with spatial resolution of about 10 meters to 30 meters or coarser. These sensors draw on a legacy of ground-based and airborne hyperspectral sensors[12] and hence are judged to be of medium technology risk. If significant programmatic risks exist, the resulting overall technical risk is elevated to high.

The focal plane technology needed for hyperspectral sensors is available in the visible/near-infrared (VNIR) (0.4- to 1.1-micron) and shortwave infrared (SWIR) (1.1- to 2.5-micron) portions of the spectrum. However the focal plane technology is not mature in other spectral regions. Thus possible future hyperspectral sensors operating, for example, in the thermal infrared region will require further technology development and hence are of high technology risk. Hyperspectral sensors that attempt to significantly improve spatial and spectral resolution will begin to encounter problems with achieving adequate sensitivity and hence also are judged to be of high risk.

Spacecraft

The spacecraft is an additional area of technical risk for remote sensing systems. Key technologies for remote sensing spacecraft include

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[11]Because the azimuth resolution of a SAR sensor improves with increased Doppler bandwidth, not with increased antenna size, it is generally necessary to use a smaller SAR antenna to get improved azimuth resolution. With a spotlight mode, the antenna beam is steered fore and aft in the along-track direction. This simulates the broader beamwidth, and hence the broader Doppler bandwidth, that would be realized with a smaller antenna. The spotlight mode thus improves azimuth resolution of a smaller antenna while using a larger antenna that has greater area for power collection, hence reducing power requirements.

[12] For example, two U.S. airborne systems with hyperspectral sensors are NASA's Airborne Visible and Infrared Imaging Spectrometer (AVIRIS), which is mounted on the NASA ER-2 aircraft, and the Hyperspectral Data Image Collection Experiment (HYDICE). Similarly, NASA's EO-1 Earth-observing spacecraft, which was launched in November

attitude sensors (earth sensors, sun sensors, star trackers, gyroscopes, magnetometers) to determine the spacecraft's orientation, control actuators (momentum wheels, gas jets, magnetorquers) to reorient the spacecraft, power generation and storage (solar arrays, batteries) to provide electrical power, propulsion systems for orbit maintenance, onboard memory to store images for subsequent transmission to the ground, a communications system for transmitting imagery to the ground, space-qualified computers, and lightweight structures. These technologies are readily available from several U.S. and foreign firms. In addition to components and subsystems, several organizations offer complete standard spacecraft that can be used or modified for different remote sensing missions. High operational reliability, however, has not always been demonstrated, with the result that the technology risk for the spacecraft remains medium. To the extent that programmatic factors may result in reduced quality control or quality assurance measures, these may increase the overall technical risk of the spacecraft to the medium-high level.

LAUNCH SEGMENT TECHNICAL RISK

Launch vehicles place remote sensing satellites in low-Earth orbits at the desired altitude and inclination. Launching satellites entails an unavoidable level of risk. As Table 2.3 illustrates, even mature, reliable launch vehicles typically do not offer reliability greater than about 90-95 percent, while some launch vehicles offer significantly lower reliability. Thus, a remote sensing satellite has a 5 to 10 percent chance of never reaching orbit, even if a highly reliable launcher is used. Two standard approaches to managing this risk are launch insurance and production of a spare satellite or satellites. When these approaches are used, the overall technology risk posed by the launch segment is medium.

2000, is operating with a hyperspectral sensor known as the Hyperion that can collect over 200 spectral bands.

Table 2.3: Reliability of Several Launch Vehicles Used for Launching U.S. Remote Sensing Satellites

Launcher	Launches/Failures	Reliability	Remote Sensing System	Launch Result
Cosmos-3M	405/22 (as of 6/99)	94.6%	Quickbird	Failure
Start 1	3/0 (as of 6/00)	100%	EarlyBird	Success
Athena	6/2 (as of 6/00)	66.7%	IKONOS 1, 2	1 Failure, 1 Success
Delta 2	63/2 (as of 6/00)	96.8%	Landsat 7	Success

Launch risk may be significantly exacerbated when programmatic factors come into play. Funding constraints may drive system operators to choose newer, low-cost launch vehicles that may have lower reliability or that do not have a sufficient launch record from which to accurately judge their reliability. In this case, launch insurance may not be available or may be prohibitively expensive. At the same time, inadequate funding may preclude the production of spare satellites. Thus, programmatic factors may boost the overall launch segment technical risk into the medium-to-high level.

Even when launch insurance is available, the effects of a launch failure on the overall business prospects of a remote sensing venture vary widely depending on the structure of the venture. Unlike other technical breakdowns that may degrade but not necessarily eliminate system performance, launch failures tend to be catastrophic, resulting in the complete loss of the system. Small, start-up commercial remote sensing firms need to demonstrate revenue streams if they are to maintain investor interest. While launch insurance may allow the firm to purchase a new satellite or a new launch in the event of a launch failure, the possibly long delay in getting to market and generating revenue may increase the risks that the venture will not success in the commercial marketplace. This may be less of an immediate factor for government-backed programs or for larger firms with other sources of cash flow. Thus, small commercial remote sensing firms may be particularly vulnerable to the effects of launch failures.

GROUND SEGMENT TECHNICAL RISK

The ground segment of a commercial remote sensing system includes the ground stations that receive the satellite imagery, the control station or stations that uplink commands to the satellite and monitor its health and status, and the communications links between these nodes. These are mature, well-understood technologies, and the technical risk attendant to the ground segment is low.

A possible future trend is the use of mobile ground stations to receive satellite imagery. The Department of Defense, for example, uses the Eagle Vision remote ground station to receive imagery from various civilian and commercial observation satellites (e.g., SPOT, Landsat, RADARSAT, ERS, etc.). Such mobile stations may increase the flexibility and decrease the cost of the ground segment; we do not, however, judge that they will materially increase the technical risk.

USER SEGMENT TECHNICAL RISK

The user segment includes technologies for managing and archiving imagery data, processing the imagery and integrating it with other geospatial data sources to produce information products for end users, and delivering the resulting products to users. The risks associated with this segment are not basically technical in nature. Companies know, for example, how to write software to implement image-processing algorithms. Rather, the risks stem more from the uncertainties concerning the types of algorithms, and indeed what types of information, are needed to provide users with what they perceive as high-value end products.

Until recently, satellite remote sensing firms considered imagery or information directly derived from imagery (such as land cover or digital elevation models) to be their primary end-user products. Within this business model, technologies and software for such functions as radiometric calibration, geometric calibration, geocoding, and orthorectification of imagery have been developed and are well understood and mature (Table 2.4). However, as discussed more fully in Section 3, this business model is changing.

Table 2.4: Standard Image Processing Functions

Type of Processing	Functions
Radiometric Calibration	• Image corrected for sensor responsivity • Allows measurement of scene radiance
Geometric Calibration	• Image corrected for geometric errors caused by the sensor, Earth curvature and rotation, and incidence angle of the sensor
Geocoding	• Image put into map coordinates either using location information recorded by the satellite or using ground control points or GPS measurements
Orthorectification	• Image corrected for horizontal and vertical distortions caused by terrain elevation

Satellite remote sensing firms increasingly realize that they must evolve into information companies, whose product is customer-oriented information derived from multiple data sources, not just from imagery. Making this transition entails significant risks.

Currently, users of remote sensing data require a high level of technical training and expertise to use imagery within their applications, which increases the cost of using imagery. For example, image analysts are needed to interpret and extract features from image data; it remains technically very difficult to automate this process. This limits the attractiveness or feasibility of using imagery-derived information in applications where technically trained personnel or image analysts are not widely available. This problem might be alleviated by developing automated image analysis and feature extraction algorithms. Although a large amount of R&D has been devoted to developing automated feature extraction techniques, the task remains one that computers cannot do very well, and the risks associated with successfully developing acceptable products remain high.

Similarly, a large amount of R&D for interpreting and analyzing multispectral or hyperspectral imagery for different application sectors still needs to be conducted. For example, agriculture applications research is needed to assess which spectral bands and which algorithms can best provide such information as evaluating which pest is infesting a particular crop, and how the choice of bands and algorithms varies from crop to crop. Such R&D is needed to develop specific application information for the agricultural marketplace. As long as user-oriented multispectral and hyperspectral algorithms remain in the R&D phase the risks associated with them will remain high.

Another technical challenge is how best to use new communications media, such as the Internet or wireless data technologies, to distribute imagery to users. Image compression technology is making impressive gains that will facilitate such distribution, but widespread use of these algorithms or their application to multispectral, hyperspectral, or SAR imagery remains to be demonstrated.

Thus, commercial remote sensing companies must develop or acquire algorithms and software to process their imagery and integrate it with other data in ways that provide users with what they perceive to be high-value information. It is desirable that the processing be as automated as possible and not require highly trained or specialized personnel. The required algorithms and software will generally vary from application to application. In many potential applications, the feasibility or cost-effectiveness of using satellite imagery remains to be demonstrated. As a result, we judge the user segment, and specifically the appropriate integration of algorithms and software to convert satellite imagery to cost-effective, applications-oriented information of high value to end users, to be of high technical risk.

SUMMARY

In summary, for the space segment of current-generation remote sensing systems the purely technological risk is low; however, programmatic risks may raise the overall technical risk of the space segment to the medium level. Similarly, launch risk, which would otherwise be at the medium level, may be raised to the medium-to-high level by programmatic risks. Full growth of the user segment to enable new or expanded applications of remote sensing information demands the development of new information-extraction algorithms and demonstrations of their feasibility and effectiveness. This entails high technical risk.

Overall, we judge the technical risks facing the commercial remote sensing firms to be somewhat higher today than was originally perceived

in the early 1990s when the initial satellite programs were initiated. This somewhat higher assessment arises largely from having a more realistic appreciation of the challenges involved in developing, launching, and operating a sophisticated imaging satellite system while operating with more constrained resources and expertise compared with U.S. government satellite programs.

3. MARKET DEVELOPMENTS

To appreciate the market risks facing commercial remote sensing satellite firms, it is critical to understand two key points. First, the perception of market risk was unrealistically low in the early 1990s. Only recently have satellite firms in the United States developed a more realistic view of the market's relatively small size and growth potential and the challenges of competing in this marketplace, especially when compared with the parallel rise of other geospatial technologies, such as GPS and GIS. Second, the demand for commercial remote sensing products and services continues to evolve. Other technologies, such as geographic information systems (GIS) and other kinds of geospatial technologies are using remote sensing data in the creation of new and unique value-added information products. Satellite remote sensing is thus becoming a part of the emerging broader geospatial technology marketplace, within which it occupies only a very small niche. Within this marketplace, U.S. commercial remote sensing satellite firms face strong competition from other providers of data, especially aerial and international satellite remote sensing sources, and from providers of lower priced geospatial data that comes from sources other than overhead imagery.

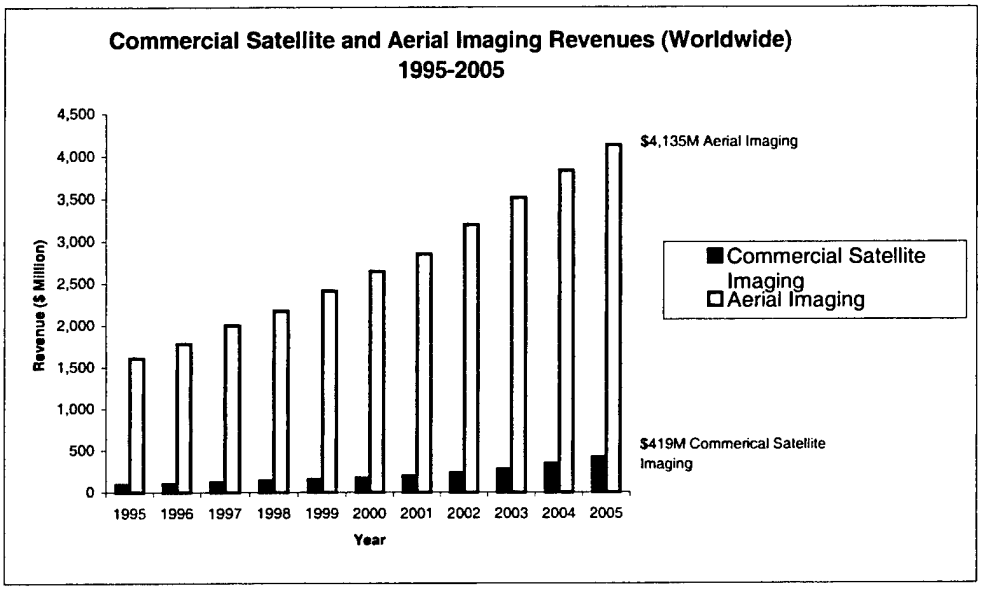
This section explores how this marketplace and its attendant risks are evolving. First, we examine market trends. Second, this section offers an overview of the broader geospatial technology marketplace and where the U.S. commercial remote sensing satellite companies fit within it. Next, we examine how company business models are adapting to compete in this marketplace. The section concludes by summarizing the main risks companies face in achieving commercial success in this dynamic and complex marketplace.

REMOTE SENSING MARKET TRENDS

Commercial markets for satellite imagery data have been slow to develop even though the overall marketplace for remote sensing data has been growing for both aerial and satellite remote sensing data. Figure

3.1 shows the historical and current revenue growth rate for U.S. commercial aerial and satellite remote sensing markets. It is an important reminder that aerial platforms have traditionally generated most of the revenues among the remote sensing data providers and that they are projected to account for the majority of commercial remote sensing revenues on a worldwide basis for at least the near term.

Figure 3.1: Commercial Satellite and Aerial Imaging Revenues, 1995-2005
(Source: Frost & Sullivan, World Remote-Sensing Data and GIS Software Markets, 1999.)



The growth rate for satellite commercial remote sensing markets has been slower than anticipated for a number of reasons. In the early 1990s, estimates of the demand for remote sensing data and derivative products were highly inflated. Projections of the annual size of the satellite imagery market by 2000 ranged from a relatively conservative $2 billion to an astonishing $20 billion.[13] Despite these optimistic projections,

[13] Gabbard, C. Bryan, Kevin M. O'Connell, George S. Park, and Peter J. E. Stan, *Emerging Markets of the Information Age: A Case Study in Remote Sensing Data and Technology*, Center for Information Revolution Analysis, RAND, Santa Monica, Calif., 1996, p. 18. Also see "Statement by the Press Secretary," The White House, Office of the Press Secretary, Washington, D.C., March 10, 1994, p. 1, which accompanied the White House Fact Sheet, "Foreign Access to Remote Sensing Space Capabilities."

the actual demand for satellite remote sensing data has, to date, been limited. An important driver of such demand is price. Satellite remote sensing data was originally expected to drop in price. However, prices have remained relatively high, which has limited the growth of the market for satellite remote sensing data.

Several factors contributed to overly optimistic forecasts of the satellite imagery market. First, the end of the Cold War removed many of the barriers that had hampered the growth of a robust remote sensing market during the previous decades, so people assumed it would grow substantially. Second, the existing size of the overall remote sensing market, approximately $1.7 billion globally in 1995, led many to believe that a robust market for space-based remote sensing data already existed.[14] Early investors in high-resolution satellites were convinced that their systems could capture a significant portion of the remote sensing market from the aerial firms that have traditionally been the primary providers of commercial remote sensing imagery data products and services. Moreover, there was optimism that other potential consumers of remote sensing data whose needs could not be satisfied by the existing sources of imagery would begin buying remote sensing data once the new generation of high-resolution, earth observation satellites became operational. Third, the early success of SPOT Image, which experienced a 42 percent growth between 1986 and 1991, encouraged observers of the industry unwisely concluded that this growth would be maintained and that it signaled a rapidly growing marketplace for commercial remote sensing satellite products and services. Fourth, technological advances in remotely sensed data acquisition, storage, and processing, along with quick and efficient capabilities for

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[14] This statistic includes revenues from both aerial ($1.6 billion) and space-based ($0.1 billion) platforms. *World Remote-Sensing Data and GIS Software Markets*, Frost & Sullivan, 1999, p. 2-3 and 3-2. Although any revenue forecasts should be approached with great caution give the past propensity for optimistic forecasts of sector growth, the year 2000 revenues for the commercial remote sensing industry (satellite, aerial, and image-based GIS applications) was roughly estimated as part of a ASPRS/NASA Ten-Year Industry Forecast project. See the webpage of the American Society for Photogrammetry and Remote Sensing (ASPRS) at http://www.asprs@asprs.org/asprs/news/remote_sensing_growing.html.

electronically transferring such data files further improved the outlook for the growth of the remote sensing market. In addition, significant barriers to market entry and development existed in the satellite commercial remote sensing industry that has made it difficult for rapid commercial success of this industry. A major market barrier has been the long time-line from conception to actual operations and revenue streams. Also, there were unexpected technical delays and high fixed costs for satellite companies. Last, companies underestimated the effort required to turn remote sensing data into useful information for users' application needs. The original optimistic projections also assumed lower prices for satellite remote sensing data. Many of the aforementioned factors led to higher costs, and thereby prices, for satellite remote sensing data that inhibited market growth because potential customers could turn to cheaper sources of information.

However, given the natural state of market developments in related technology fields, it is not surprising that the industry has not grown faster. The commercial remote sensing satellite marketplace is very new, and technologies typically need time to mature before much market growth can be expected. Such was the case for the telecommunications industry.

To understand how the commercial satellite and broader remote sensing industry is evolving, one must first understand the broader geospatial technology marketplace trends (and even broader information technology (IT) market trends) and how remote sensing fits into this larger marketplace.

BROADER GEOSPATIAL TECHNOLOGY MARKETPLACE TRENDS

The importance of geospatial information throughout our society has created a growing marketplace for the development and use of digital geospatial information and the technologies that enable this information to be useful for application needs of diverse users. Most business and government datasets have significant geographic content. It has been estimated that 75 percent of business data have some type of geospatial content, but less than 10 percent of businesses use such data in a

traditional geographic context.[15] Geospatial information is needed for numerous government and business functions, including transportation of goods and services; understanding market conditions and demographics; analyzing environmental conditions; producing food; and constructing, maintaining, and designing buildings, supporting infrastructures and communities; and providing public safety and national defense. A recent National Academy of Public Administration (NAPA) study estimates that geographic information "plays a role in about one-half of the economic activities of the United States."[16]

Before analyzing the geospatial technology marketplace we must better understand what it is. The geospatial technology industry includes any technology being used to collect, process, analyze, use, or display geospatial data and information to create a useful product for an end user.[17] This broad definition includes a range of geospatial application enabling technologies, such as Geographic Information System (GIS), remote sensing, Global Positioning System (GPS),[18] and Computer-Aided Design (CAD)[19] technologies. It also includes applications of 3-D imaging and other visualization tools.

The geospatial technology marketplace is dynamic and growing, and includes numerous application areas/sectors and diverse user groups. It also consists of many different technology types. GIS technology in particular plays a key foundational role in the use of remote sensing data within the broader geospatial technology industry.

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[15] Frost & Sullivan, 1999, p. 5-2.

[16] NAPA, January 1998, p. 11.

[17] Note we choose to use the term geospatial instead of spatial throughout this paper. One technical definition for geospatial is applications with locations on the earth, while spatial refers to applications that involve any coordinate system. However, many people use the terms interchangeably. We chose geospatial because most of the applications involve locations on earth. However, other coordinate system applications are included in the scope of this paper. Also, when we use the term geospatial data, we mean digital geospatial data.

[18] GPS is a geospatial technology that enables a portable handheld device to provide a precise location almost anywhere on the earth by processing signals with a constellation of satellites.

[19] A CAD is a computer-based system to support technically precise object and layout designs, such as architecture and engineering design applications of structures and other man-made facilities.

GIS Enabling Technology for Transforming Remote Sensing Data into Useful Information

A GIS is a computer-based tool for storing, handling, and manipulating geographically referenced information. GIS serves as a framework for integrating geospatial data and technologies into useful information for a wide range of technical and nontechnical users in business, government, consumer pursuits, research, and other decisionmaking roles. GIS provides a foundation for making geospatial information and technologies useful in a wide range of markets throughout the world's economy. For example, university researchers have used a GIS system, along with aerial and satellite image data, to study changes in land-use and development growth in the Chesapeake Bay region over the last 50 years.

There is a growing marketplace for GIS applications, and the remote sensing industry is trying to exploit this growth. During the late 1990s, the GIS marketplace started to expand from limited specialized market sectors into this broader marketplace in the United States. GIS capabilities and systems are being used in a wide range of application areas, including agriculture and forestry, banks and insurance industries, communications/media, demographic and census applications, environment and natural resources management, extraction industries (oil, gas, coal, mineral mining, etc.), health services, mapping, national security (military and intelligence applications), real estate, retail services, safety and emergency services, transportation, and utilities. GIS has become a standard operating tool in many areas, such as environmental, natural resource and transportation planning and analysis efforts. Because 80 percent of a utility company's daily work has geospatial aspects--namely, knowing the physical location of customers and equipment--the use of GIS is quite common in the utility industry.[20] The 1998 NAPA report on geospatial markets estimates that the U.S. budget for GIS was $4.2 billion to $4.5 billion in 1998 and that U.S. federal agencies spend $2.5 billion to $3.0 billion annually

[20] Korzeniowski, Paul, July 1999.

on collection and management of geospatial data.[21] The remote sensing industry hopes to ride this wave of GIS market penetration.

Potential Geospatial Technology Marketplace By User Types

By 2001, many different types of geospatial technology users have emerged. They range from a "thick client," the sophisticated user with a high degree of technical knowledge, to a "very thin client," the average consumer or other user with no expert knowledge about the technologies or how to use them. We classify the geospatial technology end users into five main types: traditional image analysts, traditional GIS users, users from other disciplines, mainstream business PC users, and consumer and nontechnical business users. Table 3.1 provides examples of each of these user types. These diverse geospatial technology users are also potential remote sensing user types.

Traditional image analysts are people who have had years of technical expertise and experience in analyzing, interpreting, processing, and manipulating overhead images. They have very specialized technical knowledge about imagery data. Traditional GIS users are geospatial technology experts and researchers who are the specialized technology users. Such users are accustomed to handling geographic information, and it is a major part of what they do, such as in sectors that involve facilities management and land information. The other discipline users have expertise in their own business or discipline areas and use geospatial technologies and information to help them in their processes. They have some technical and analytical expertise so that they can use geospatial technologies and information to enhance their business processes. The mainstream business PC users have possess very limited geospatial and other technical expertise for their application need. These average business users need simple geospatial information in their day-to-day jobs. Industries with small business users and less technical orientations are classic users or potential users in this category. Consumer and nontechnical business users have extremely

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[21] NAPA, Geographic Information for the 21st Century, Washington, D.C., January 1998, pp. 297-298.

Table 3.1: Geospatial Technology User Types

User Type	Sample Users	Sample Application
Traditional image analysts	Intelligence/military analysts	Using ERDAS IMAGINE to calculate weapons line of sight for wargame simulation
Traditional GIS users	GIS analyst at a state department of transportation	Using ARC/INFO to maintain electronic and street database to plan street maintenance operations
Other Discipline Users	Planners and technical managers, such as a health analyst or forest manager	Using Fire!, an ArcView vertical application, to analyze forest fire behaviors
Mainstream Business PC Users	Fast food or retail chain operator	Using PC GIS, such as Microsoft's MapPoint 2000, to analyze relationships between customers locations and chain location.
Consumers & Non-technical Business Users	Average person planning auto trip	Using MapQuest.com to print map with directions.

limited geospatial and other technical expertise for their application needs. These users want geospatial information where the technologies are seamless. Consumers want such information for personal needs, while business want such information to make their jobs more efficient. Such users are average citizens that need information that contains or can be derived from geospatial information.

Each of the potential user communities presented in Table 3.1 can be distinguished by its potential size. Mainstream business PC users are numerous, and consumers and non-technical business users even more so, potentially including everyone. These two categories present the largest market opportunity in numbers of potential customers for GIS, remote

sensing, and other geospatial technology firms. Many of the geospatial technology companies hope to reach more of these potential customers.

GIS applications are used extensively by traditional image analysts and geospatial technology users, and even other discipline users. GIS capabilities are currently being used by some mainstream business PC users, such as those with service industries. Also, we see embedded GIS capabilities being used by consumers and nontechnical business users, such as in car navigation systems. These last two categories are not as widespread as the first three, but they are growing.

Remote sensing data are used mostly by traditional image analysts, and less often by GIS users. The remote sensing industry hopes to reach more of these other user types, as GIS has. However, how much of this broader marketplace can be penetrated by remote sensing companies still remains to be seen.

GIS AND GEOSPATIAL TECHNOLOGIES MERGING INTO THE BROADER IT MARKETPLACE

At the same time that GIS technologies are creating niche markets for remote sensing data, GIS technologies and capabilities are merging into the broader information technology (IT) industry and becoming mainstream technologies. Evidence of this is that "an important trend fueling the industry's growth is increasing adoption of GIS by organizations previous unacquainted with GIS."[22] Specifically, more users and application products are being developed for and used by nontechnical business users and consumers. For example, Microsoft has developed its own mapping software for business users on their desktops, MapPoint, which illustrates the importance of geospatial technologies in the IT world. GIS datasets and capabilities are on the verge of becoming a standard personal computer desktop application, like a spreadsheet package. On the consumer side evidence of mainstream usage occurs with World Wide Web (WWW) mapping applications. For example, in spring 2000, the MapQuest.com web site continued to rank in the Media Metrix list of the 50 most popular web sites and had 4.5 million visitors in one month.[23]

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[22] Daratech, 1999.

[23] Francica, Joe, May 2000.

There are several key trends that are happening as part of this process:

- Marketplace moving from geospatial technologies to information services.
- Geospatial technologies are being integrated more and more for user applications.
- Users want seamless applications.
- Distributed yet integrated applications are emerging through the Internet/WWW.

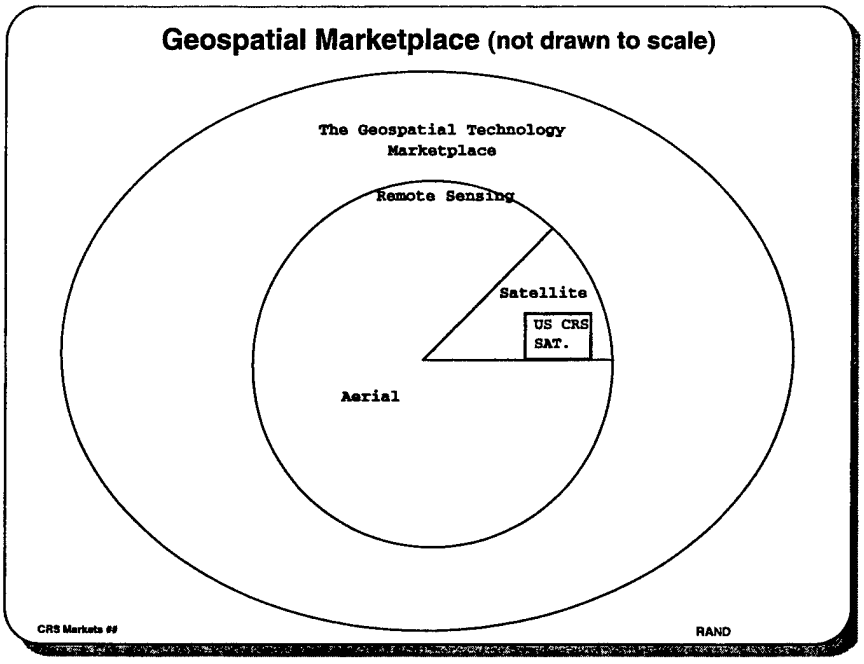
These trends are likely to continue and could substantially influence how the remote sensing industry develops. For example, such trends can help open the door for new remote sensing applications and they can also affect the company's business models and data prices. See Appendix D for a more in-depth discussion of these trends and their potential implications.

U.S. SATELLITE COMMERCIAL REMOTE SENSING INDUSTRY IS A SMALL PIECE OF THIS GEOSPATIAL INFORMATION MARKET

The geospatial technology industry is growing. However, the demand is for information rather than data. Most applications do not use remote sensing data, and those that do mostly use a small amount of image data to create smart GIS datasets. Such data are integrated with other information and geospatial datasets for user application needs. Figure 3.3 presents a notional diagram of this marketplace, which is not drawn to scale.[24]

[24] To represent the relative role of that remote sensing plays in the broader geospatial technology marketplace more accurately, the remote sensing circle would need to be 10 to 100 times smaller than shown in this figure.

Figure 3.3: Geospatial Technology Marketplace



This diagram illustrates how small a portion that U.S. commercial remote sensing satellite companies currently account for in this broader geospatial marketplace. However, these companies hope to take advantage of this broader geospatial marketplace. Given that they are such a small part today, how realistic is their goal of substantially expanding into this broader marketplace in the future? How realistically can they compete with the aerial and international remote sensing competition? To answer these questions, we must first understand how the remote sensing marketplace fits into this broader marketplace.

Many Potential Market Sectors for Remote Sensing Information

Satellite remote sensing companies are still trying to find commercial niches in the broader geospatial marketplace. The remote sensing marketplace consists of many different niche market sectors, most of which require customized information products derived from remote sensing data. Table 3.2 shows the demonstrated remote sensing market niches and potential markets. The left-hand column shows market sectors

Table 3.2: Niche Market Sectors for Remote Sensing Information

Markets Demonstrated for Remote Sensing	*Potential Markets*
Forestry	Agriculture
Environmental/natural resource management	Disaster response and emergency services
Extraction industries	News, media, and entertainment
Mapping	Real estate, insurance, and property finance
National security	Travel & tourism
Transportation	Outdoor recreation and sports
Utilities	Communications

remote sensing data have demonstrated their usefulness and some clear market demand exists. However, this demand is mostly being filled by aerial sources. For example, remote sensing data are used extensively to develop GIS maps and transportation datasets and to update them. The right-hand column shows market sectors that have yet to be developed and have not yet demonstrated a clear need for remote sensing data. These sectors have not seen as much use of remote sensing data, even aerial data. For example, precision agriculture is a potential growth marketplace for remote sensing data. However, not much commercial penetration into this precision agriculture marketplace by commercial imaging satellite firms has occurred to date. Sectors on the right of the table have yet to demonstrate their viability as a significant commercial market for image information from either aerial or satellite remote sensing sources. In addition, most of the niches in the entire table remain to be proven as viable commercial marketplaces for satellite imagery data and information.

Can the U.S. Remote Sensing Satellite Industry Follow Broader Geospatial Industry Growth Rates?

All of the application areas in Table 3.2 have clear geospatial information needs. Most have been growing for GIS and other geospatial technology applications. However, the issue for the commercial remote sensing marketplace is how much of this broader geospatial marketplace can they really tap into. Two important issues need to be distinguished here. First, how much demand will there be for image data and information more generally? Second, how much of that demand will likely be met by U.S. commercial remote sensing satellite companies? We address the first issue here and the second more fully in the next section on competition.

As the geospatial technology industry advances, more interest arises in using remote sensing data. However, some significant barriers also exist. First, there are clearly some technical barriers, especially barriers to creating smart GIS datasets cheaply and easily using remote sensing data. Such technology barriers are covered more in Section 2. In addition, perceptual and educational barriers must be overcome because many potential users, such as the other discipline users, are unwilling to invest substantial time and money in learning about remote sensing information. They perceive remote sensing data as being too difficult and time-consuming to use. Cost barriers are a significant reason why potential users do not use remote sensing data, because other geospatial datasets often are cheaper to acquire and use. However, it is important to note that higher risks, whether technical, political, or financial, can drive up costs and therefore the prices. In some cases, both technical skills and cost issues come into play. For example, in much of the U.S. agricultural industry the profit margins are so tight that even GIS tools have not made significant market penetration.[25] Agricultural users are not as knowledgeable about the benefits of geospatial technologies, especially when compared to

[25] Ground-based sensing technologies, such as proximal sensing using GPS calibrated, ground mobile sensors, are only beginning to be used for agricultural applications. See Terry L. Kastens and Heather Nivens, "Precision Agriculture: Is it Time to Get Involve?," Risk and Profit Conference, Kansas State University, Manhatten, Kansas, August 20-21, 1998.

those in related industries, such as forestry, where GIS is a standard tool for many resource managers and forestry researchers.

Some of these special niche marketplaces seem more promising for remote sensing data than others. For example, environmental monitoring is an area that shows growth potential for remote sensing data, especially satellite information. An example of such an application is monitoring for oil spills with satellite imagery. Ocean oil pollution from ships is a significant international problem. "More than 45 percent of oil pollution results from illegal operational cleaning of tanks and engine rooms, performed by all types of ships usually during the night."[26] Aerial and satellite imagery have been successfully used in Europe to detect and prosecute these oil polluters. As concerns about the environment continue to grow, and attempts to achieve sustainable development increase, and environmental problems spread across national boundaries, and satellite remote sensing technologies offer a means for detecting environmental changes remotely and quickly. Thus, the environmental monitoring marketplace has growth potential for the commercial remote sensing satellite firms. Many of the U.S. satellite companies operate on the assumption that the early customers will be governments, especially national security users. Other potential customers, such as agricultural sector discussed earlier, seem somewhat less promising for the industry, at least in the near term, because of the aforementioned challenges.

Some of the U.S. commercial remote sensing satellite companies (Appendix A) are mainly focused on the private sector rather than U.S. or foreign government customers. However, all of the companies acknowledge that they are still finding their commercial niches.

It remains unclear which of these sectors will be commercially profitable for U.S. private remote sensing satellite firms. Numerous factors affect the market development, and international markets often differ for these different sectors when compared with U.S. market sectors. Also, many of these sectors, such as environmental or agriculture, often have widely different market subcomponents. For

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[26] Petrocchi, Andrea, "Slick Sensing: Monitoring Oil Spills with Satellite Imagery," Geo Info Systems, May 2000.

example, within the agriculture sector there are the regional agricultural assessments and precision agriculture sectors. There also are differences by crop types and domestic versus international agriculture.

Some technology innovations help expand remote sensing data's usefulness in the broader geospatial marketplace. For example, three dimensional (3-D) imaging is a recent technology that potentially helps open the door for new or enhanced geospatial applications that use remote sensing data. New 3-D GIS applications using remote sensing data are just being developed for the tourism and entertainment industry, where resort operators and sporting event promoters give their clients virtual tours. For example, a U.S. state tourism board uses ERDAS IMAGINE VirtualGIS software and satellite imagery to allow potential visitors to take a virtual fly-through tour of a scenic area.[27] Another example: 3-D imaging and GIS software were used to produce a 3-D GIS map of the January 2000 Alaska Airlines crash off the California coast. This underwater map, used extensively by the news media, provided a comprehensive view of the disaster scene. The undersea crash map could also have been used in emergency response.[28] Such 3-D capabilities have been expanding, but they are not necessarily needed in many geospatial applications, such as location-based services that need only an accurate street network with address information. For example, why does a car navigation system need imagery data? Some industry members feel 3-D visualization will penetrate even this location-based services marketplace--namely, that consumers will also want to see the 3-D images. However, given the additional expense and expertise needed for using 3-D imagery, it is not likely to be a large marketplace any time in the near future.

To summarize, remote sensing technologies are a smaller part of this broader geospatial marketplace, and major uncertainties exist over how large they will grow. Many applications do not currently need remote sensing data. Remote sensing data may offer additional information, but no clear or outstanding benefit for remote sensing data

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[27] Jordon, Lawrie, July 2000.

[28] Hodges, Mark, May 2000.

has yet to emerge, as has occurred with GIS capabilities and GPS technologies. With these technologies, clearly significant value was added by using the GIS and GPS technologies. For example, GPS provides the unique ability for a user to know the exact location of objects anywhere on the globe in real time. It is unlikely that remote sensing technologies will find such a unique widespread benefit in this marketplace. Namely, a "killer application" for the remote sensing marketplace that causes dramatic market growth has yet to be identified. Overhead imaging technologies are obviously very useful and provide important data and information. However, remote sensing technologies are unlikely to penetrate this broader geospatial marketplace to the same extent that these other technologies have experienced. (i.e., GPS and GIS). But users may start demanding more overhead images and 3-D images in the future, which will increase the remote sensing piece of this broader marketplace. Even though satellite imagery may not expand in this broader geospatial marketplace as much as the early optimists projected, a strong marketplace for overhead imagery information exists, as aerial remote sensing firms have demonstrated. Therefore, the question for the U.S. commercial remote sensing satellite companies is how competitive can they be in this remote sensing piece of the geospatial marketplace?

U.S. COMMERCIAL REMOTE SENSING SATELLITE COMPANIES MUST COMPETE IN THE BROADER GEOSPATIAL TECHNOLOGY MARKETPLACE

The broader geospatial technology marketplace is competitive and very dynamic. The remote sensing industry is also part of a very competitive marketplace, particularly because it is only a subset of the broader geospatial marketplace. Satellite companies have high fixed costs and start-up costs that make it more challenging for them to make a profit in this highly competitive marketplace. Companies must deal with the desire of end-users for information not data, and the fact that they do not care where the data comes from. Users also have many different options for their data and information, both in terms of sources and types of data and information.

Users Have Many Sources of Information

Competition is very strong in the geospatial marketplace with many different sources of data and information. The information that users need can come from a range of other sources, including imagery data. First, users may opt for preexisting, lower priced non-image geospatial datasets rather than choose to purchase and have to deal with image data.[29] Second, users may decide to use in-situ monitoring and other on-the-ground data collection techniques instead of remote sensing techniques. For example, a user may choose to use ground survey techniques to collect road geospatial information for transportation GIS applications rather than using remote sensing data. Last, a user may decide not to use digital geospatial data at all but instead rely on other techniques for decisionmaking needs, such as tabular or statistical data or paper maps.

If users choose remote sensing data, they have many different options. They have choices in types of sensors and data, sources by type of platforms, and data provider. Sensor options for different remote sensing imagery types include panchromatic, multispectral, hyperspectral, SAR and LIDAR. These different types of data have different strengths and weaknesses. Some are more mature and therefore more marketable in the commercial marketplace than others. For example, U.S. industry has more than five decades of experience in using panchromatic images but relatively little experience with hyperspectral data. Users can also choose from non-U.S. satellite imagery data providers, government sources, or U.S. commercial companies. Users can also choose aerial remote sensing data instead of satellite imagery data.

Given all these options, a geospatial information user has many decisions to make about what types of data to use from which sources. Two sources that will be key drivers for the future of the U.S. commercial remote sensing satellite industry are the aerial and international satellite imagery data providers. This section discusses

[29] Many users, such as traditional GIS users and other discipline users, would rather use traditional GIS point, line, and polygon data than deal with image datasets.

the aerial competition while Section 4 discusses the international satellite imaging competition.

Strong Aerial Remote Sensing Marketplace

One of the most important challenges for the U.S. commercial remote sensing satellite industry is competing with the aerial remote sensing industry. Aerial remote sensing firms are well established in the marketplace. The aerial remote sensing market is also much less regulated than the satellite remote sensing market. About the only regulations aerial companies face are standard Federal Aviation Administration (FAA) ones concerning aircraft safety and flight operations. In addition, the market for aerial remote sensing data has been growing, especially for digital data. Originally, satellite companies thought they would enjoy a competitive edge over the aerial companies and acquire a large portion of their market share. The satellite companies now know this unlikely to occur because the aerial companies are strongly competitive in a number of ways.

First of all, aerial companies have been advancing their industry while the satellite firms were busy trying to commercialize, build, and launch their high-resolution satellites into orbit. The aerial remote sensing industry has been adapting and responding to the latest technological developments. For example, some aerial companies use the latest GIS software, GPS-assisted inertial guidance for precision navigation, new digital cameras, and LIDAR sensors. They are streamlining image processing times and flying multiple sensors on a single airborne platform to make their firms even more efficient data collectors. All these changes make them extremely competitive with the satellite companies, especially because satellite companies have such high start-up and fixed costs for doing business. In addition, aerial companies can update their technologies more rapidly than satellite firms can by switching sensors that they employ on their airborne platforms while the satellite firms are locked into their technology designs for years following a satellite launch (unless they plan to develop and launch a new imaging satellite).

Second, aerial companies have some distinct market advantages. They can collect data at higher resolutions than most satellites can. Resolution range from 6 inches, 1 foot, 2 feet, to 1 meter resolution, as needed. Many remote sensing clients want sub-meter data so they can provide imagery data that the satellite companies cannot yet provide. For example, aerial firms are a regular data source for urban planning and transportation applications in which sub-meter data are needed to accurately distinguish land-use and transportation infrastructure elements in the images. In fact, much of the U.S. demand for overhead imagery data is for imagery with sub-meter resolution.

Another strength of the aerial companies is that they are well positioned in the marketplace. In the United States, many aerial companies have been flying for decades. Thus, they often possess a historical customer base, technical and market sector expertise, and infrastructure. For example, aerial firms may routinely fly over a county or state to help governments update their transportation GIS databases for transportation planning and infrastructure maintenance. These aerial firms have the survey knowledge and expertise to provide the highly accurate information needed for the transportation sector. Internationally, aerial companies are also well positioned in the marketplace, though mostly in developed countries.

Lastly, many aerial companies are dynamic and responsive to user needs. They provide fully integrated service deals that meet customer needs. They provide their data in end-user products, such as ARC/INFO coverages and shape file-formatted datasets for the users' GIS needs. One important market driver is that many aerial companies will let the customers of large jobs have the data without strict access or licensing restrictions. Because the customer paid for it, they can do whatever they want with the data--even place the data in the public domain using the WWW. Because of state open-records laws that require government data to be in the public domain and government open-data policies and their desire to share data freely, such data sources are often more attractive than satellite remote sensing data, which can come with access and licensing restrictions. Thus, all of these factors make

aerial remote sensing firms a source of strong competition for satellite remote sensing firms.

Satellite Remote Sensing Potential Market Advantages

In some areas, U.S. commercial remote sensing satellite firms have market advantages in competing with the aerial companies. The satellite firms have a market advantage in certain international applications, such as acquiring images over denied areas or areas with limited aerial infrastructure. Satellite data are more competitive in providing overhead images of denied areas (i.e., where governments or non-state actors are tightly controlling outside access) and where commercial aircraft are restricted from taking images or unwilling to make overflights because of risks to their safety. Similarly, areas with limited aerial infrastructures that make it much more expensive for aerial imaging operations also could give a market advantage to satellite imagery firms. Such areas are mostly in the developing countries and the more remote areas. However, even in the more developed countries, satellite companies can be competitive. For example, in many foreign countries, the aerial remote sensing industry is under direct or indirect government control. If for some reason the indigenous aerial firm does not want the business or is not responsive to the commercial customer's need, a U.S. commercial remote sensing satellite company could offer an attractive alternative. For example, in some cases, when U.S. firms do business in foreign countries, such as infrastructure development or extraction (i.e., mining or energy exploration and production), they could address a need for overhead imagery data that is not being satisfied in a cost-effective or timely manner by in-country sources.

Another potential marketplace advantage for the commercial remote sensing satellite firms involves customers who want a single image or an occasional update image. Given the fixed costs associated with flying an aircraft, acquiring a single image would not be a cost-effective operation in most cases. In comparison, commercial imaging satellites could offer a more affordable source for acquiring such images. Nonetheless, the price of acquiring an updated satellite image can run

from $500 to $4,000, depending on the satellite type, the time urgency of the order, and degree of image processing desired.[30]

Commercial remote sensing satellite firms also have an advantage in stability and repeatability of imaging operations because of the satellite technical specifications. However, aerial firms, especially the larger more technically advanced firms, have sufficient stability and repeatability for most jobs. The exception is precise science applications. However, not many of these are in the commercial marketplace, so it is not a significant advantage for the satellite firms.

Another potential marketplace advantage for satellite firms is their ability to process and turn data around quickly. However, the aerial firms are competitive in providing close to real time data. Some aerial companies now do part of their digital processing on airborne platform to avoid the delay of transferring data to ground facilities. For example, Earthdata,[31] a leading large-scale U.S. aerial firm, can process and turn data around within 24 hours, if required. They have demonstrated this capability in performing overflights of tornado damage areas. Whereas it previously required 32 weeks for processing a county's Digital Orthophotograph Quadrangles (DOQs), it now takes only 12 weeks to process and deliver DOQs because of digital cameras and new automated processes.[32] Given the technology, in theory, satellite remote sensing firms should be able to download and process image data within a few hours. However, their prices for rapid response service are relatively high and they have yet to show that they can do this commercially. Slow progress in negotiating worldwide ground station agreements, along with image processing and cloud cover problems for optical imaging systems, all place practical limits on the ability of

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[30] The price of images can be substantially reduced if the customer is willing to accept imagery data from existing archives rather than seeking new imagery data that would involve collecting new satellite images and then processing the satellite imagery.

[31] EarthData views itself as a spatial data, mapping, and GIS services company that provides its clients with customized products and service to support a wide range of land-use and natural resources management activities.

[32] Personal communication with EarthData, February 2000.

satellite firms to provide quick image data turnaround services on a routine basis.

Thus, despite their various advantages, commercial remote sensing satellite companies are likely to face continuing tough competition from aerial remote sensing companies. The U.S. satellite companies are changing and trying to respond to this competition, especially in their business models. It is too soon to know how successful they will be, particularly given their relatively high start-up costs compared to the aerial firms.

CHANGING BUSINESS MODELS AND FINANCIAL APPROACHES

Because of the strong competition and broader geospatial marketplace developments, remote sensing companies are beginning to change business models and financial approaches. Satellite-based remote sensing companies recognize the need to evolve from being image data providers into information age image companies. Table 3.3 summarizes the main characteristics of the business models for companies that are image data providers and those that are information age companies.

None of the U.S. commercial remote sensing satellite firms are information age companies yet. However, these companies know that they must change their business models and have started the transformation process (outlined in Table 3.3) to become information age companies. The companies recognize the need to have multiple data sources and that they must focus more on customer needs and user application products. They also know they must develop vertical market expertise, particularly through partnerships or by acquiring other companies with special expertise, to be commercially successful.

The U.S. commercial remote sensing satellite companies have started adopting the changes needed to become information age companies. However, it is too soon to know if they can successfully make this transition and be competitive in this marketplace. We will briefly discuss three key issues that could be critical to changing business models and the commercial success of these companies. The first is the evolution of a multi-tier system for geospatial data. The second is how

Table 3.3: Commercial Observation Business Models Are Changing

Traditional Image Data Provider	Information Age Image Company
Produces data	Produces information
Satellite data only	Multiple data sources
Isolated	Partnerships
Limited pricing and access policies	Flexible pricing and access
Knows data only	Oriented on customer needs
Only collects, processes and disseminates data	Integrated into broader geospatial technology/IT marketplace
	Vertical market expertise

financial models are changing. The third is the critical need for the companies to develop partnerships and vertical market expertise to extend market reach and to develop more marketable applications.

Multi-tiered Geospatial Data System Developing

More and more geospatial data of different types and quality are available for users. Geospatial data prices have been decreasing. Technology advances have brought costs down. More geospatial data at cheaper prices and better quality are available than ever before. For example, 10 years ago a basic GIS street network database that included street addresses was expensive and not of very high quality, while today many different and better quality street network databases are available at cheaper prices. We explain how a multi-tiered geospatial data system is developing by discussing how the extremes are developing: free and cheap geospatial data and the demand for more expensive data.

Increase in free and cheap geospatial data

Free and cheap geospatial data are proliferating for a number of reasons, including the competition, technology advances, and government and NGO data policies and data-sharing activities. First, the highly competitive geospatial data marketplace, briefly discussed earlier, and

technology advances are helping to bring data prices down. In addition, more datasets are being placed in the public domain by governments and other organizations because of the numerous benefits of sharing data among many different users. Data sharing helps organizations save resources while increasing data availability. U.S. and foreign governments, end-user companies, and other organizations recognize the benefits from sharing geospatial data. Organizations save time and money when they share in the data collection and maintenance process. Sharing geospatial data can defray the cost of producing and maintaining those data. Sharing data in a geographic area can also increase individual organization's view of data for the region and can aid cross-jurisdictional or cross-organizational analysis and decisionmaking. In addition, data sharing can improve data quality because more individuals see the data and find and correct errors.[33] Such geospatial trends have potential positives and negatives for satellite remote sensing companies. The main negative is driving all geospatial data prices down, including imagery data. The main positive is creating more familiarity and expertise with geospatial data, thereby expanding applications, increasing demand, and growing the size of the overall marketplace.

Many U.S. state and local governments, as well as universities and NGOS, are developing geospatial data clearinghouses to help users share geospatial data and save costs in acquiring and maintaining such data.[34] Other countries are also developing such clearinghouses. Data sharing for public decisionmaking and research, such as for planning, environmental, and transportation applications by international, national, state, and local governments can help improve the efficiency and effectiveness of government services as well as scientific understanding. For example, consider El Salvador, which is making geospatial data available freely through the Web and working with other Latin American and Caribbean countries in geospatial data sharing to be able to access data more quickly in a disaster situation.[35]

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[33] Sommers, Rebecca, 1997.p. 10-11.

[34] See Lachman, Beth E., April 2000, for examples of such U.S. geospatial data clearinghouses.

[35] In addition, Ana Maria Majano, Minister for Environment for El Salvador, explains her government's decision to share geospatial data

In addition, the development of framework data makes more free and cheap geospatial data available to users. Framework data are a widely available source of basic geographic data. The framework consists of basic spatial data that users benefit from sharing. Framework data are being developed globally as well as by individual countries. For example, nearly 80 national governments from around the world are participating in the United Nations Global Map Project. This project is using satellite remote sensing and other data to develop a global framework database consisting of vegetation, elevation, land use, transportation, drainage systems, and administrative boundary layers.[36] In the United States, most states and many local governments are developing some sort of framework data.[37]

Such framework efforts, which often include extensive remote sensing data, will help increase user familiarity, technology developments and market developments for remote sensing data. To appreciate the significance of such developments consider framework development efforts of Texas (see box). Texas is placing $40 million of geospatial data in the public domain, including 17,000 remote sensing images.

Some commercial companies have argued that the U.S. government and other organizations place so much geospatial data in the public domain at the cost of distribution or for free that it is hurting the commercial geospatial marketplace. Such policies in the near term may hurt a few data provider companies, but long term and overall they have helped the marketplace and are likely to continue to do so. Actually, more data in the public domain will likely speed the development of the various geospatial marketplace segments. Public domain data make it cheaper for users to use the data and more quickly learn and spur the

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free of charge through the Web: "It's cheaper for us to have a certain amount of data on the Web, instead of having to pay personnel to attend to every request that comes through our office." Pratt, Timothy, July 2000, p.48.

[36] Divis, Dee Ann, July 2000, and Kline, Karen, et al, March 13-15, 2000.

[37] See Sommers, Rebecca, September 1999, for some initial results from a survey of framework development activities of more than 5,200 organizations across the United States.

Texas Strategic Mapping Program

Texas has a $40 million framework development effort called the Texas Strategic Mapping Program, also called StratMap. StratMap is a Texas-based cost-sharing program to develop digital geographic data layers in partnership with public and private sector entities. This framework consists of seven data layers: digital orthoimages, digital elevation models, contours (hypsography), soil surveys, water features (hydrology), transportation, and political boundaries. StratMap includes a 1 meter resolution layer of digital orthoimages consisting of more than 17,000 images to cover the entire state. This dataset is being created from aerial photography remote sensing data rather than satellite data. All of the data, which are available for free to anyone who wants them, are extensively use by commercial and public users.[38]

evolution of the technology. To illustrate this point, consider the use of the U.S. Census Bureau's TIGER database during the last two decades. The Census Bureau developed the Topologically Integrated Geographic Encoding and Referencing System (TIGER) database in the 1980s. TIGER street network data were available for the entire United States, namely, every street segment in the country, at the cost of distribution.[39] Although the TIGER databases were not the best quality data, vendors and others, such as state and local governments, enhanced and used the TIGER data to develop street networks and other GIS databases and applications. The extensive availability of such low-cost data helped create more interest and demand in GIS and spur the development and use of GIS in the late 1980s and early 1990s, especially in the transportation and local and state government market segments.

This TIGER data example illustrates how public data have most likely helped to expand the geospatial marketplace by making it cheaper and easier for people to use and develop the technologies and how it was instrumental in bringing overall prices down. In fact, some could argue that public domain data in limited areas, such as framework data efforts, actually are needed to help spur the market development of

[38] For more information about this effort see Texas Geographic Information Council, "Geographic Information Framework for Texas: Resolutions for Action," Austin, Texas, January 1999, and http:www.stratmap.org.

[39]

geospatial data and future integrated geospatial applications where users share some basic data. The public availability of such data in Texas will likely increase user knowledge, use, and demand for remote sensing data, much as the TIGER data helped spur demand for spatial street network databases and related GIS applications. Similarly, the international framework and data-sharing efforts will increase user knowledge and demand for remote sensing data. If public domain data are limited to certain areas, such as by level of scale and to certain generic base data layers, plenty of opportunities remain for the commercial sector to develop specialized datasets needed for diverse user needs.

Still A Need for More Expensive Data

Even though numerous datasets are available in the public domain, the need for more expensive data exists. First of all, cheaper and public domain data often present issues of quality and timeliness. Many international, U.S. federal, state, and local government geospatial databases in the public domain are dated, including U.S. Geological Survey DOQs and topographical maps. Users currently must pay extra for more timely data, which typically cost more. With remote sensing data, this difference is also seen in the type of product. For example, at Maryland's MERLIN public Web site, you can download a JPEG image of the state (e.g., imagery data from SPOT Image), but you cannot download a dataset usable within a GIS system. Higher quality datasets currently cost more and will continue to do so.

The highest costs for satellite imagery data are often those that require tasking of an imaging satellite. Such special tasking is likely to be infrequent, particularly given the added costs. However, some customers, such as national security users, are usually more willing to pay for this timely collection and delivery of satellite imagery data.

In addition, most of the public and cheap datasets are for framework data that provide basic information, such as land-use, land cover, transportation, and hydrology datasets. To address specialized needs, users must pay more for their geospatial datasets. Special needs mean customizing data, which usually costs more. For example, forest

managers at Bridger-Teton National Forest in Wyoming need some more specialized geospatial data with specific tree types and other vegetation information, so they are acquiring more detailed geospatial data. Public domain datasets, such Landsat basic land cover information, is unlikely to satisfy the specialized needs of some users. Therefore, they must supplement such data with other data sources, including on-the-ground vegetation surveys in their northern wilderness areas.[40]

Pricing Practices are the Key to Changing Financial Approaches

To compete in a marketplace with declining geospatial data prices and strong aerial and international competition, U.S. commercial remote sensing satellite companies must be creative in how they earn their profits. In addition, changing financial approaches for remote sensing companies are being facilitated by broader geospatial and IT developments.[41] Traditionally, remote sensing and other geospatial technology companies, like other companies, had business models that focused on recouping costs and generating revenue by selling data, software, or other products or by providing consulting services. However, sources of revenue have been changing. The Internet has facilitated new types of business transactions, such as e-business, business-to-business, and business-to-consumer applications through the Web. Such business models may be based on recouping costs through transaction fees, subscription services, rental fees, royalties, or advertising, instead of traditional data or software sales. In the IT world, an important current trend involves companies renting application services to users instead of selling them computer products, namely, the increasing trend of application service providers (ASPs). This IT trend is likely to influence geospatial applications, as it already has some CAD applications. In the future, such a trend could even change the nature of geospatial companies. For example, instead of purchasing GIS

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[40] Personal communication with Bridger-Teton National Forest vegetation analysts, summer 2000.

[41] See Appendix D for a more detailed discussion of how GIS and geospatial technologies are merging into the broader information technology marketplace.

software packages customized software services will be delivered through the Web, thus allowing GIS software vendors to change how they create and deliver their products.

The use of subscriptions is increasing for geospatial companies, and remote sensing companies are starting to provide subscription data and services. For example, the Orbital Imaging Corporation (OrbImage) provides a subscription service of fish-finding maps for large tuna-fishing fleets throughout the world. OrbImage integrates SeaWIFS satellite imagery data and other data to provide the tuna fleet captains with fish-finding maps several times a week. Another type of innovative price mechanism involves royalties from image data use. Companies recognize that the profit can come from providing information derived from image data rather than the data itself, so they are increasingly seeking royalties from value-added-reseller firms. GlobeXplorer provides an example of how remote sensing companies receive such royalties. GlobeXplorer supplies imagery data and products to businesses over the Internet. Its subscription service offers access to more than 12 terabytes of imagery through the Internet to e-business customers in such industries as real estate, insurance, travel and leisure, news media, transportation, and entertainment. Subscribers enter city addresses or other position information and can choose different high-resolution images in real time.[42] Customers can choose image data from many different data sources, including aerial and satellite remote sensing firms. When a customer selects a data product a royalty (taken from part of their subscription fee) goes to the data supplier, such as Space Imaging, which supplies IKONOS data to GlobeXplorer.

Another important trend: satellite companies are starting to allow more flexibility in licensing and access to compete with aerial firms. Such "conditional licensing" may allow the customer to share the data among limited users (e.g., other state government agencies, educational

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[42] Paul E. Smith, "Geographic Content for the Internet: Multi-Terabyte Image Server Technology," presentation at the XIX Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS) 2001 conference, Amsterdam, The Netherlands, July 19, 2001. For more information see www.globexplorer.com.

institutions, various national security agencies), or put limited data types in the public domain, such as a JPEG image. Such licensing is especially important for U.S. state and local governments that want to share data among users and put data in the public domain. SpotImage has become a leader with some of these approaches. This satellite data provider has developed "SPOT USA Select," a special package oriented towards U.S. states. For $1,400 to $35,000 per state (depending on state size) a state can have imagery data covering the entire state, which can be shared among state and local agencies and educational institutions, depending on the specifics of the agreement.[43] Several states have purchased this product, including California, West Virginia, and Kentucky. In addition, in Maryland such SpotImage data are in the public domain for Web viewing only (in JPEG format), while the state agencies can share actual GIS formatted datasets of these images.

With decreasing geospatial data prices, companies recognize that they may have to underprice some data and generate revenues in other ways. They also recognize that they must reach as many different market sectors as possible and go for volume sales, since geospatial data prices have decreased and are likely to continue decreasing. Such adaptations to the changing and competitive marketplace are good signs. However, given satellite companies' high fixed costs, the strong competition, numerous niches markets, and other complexities of this marketplace, it is too soon to know whether or not the U.S. satellite companies will be a large part of this dynamic marketplace.

Partnerships and Vertical Market Expertise Are Critical

Another important part of changing business models for the remote sensing companies in the information age economy is the development of partnerships and vertical market expertise. U.S. satellite companies also must develop vertical market expertise either through partnerships or by acquisition to enable their remote sensing data to be useful information in user demanded products. In the highly competitive geospatial marketplace, with so many diverse market sector needs and with decreasing geospatial data prices, remote sensing companies cannot

[43] SpotImage presentation at GeoTech 2000 conference.

make a profit by just providing raw image data. Different market-sector users need their own customized image products. For example, mining companies need multispectral image data to be processed to show likely locations of different mineral deposits, while forest managers need the same data to be processed to show vegetation information. For most users, raw image data require too much special processing, so the remote sensing companies must bridge the gap by making certain specific users' information products are developed.

To develop such products, the U.S. satellite companies must either acquire the vertical market expertise internally or partner with other companies to provide it. For example, to develop their fish-finding map product, OrbImage hired experts with oceanographic and biological skills. It also invested large amounts of time and resources to learn the tuna-fishing industry and connect with the users. Such vertical market expertise is expensive, and in the future this company will likely partner with other companies that already possess such knowledge and skills in other market sectors. Space Imaging acquired Pacific Meridian, a GIS applications developer company, to help them compete in such marketplaces as forest and environment management.

To achieve the levels of sales needed to survive, the satellite companies need to reach many different vertical markets without delay. One critical approach to reaching numerous markets is to partner extensively with other organizations. Partnerships enable entities to share individual resources, skills, and strengths for shared benefits. Successful partnerships build on the strengths of each organization to be able to do things that each organization would not do alone. U.S. satellite companies are partnering with specific market experts to provide the expertise to create useful information out of their products.

In addition, remote sensing companies are partnering to reach as many end-users as possible. For example, Space Imaging recently signed an agreement with ESRI, the leading GIS vendor, to allow ESRI's sales force and resellers to sell Space Imaging CARTERRA products. The CARTERRA products are the 1 meter panchromatic and 4 meter multispectral color images derived from the IKONOS satellite data. Because ESRI has

more than 400 sales representatives, this agreement increases Space Imaging's market potential for this product by reaching out to more GIS users.[44]

Because of potential synergies and the strength of the aerial firms, many of the satellite companies have started forming partnerships with aerial remote sensing firms or even purchased aerial imagery capabilities. The U.S. satellite companies now see aerial companies more as offering complementary products and services rather than competitive ones, especially while the satellite firms are still trying to develop their marketplaces.[45]

Aerial remote sensing firms have already used partners to help them succeed in the marketplace. For example, EarthData consists of a network of relationships--a group of dynamic and growing companies, affiliates and partnership relationships with aerial firms located in various regions of the country. These companies and their other partners enable EarthData to provide aerial remote sensing products and services throughout the United States (and abroad) and to customize these end-user products for different market niches. To survive in the geospatial technology marketplace, U.S. satellite companies need to develop such successful relationships. Namely, they need to partner with other companies to reach the many different niche marketplaces and to supply the needed expertise to create useful information from their products.

SUMMARY

Satellite remote sensing is part of the broader geospatial technology marketplace, and this marketplace is growing. However, U.S. commercial remote sensing satellite firms currently are and will likely continue to be only a small piece of this larger market. The U.S. satellite firms face strong competition from other data sources,

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[44] Space Imaging, "Space Imaging Signs on ESRI as a Master Reseller", Press Release Newswire, October 17, 2000.

[45] A good example is the March 2001 agreement of Space Imaging to be a master distributor for the Eastman Kodak Company's CITIPIX aerial imagery and other imaging products, which enables Kodak to leverage more than 150 resellers associated with Space Imaging in selling its high-resolution (six-inch to 1 meter) aerial imagery of major metropolitan areas in the United States and Canada.

especially from aerial and non-U.S. satellite imagery sources, as well as from lower priced, non-image geospatial data. Satellite firms are still trying to develop and find their commercial niches. The broader geospatial technology marketplace is changing and merging into the IT marketplace. Geospatial technologies are becoming more and more integrated. Users increasingly want distributed and seamless geospatial applications through the Internet. Also, geospatial data prices have been decreasing. In addition, cheap geospatial data are more readily available and even desirable because of data-sharing benefits and potential geospatial applications conducted through the web. Users demand information, not remote sensing data. Those applications that use remote sensing data mostly use it to create smart GIS datasets. Technology challenges still exist for using remote sensing data in geospatial applications, such as turning imagery data into smart GIS datasets.

All these marketplace developments place more pressure on U.S. commercial remote sensing satellite firms. To address these different remote sensing markets and the broader geospatial market developments, U.S. satellite firms have a strong need to transform from data providers into information age companies. To achieve such a transition, the satellite firms need to be responsive to changing business models in the marketplace. Specifically, they must develop flexible data pricing and access deals, and they must seek partnerships and vertical market expertise to survive in this marketplace.

Given these basic market developments, the risks to U.S. commercial remote sensing satellite firms succeeding in such a marketplace are very high. There are three critical challenges that these firms face in dealing with market risks:

- Whether or not the commercial remote sensing satellite companies can successfully leverage off the growth of the geospatial technology marketplace?

- Whether or not the satellite firms can successfully formulate and implement new business models that transform them from traditional image data providers to information age companies?

- Whether or not the satellite firms can effectively compete with aerial remote sensing firms and non-U.S. remote sensing satellite enterprises?

The U.S. commercial remote sensing satellite industry is in a challenging position in the marketplace and facing significant risks of not becoming commercially viable over the long term given this competitive marketplace. However, our analysis also suggests that the new U.S. satellite firms, which are still in their infancy, are responsive to the marketplace pressures and can probably successfully manage these risks by adopting business models, pricing practices, and partnership approaches that are best suited for this complex and dynamic remote sensing marketplace.

4. INTERNATIONAL CONTEXT: COMPETITION AND COOPERATION

U.S. commercial remote sensing firms operate in an environment that includes many foreign remote sensing systems. These systems, often owned or operated by foreign governments, compete for market share in the still nascent satellite remote sensing market. To fully exploit the global coverage of satellite systems, remote sensing firms must be able to market their products worldwide, with open access to foreign markets. Access to foreign markets, and the ability to understand and serve those markets, may be enhanced by having foreign companies participate in remote sensing ventures as equity investors or as strategic partners. We explore below some of the issues that arise from this international context of satellite remote sensing.

The prominent role of foreign remote sensing satellites as providers of imagery data in the global marketplace is highlighted in this section. The non-U.S. imaging satellites include the traditional parastatal remote sensing satellite programs that usually involve larger satellites that are heavily supported by governments, as well as an emerging generation of smaller imaging satellites that could provide low-end imagery satellite data. This section also explores the potential challenges that appear for gaining access to foreign markets as national governments struggle with deciding whether to loosen traditional restrictions on domestic access to higher resolution spatial data, including commercial satellite imagery. Finally, special attention is given to the importance of international partnerships and investors to the success of the new U.S. commercial remote sensing satellite firms.

COMPETITION FROM FOREIGN SYSTEMS

As Figure 4.1 illustrates, the number of foreign remote sensing systems is growing rapidly and will continue to do so over the next several years. A number of these foreign systems (EROS, Cartosat,

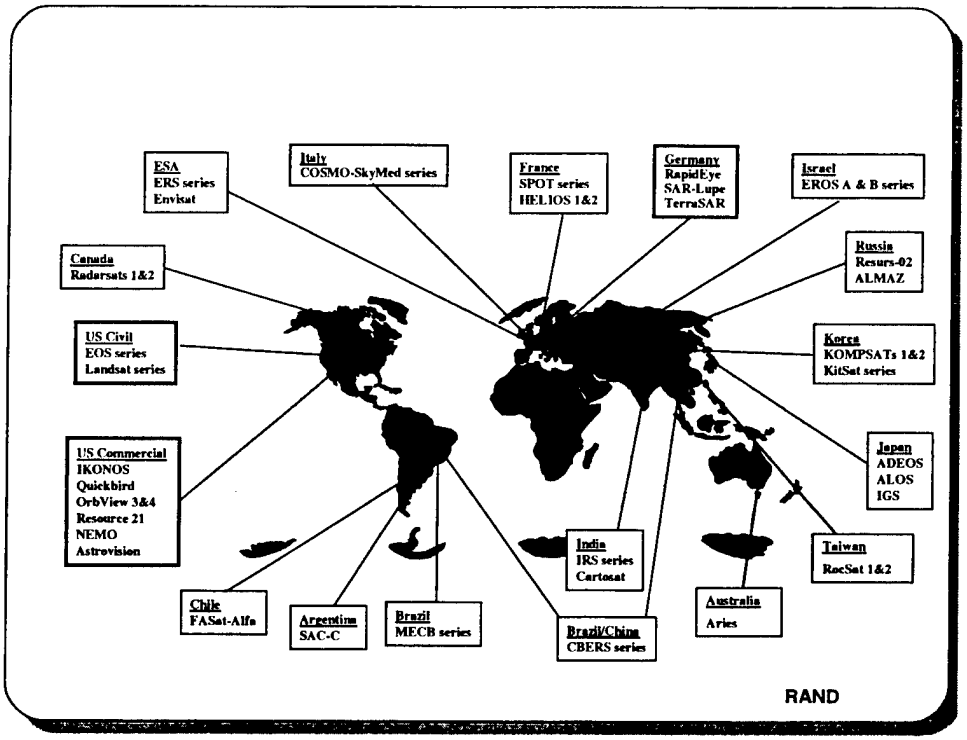

Figure 4.1: Worldwide Satellite Remote Sensing Systems

Kompsat 2, SPOT 3S, COSMO SkyMed, RESURS DK1) will offer electro-optical imagery at or near 1-meter resolution, in direct competition with first-generation U.S. commercial remote sensing firms. Others (Radarsat 2, SAR Lupe, COSMO SkyMed) plan to offer SAR imagery with resolution in the range of 1 to 3 meters, which could compete with future U.S. entrants in the market for commercial SAR imagery. Thus, foreign remote sensing systems, which according to a recent Frost & Sullivan study[46] already accounted for about 70 percent of worldwide satellite imagery sales in 1998, pose an increasing competitive threat to U.S. systems.

Not only are U.S. firms facing an increasing array of foreign competitors, but almost all of these competitors also are, to varying degrees, government-owned or government-supported entities. Table 4.1 illustrates the different ways in which remote sensing systems benefit from government support. For foreign systems, the space segment (satellite and sensor) and launch costs are usually borne by the government. In some cases, such as Radarsat 2, the commercial entity

[46] *World Remote-Sensing Data and GIS Software Markets,* Frost & Sullivan, 1999

may put up a minority share of the capital costs (roughly 25 percent in the case of Radarsat), and the government is promised preferred pricing of imagery products in return for its up-front financing of the spacecraft, sensor, and launch. In most cases, however, complete government funding of the space segment remains the norm.

Table 4.1: Government Involvement in Commercial Remote Sensing

	DECREASING GOVERNMENT CONTROL & FINANCIAL SUPPORT →			
Government-Commercial Relationship	Government-owned and operated system. Government marketing and sales of products.	Government-owned and operated system. Commercial marketing and sales of products.	Government/commercial sharing of space segment and/or launch costs. Commercial operation of satellite and marketing of products. Imagery provided to government at low or no cost.	Commercial funding of space segment and launch costs. Commercial operation of satellite and marketing of products.
Primary Government Roles	Owner Imagery data distributor	Owner Regulator Customer	Regulator Customer Patron	Regulator Customer
Examples of Imaging Satellites	ALOS Landsat 7	ERS series ENVISAT IRS series Landsat 5 RADARSAT 1 SPIN-2 SPOT series	EROS series OrbView 4 RADARSAT 2	IKONOS, OrbView 3 QuickBird

The commercial entities that sell the imagery products also may benefit from significant government backing. For example, CNES, the French national space agency, is the largest shareholder in SPOT Image, the entity responsible for marketing and selling products from the French SPOT remote sensing system.

Many foreign remote sensing systems are national systems that support broader policy objectives of their sponsoring government. These objectives frequently include national prestige, development of advanced technologies, management of national resources, and support of national security requirements. Such national systems are sheltered from some of the market forces that may buffet more commercial enterprises. France, for example, has long established the fielding of an indigenous civil remote sensing system as part of their national policy and has continued to finance successive generations of the SPOT system. The roughly 8 billion French francs (approximately $1.3 billion) spent by the French government on the SPOT program through 1994 would be hard to justify based solely on the revenues generated by SPOT Image, which have averaged less than $50 million per year.

DEVELOPMENT OF SMALLER REMOTE SENSING SATELLITES

The growth in competition from foreign remote sensing systems is likely to be further fueled by technology trends that are making small, high-performance remote sensing satellites an increasingly attractive option. As Table 4.2 illustrates, for example, the EROS B2 through B6 satellites planned by ImageSat International will, if successful, provide performance comparable to that of the IKONOS system from a satellite of less than half the mass. The reduced mass is important because it translates to reduced satellite cost and launch cost. Similarly, the French plan to reduce the size of their remote sensing satellites under the 3S program to weigh about 500 kg, as opposed to over 2,000 kg for the SPOT satellites. They also estimate that these smaller satellites will each cost on the order of 200 million French francs to build, launch, and operate, as opposed to about 2.6 billion French francs for current SPOT satellites. Such cost reductions will lower entry barriers for new providers of satellite imagery.

Remote sensing satellites considerably smaller than EROS are emerging. These systems may cost on the order of millions or a few tens of millions of dollars, as opposed to hundreds of millions of dollars for more conventional designs. Governments that previously thought satellite remote sensing too expensive can now afford to field imagery systems. Remote sensing satellites are now even within the financial reach of universities. For example, the Sunsat system presented in Table 4.2 was fielded by the University of Stellenbosch, South Africa, in cooperation with Surrey Satellite Systems Ltd., itself affiliated with the University of Surrey in the United Kingdom. This 63-kg satellite provides imagery approaching the resolution of the panchromatic imagery from the current SPOT system. Surrey Satellite has

similar joint development or technology transfer programs with a number of governments and universities. While it remains to be demonstrated that these very small (less than about 100 kg) satellite imagery systems can provide the image quality and geodetic accuracy needed for demanding cartographic users or other applications that require the highest levels of mensuration accuracy, they can provide a potentially low-cost alternative source of data for users who don't need such metric accuracy.

Table 4.2: Small Satellites Can Be Competitive

	Sunsat	**EROS B2 through B6**	**IKONOS**
Mass (kg)	63	350	720
Orbit (km)	520 x 850	600	681
Resolution (m)	15	1 (panchromatic) 4 (multispectral)	1 (panchromatic) 4 (multispectral)
Swath (km)	45	16	13
Pointing (deg)	+/- 23 (along and cross track)	+/- 45 (along and cross track)	+/- 26 (along and cross track)
Geodetic Accuracy (m) **(no ground control points)**	N/A	< 30	12
Design Life	5 years	6 years	5 years

ACCESS TO FOREIGN MARKETS

Satellite remote sensing systems are, by their very nature, global systems. To benefit from this global coverage, however, commercial

imagery firms must be able to sell their products worldwide. There has been concern that some countries may restrict or limit the sale of U.S. imagery products within their borders. Such restrictions may be enacted to protect the domestic imagery market for that country's own satellite imagery system. Alternatively, restrictions may arise from security concerns raised by high-resolution imagery. In some countries only the government is permitted by law to possess high-accuracy maps. Thailand, for example, restricts detailed maps and imagery.

Some cases of restrictive access to foreign markets are beginning to arise. In India, the government has agreed to allow the sale of IKONOS 1-meter imagery, but the Indian government will maintain tight control over its distribution. Space Imaging will not be permitted to sell IKONOS products directly to Indian customers. Instead, IKONOS imagery will be distributed through Antrix Corp, the commercial arm of the Indian Space Research Organization (ISRO). Other countries also may limit the sale of high-resolution imagery to government agencies or government-specified organizations. In South Korea, for example, the government reportedly will not allow high-resolution imagery to be exported from the country. If this policy is enacted and enforced, it will preclude regional distribution of imagery that may be downloaded to a Korean ground station. Public access to high-resolution imagery is also uncertain in Singapore. In the case of Israel, the restrictions are not on distribution of imagery but on its collection. U.S. firms currently are precluded from collecting and disseminating imagery of Israel at better than 2-meter resolution. (See Section 5.)

While these developments are troublesome, it remains too early to tell whether they are the exception or the norm. It thus remains necessary to monitor foreign regulations and restrictions on market access. U.S. government intervention to ensure fair market access may be needed on a case-by-case basis.

INTERNATIONAL PARTNERSHIPS

International participation in U.S. commercial remote sensing enterprises is important for at least two reasons: access to foreign capital to help fund the systems and improved access to foreign markets

through regional partners or affiliates. It had at one time been feared that restrictive interpretations of regulations on the U.S. systems might preclude U.S. firms from seeking the levels of foreign participation that they felt were needed to meet their business objectives. However, current regulations have not stopped firms from attracting foreign equity partners or regional affiliates.

System operators also desire regional partners who will operate ground stations that receive regional imagery from the satellites. Such regional ground stations reduce the amount of onboard data storage that otherwise would be needed to retrieve imagery from around the world, thus decreasing the technical demands on the satellite and increasing the operational flexibility of the system.

U.S. companies also participate in various ways in foreign remote sensing systems. Core Software Technologies of the United States, for example, is a founding shareholder in ImageSat International, together with Israel Aircraft Industries (IAI) and Elop, both of Israel. Space Imaging is the global distributor of imagery from the Indian IRS system. OrbImage acquired the rights to be the distributor of imagery from the Canadian Radarsat 2 system, while SPOT Image will distribute imagery from OrbImage's high-resolution OrbView-3 and -4 satellites in Europe.

In some cases, countries may have effective control of a remote sensing satellite without having to be an initial investor or operator of the system. ImageSat International, for example, offers the Satellite Operating Partner (SOP) service. An SOP has dedicated use of one or more ImageSat satellites when it is within the reception footprint of the SOP's ground station. The SOP directly tasks the satellite and receives regional imagery in real time.

Thus while there is a tendency to identify remote sensing systems with a particular country the accuracy of such identification is becoming increasingly questionable.

SUMMARY

The international environment for remote sensing systems thus will see intense foreign competition and cooperation proceeding hand in hand.

U.S. firms will be competing against foreign systems that generally have a different approach to commercialization and that at least partially benefit from government financial support. Technology trends will lower cost barriers for remote sensing systems, encouraging new, nontraditional system operators to enter the field; some of who, such as universities, may be inclined to provide free or very low-cost imagery. At the same time, commercial satellite remote sensing systems are truly becoming global systems. Multinational investors and international users with tasking rights to commercial systems will make it increasingly difficult to unambiguously identify a remote sensing system with a single country. System operators also want worldwide ground stations to make it easier to get their imagery from the satellite to the ground without needing excessive onboard data storage, further contributing to the global nature of the systems. Finally, the degree of open access to foreign markets for high-resolution imagery products remains uncertain.

5. POLICY AND REGULATORY ISSUES

U.S. government policies and regulations can exert a major influence on the choices open to commercial remote sensing satellite firms. This influence arises from the multiple roles that government plays in shaping the policy environment for the commercial remote sensing industry. The dual-purpose nature of imaging satellites, which can be used for both military and non-military (i.e., civilian and commercial) purposes, also places a special responsibility on the U.S. government for regulating and monitoring the activities of commercial observation satellites. Thus, unlike the aerial data providers and value-added firms of the remote sensing industry, the emerging U.S. satellite data provider firms operate under significantly more government regulation.

This section assesses the potential risks that the U.S. policy and regulatory environment poses for American private firms pursuing commercial remote sensing satellite programs. It begins by examining the evolving policy and regulatory environment that highlights the multiple policymaking roles that the U.S. government plays. Attention is next given to the specific concerns that U.S. remote sensing satellite firms have raised about performance and operational restrictions, policymaking uncertainties, and the question of internal advocacy. Finally, their concerns are assessed within a broader perspective on the strengths and shortcomings of the evolving U.S. policy and regulatory environment.

U.S. POLICY GUIDELINES

The primary U.S. government authority for licensing U.S. private firms interested in acquiring and operating commercial observation satellites is found in the Land Remote Sensing Policy Act of 1992. Specific U.S. government guidelines were subsequently provided in the Presidential Decision Directive 23 (PDD-23) of March 1994. The driving principle underlying PDD-23 is "to support and to enhance U.S. industrial competitiveness in the field of remote sensing space capabilities while at the same time protecting U.S. national security

and foreign policy interests."[47] This presidential decision encouraged progress by suggesting that the government would favorably consider

Table 5.1: Multiple U.S. Government Roles for Commercial Remote Sensing

USG Roles	Examples of U.S. Government Policy or Regulatory Effects
Regulator	• PDD-23 policy framework (e.g., multi-tier licensing) • NOAA licensing regulations for operating a private commercial remote sensing satellite system • Space remote sensing technologies and knowledge as part of the U.S. export controls
Customer	• NIMA: Commercial Imagery Strategy • NASA: Science Data Buy • NOAA: Coral Reef Initiative for purchasing imagery • USGS: National Photography Program (NPP)
Patron	• NASA: funding support for developing OrbView-2 ocean monitoring for SeaWiFS/SeaStar missions • USAF: funding development of the Warfighter (hyperspectral) sensor for use on OrbView-4 • USN: partnership with U.S. private firm to develop the Naval Earth Map Observer(NEMO)imaging satellite • NASA: commercial remote sensing program, as part of the Earth Science Enterprise Applications
Potential competitor	• Landsat 7 data policy for imagery sales based on the cost of fulfilling user requests (COFUR) • Declassification of U.S. intelligence imagery (e.g., CORONA satellite imagery, U-2 aircraft imagery)

[47] An unclassified version of the key provisions of the PDD-23 decision was made public in White House Fact Sheet, "Foreign Access to Remote Sensing Space Capabilities," (March 10, 1994), p. 1.

license requests by U.S. firms proposing high-resolution Earth observation satellite systems with performance capabilities and imagery quality characteristics determined to be comparable to existing or planned imaging satellites available in the world marketplace. However, translating the PDD-23 objectives into a coherent policy for guiding the development of U.S. commercial remote sensing satellite programs is challenging because of the multiple roles that the U.S. government plays as regulator, customer, patron, and potential competitor in shaping the policy environment for the commercial remote sensing industry. Table 5.1 uses these categories to distinguish many of the specific actions that the U.S. government is taking in shaping the broader policy and regulatory environment for the commercial remote sensing firms.

Regulatory Issues

The PDD-23 decision built on earlier U.S. government policies that encouraged the growth of the satellite component of the U.S. commercial remote sensing industry. Most important was the Land Remote Sensing Policy Act of 1992 (P.L. 102-555), which set out the legal basis for U.S. private firms seeking to become operators of remote sensing satellite systems. In a major change to earlier legislation, the 1992 Act relaxed the previous requirement that private operators of imaging satellites must adhere to the nondiscriminatory access data policy, which guides U.S. government data policy for civilian Earth observation satellites. The change significantly increased the incentives for private firms to enter the commercial remote sensing satellite field. U.S. firms are still required to make unenhanced imagery data available to the governments of sensed states (i.e., any state that has been imaged by a remote sensing satellite) as soon as the data are available, and on reasonable terms. However, they now have leeway to charge market prices to other potential customers on their own terms.[48]

In January 1993, the Bush administration issued the first license under the 1992 Act to a U.S. company, WorldView Imaging, Inc., for a commercial imaging satellite that could collect 3-m panchromatic imagery and 15-m multispectral imagery.

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[48] The Land Remote Sensing Commercialization Act of 1984 (P.L. 98-365), which provided the legal basis for transferring Landsat 4 and 5 data sales to a private sector firm (EOSAT), actually constrained commercialization by requiring EOSAT to make unenhanced imagery data

In March 1994, a three-tier control system (Figure 5.1) was established as a result of the PPD-23 decision on managing U.S. commercial remote sensing satellite policymaking.

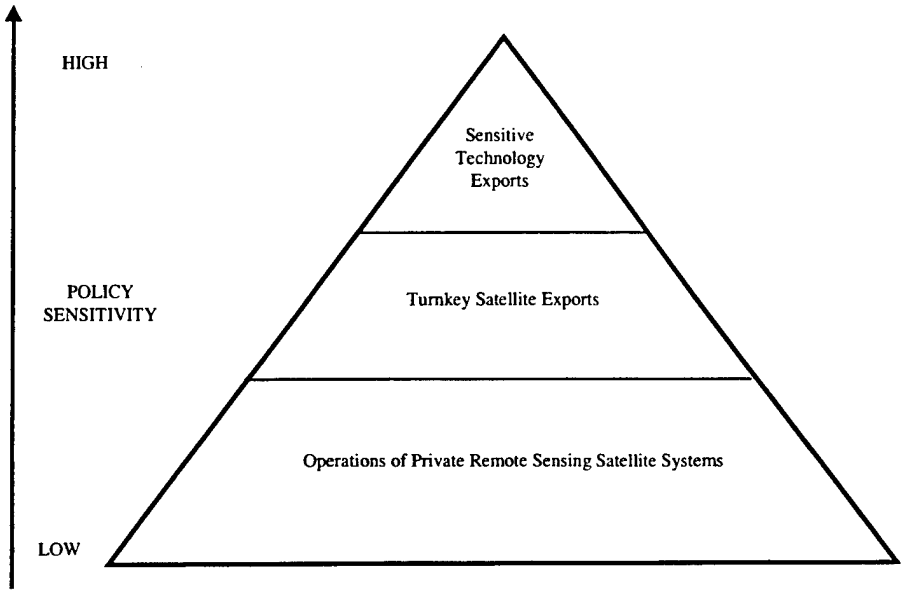

Figure 5.1 Multi-tier Control System.

The PDD-23 policy framework outlined guidelines for the following types of policy decisions:

- *Licensing and operations of private remote sensing systems*: requests by U.S. firms seeking licenses to operate private imaging satellite systems are reviewed on a case-by-case basis, and those approved by the U.S. government must adhere to a range of conditions, including the acceptance of the government's right to impose "shutter controls"[49] if necessary.

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available to all potential users on a nondiscriminatory basis. Its provisions also inhibited EOSAT from competing with value-added firms.

[49] Shutter controls is the popular characterization of policies or actions taken to restrict the collection and/or dissemination of satellite imagery data.

- *Transfer of "turnkey" imaging satellite systems*: the U.S. government will consider on a case-by-case basis requests by American firms to export advanced remote sensing systems, which could require a government-to-government agreement.

- *Transfer of sensitive technologies related to imaging satellites*: applications to export sensitive components, subsystems, and information involving imaging satellites require a government-to-government agreement that could include end-use and retransfer assurances.

The multi-tiered control system is based on a risk management approach that carefully distinguishes among three major concerns associated with authorizing commercial remote sensing satellite systems: imagery data, turnkey systems, and sensitive technologies. The licensed U.S. firms enjoy substantial leeway in selling high-resolution satellite imagery data and products on the world market. In comparison, applications by U.S. firms to export either sensitive remote sensing technologies or a full 'turnkey' imaging satellite system involve higher levels of U.S. government policy sensitivity because U.S. government is being asked to allow foreign parties to receive greater access to American imaging technologies and expertise. U.S. policy is therefore more demanding in these cases; government-to-government agreements are usually required before such export requests will be approved.

Policymaking Process

The U.S. policy and regulatory environment for commercial remote sensing satellite systems is complicated by the number of stakeholders possessing legitimate interests in any licensing or export decision. The dual-purpose nature of imaging satellites, particularly for satellites intended to produce high-resolution imagery data, requires that the concerns of a wide range of U.S. government agencies be weighed in making these policy decisions. Any decision must strike an acceptable balance among the following considerations:

- Protecting U.S. national security concerns, foreign policy, and international obligations.

- Promoting the development of the U.S. commercial remote sensing industry, including its international competitiveness.

- Promoting the collection and widespread availability of Earth remote sensing data for public benefits.

The National Oceanic and Atmospheric Administration (NOAA) is responsible for regulating the operations of U.S. commercial remote sensing satellite firms. It administers the licensing of these firms, monitors their adherence to various licensing obligations, and enforces their compliance.[50] These U.S. government regulations apply directly (or through an affiliate or subsidiary) to the operation of a private remote sensing space system. NOAA recently issued the interim final regulations (15 CFR Part 960) on July 31, 2000.[51] In comparison, the licensing of exports for U.S. remote sensing satellites, satellite components, and sensitive technologies are the responsibility of the State Department. Given their potential military utility, these items are contained on the U.S. Munitions List and are subject to the Arms Export Control Act.

Although the Commerce Department (through NOAA) has the lead responsibility for licensing U.S. companies interested in operating a private remote sensing satellite system, other government agencies that have important roles in the interagency review of licensing applications include the Departments of Defense, State, and Interior, as well as the intelligence community.[52] And based on a Memorandum of Understanding (MOU), released on February 2, 2000, the Secretaries of State and Defense play the major role in determining the conditions when the U.S. government should interrupt the normal imaging operations (i.e., impose "shutter controls") on U.S. commercial observation satellites to protect U.S. national interests.[53] The National Security Council (NSC) and the

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[50] NOAA's authority in this area is delegated from the Secretary of Commerce, who has statutory authority to issue licenses to operators of private remote sensing space systems based on the Land Remote Sensing Act of 1992, the presidential policy (PDD-23) announced on March 10, 1994, and the 1998 Commercial Space Act.

[51] These regulations are revisions of the proposed regulations for licensing private land remote sensing space systems, which NOAA first issued on November 3, 1997, based on public comments and interagency deliberations.

[52] In addition, a number of U.S. federal agencies and organizations have very specific regulatory responsibilities that affect U.S. commercial remote sensing satellite firms. These include NASA (satellite disposal plan), FCC (spectrum allocation), and the Committee on Foreign Investment in the United States (CFIUS), which is managed by the Treasury Department. CFIUS assesses the broader national interests associated with the level of foreign investments in particular U.S. companies.

[53] The MOU, which was jointly released by OSTP and NSC, states that the Land Remote Sensing Policy Act of 1992 "grants to the Secretaries of State and Defense the authority to determine conditions necessary to protect international obligations, foreign policy concerns, and national

Office of Science and Technology Policy (OSTP) both play important roles in coordinating the interagency policymaking process on U.S. commercial remote sensing satellite questions.

In addition, Congress plays an important role in shaping the broader policy and regulatory environment for U.S. commercial remote sensing satellite firms. As noted earlier, the Land Remote Sensing Policy Act of 1992, which replaced earlier legislation from 1984 that had begun process for the privatization of the Landsat program, created the legal basis for commercial remote sensing space systems. In addition, congressional hearings played an important role in prompting Executive Branch action on producing the 1994 presidential policy decision, which reduced the uncertainties facing U.S. private firms interested in applying for licenses to operate commercial observation satellite systems. Congressional committees and members of Congress continue to be interested in various aspects of U.S. policy on commercial satellite imagery.[54]

Although Congress has encouraged the commercialization of land remote sensing, it has also legislated restrictions on U.S. commercial remote sensing satellite firms. In particular, the Kyl-Bingaman Amendment to the FY 1997 National Defense Authorization Act, prohibits private firms from receiving a U.S. government license to collect or disseminate imagery of Israel "more detailed or precise than satellite imagery of Israel that is available from commercial sources." This provision has been interpreted to mean that U.S. firms should not collect or disseminate satellite images of Israeli territory that possess better than 2-meter resolution (ground sample distance).[55]

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security concerns." See the February 2, 2000, fact sheet contained in the NOAA licensing regulations in the *Federal Register*, Vol. 65, No. 147 (July 31, 2000), 46836-46837.

[54] For example, see Sen. Daniel K. Akaka (D-HI), "Security and Commercial Satellite Imagery," *Congressional Record* (May 11, 2000), S3908-3909.

[55] Congress passed the Kyl-Bingaman amendment on September 23, 1996, as Section 1064 of Public Law 104-201 (the FY 1997 National Defense Authorization Act). The legislation followed an earlier expression of congressional concern on this question when 64 senators sent a letter to Commerce Secretary Ron Brown expressing concern over the plans of a new U.S. remote sensing satellite firm, Eyeglass International, to reach an imagery distribution agreement with a Saudi Arabian firm, known as EIRAD. Several House members also sent the Commerce Secretary a similar letter.

U.S. Government Encouragement as Patron and Customer

Along with its regulatory role, the U.S. government has also been an important patron for the commercial remote sensing satellite firms. U.S. government agencies have become important patrons by entering into public-private partnerships that support the development of new imaging satellite systems. NASA funding supported the development of OrbImage's OrbView-2 imaging satellite that performs the SeaStar/SeaWiFS mission by collecting Earth observation data with research and commercial applications, particularly using color images of the world's ocean areas. Similarly, DOD is funding the development of hyperspectral imaging sensors for commercial satellite systems both through the Air Force's Warfighter-1 project for OrbView-4 and the Naval Earth Map Observer (NEMO) satellite program.

U.S. government agencies are also potentially important customers for the commercial remote sensing satellite firms. In April 1999 the National Imagery and Mapping Agency (NIMA) and the National Reconnaissance Office (NRO) presented to Congress their Commercial Imagery Strategy (CIS) that outlines the U.S. government's intended approach for engaging and making use of the U.S. commercial remote sensing satellite firms. This program established working relationships with the three leading U.S. commercial imaging satellite firms (i.e., DigitalGlobe, OrbImage, and Space Imaging), as well as funded improvements to their ground infrastructures to support NIMA's goal of allowing their commercial satellite imagery to be delivered to U.S. government users within 24 hours of receiving the images at the firms' ground stations.[56]

The expectations of U.S. commercial firms concerning the potential importance of the U.S. government as a major near-term customer for their imagery data and services have widely fluctuated in recent years. For example, in 1999 the Commercial Imagery Strategy envisioned that the government would pursue a $1 billion program (over six years) to draw on the emerging U.S. commercial remote sensing satellite capabilities. However, funding shortfalls have raised serious doubts about the extent of the U.S. government commitment to making use of the first-generation U.S. commercial observation satellite systems. At the same time, NIMA has expressed greater interest in making use of the next-generation of higher resolution commercial observation satellites. Similarly, NASA's Science Data Buy initiative, which earmarked $50 million for the purchase of commercial remote sensing data and information products, has

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[56] Paula Roberts, "NIMA Embraces Commercial Imagery," *Imaging Notes* (September/October 2000), 24-25.

not yet proven to be a major source of funding for the U.S. commercial satellite imagery.

Competition from U.S. Government Programs

Government policies can also affect the commercial remote sensing industry by providing for imagery data, information products, or services that a user could otherwise obtain from commercial firms. In promoting the availability of Earth observation data and information for non-commercial purposes, the U.S. government programs can become unintended competitors to commercial imaging firms trying to develop their customer base. Two U.S. policies have particularly significant implications for the emerging U.S. commercial remote sensing satellite firms: the Landsat 7 data policy and the declassification of U.S. satellite imagery.

The U.S. policies governing the Landsat 7 program were forth in Presidential Decision Directive/NSTC-3, which the White House issued in May 1994.[57] This high-level policy decision outlined a new plan for acquiring Landsat 7 that clarified organizational responsibilities of key U.S. agencies. The declared goal of the new Landsat plans was to ensure the "continuity of Landsat-type and quality of data," while reducing the risk of data gap arising from the 1993 launch failure of Landsat 6.

The specific mission goal of Landsat 7 is to acquire and periodically refresh a global archive of daytime, generally cloud-free images of all land and coastal areas.[58] U.S. policy governing Landsat 7 imagery sales is based on the data policy guidelines outlined in the Land Remote Sensing Policy Act of 1992. It mandates the wide distribution of imagery data by requiring nondiscriminatory access to Landsat 7's unenhanced imagery data for all users at the cost of fulfilling user requests (COFUR), which is essentially the incremental cost of processing and basically correcting the Landsat 7 digital image.[59] The data policy also permits the Landsat 7 imagery data to be

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[57] The presidential directive designated NASA as the lead development agency for Landsat 7, named NOAA as the operating agency, and assigned the data archive responsibilities to the EROS Data Center of the U.S. Geological Survey.

[58] The Landsat operating plans call for collecting and transmitting up to 250 full scenes each day to the primary U.S. receiving station.

[59] The Landsat 7 imagery data can be purchased from the National Land Remote Sensing Data Archive (NLRSDA) at the EROS Data Center. For details on the Archive, and the federal advisory committee that makes recommendations on U.S. government policy in this area, see Joanne Irene

reproduced and redistributed by users without restriction or added costs.

Landsat 7 was designed for a distinctive national mission focused on producing imagery data to satisfy a broad range of U.S. civilian remote sensing needs, including global change assessments. However, its low-cost imagery data is a potential competitor to commercial remote sensing satellite systems, depending on the spatial and spectral resolution of the imagery data that the commercial satellites produce. The U.S. government's Landsat 7 data policy dictates that unenhanced Landsat imagery data will be sold at prices less than $600 per scene.[60] These prices are significantly lower than what the commercial vendors were previously charging for Landsat 4 and 5 images. The considerably cheaper Landsat 7 imagery data have already increased pressure on U.S. and non-U.S. satellite remote sensing programs to cut their imagery costs and to develop innovative pricing mechanisms.

The U.S. government is currently considering how best to ensure Landsat imagery data continuity following Landsat 7, which is expected to operate until at least 2006. One alternative being considered is to rely on private industry. However, there are questions on whether commercial firms can provide the desired imagery quality and global coverage at affordable prices. Another alternative is an international consortium to operate a moderate-resolution, multispectral imaging satellite system. Shifting away from the existing government model involves a series of questions on how imagery data will be collected, processed, and maintained in the National Land Remote Sensing Data Archive, as well as the costs of imagery data products for government and public users.

Another U.S. government program that has raised concerns about potential competition is declassified U.S. satellite imagery data. Starting in 1995, nearly 800,000 CORONA intelligence satellite images became available to the public as a result of Executive Order No. 12951, which was signed by President Clinton on February 22, 1995. Images from this large archive of film-based satellite images are sold to the public through the EROS Data Center for a relatively modest fee. Some U.S. commercial remote sensing satellite data providers have been concerned that publicly releasing the CORONA imagery, as well as any subsequent U.S. government decisions to proceed with declassifying more recent

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Gabrynowicz, "The work of the US National Satellite Land Remote Sensing Data Archive Advisory Committee: 1998-2000," *Space Policy*, Vol. 17, 2001, pp. 49-53.

intelligence imagery, could greatly diminish the nascent market demand for their higher price commercial satellite imagery.

However, an alternative perspective holds that the lower price imagery data produced by Landsat 7 and, to a lesser degree, the declassified satellite images, are more likely to bolster the commercial remote sensing industry. By having available more affordable sources of satellite unenhanced data, researchers are encouraged to develop satellite imagery applications. Thus, satellite imagery becomes more cost-competitive with alternative sources of geospatial data. In addition, value-added firms still benefit from their important role in converting unenhanced Landsat 7 imagery data into the specific information products desired by various customers.

CONCERNS OF THE COMMERCIAL IMAGING SATELLITE DATA PROVIDERS

Managers at U.S. commercial remote sensing firms have expressed various concerns over the risks that the evolving U.S. policy and regulatory environment pose to their commercial success.[61] Senior managers at the leading U.S. firms have identified the following types of concerns:

- *Performance restrictions*: policies that limit the imaging capabilities allowed for U.S. commercial observation satellite systems.

- *Operational restrictions*: policies that constrain how U.S. commercial remote sensing firms can collect and/or disseminate imagery data to their customers.

- *Policymaking uncertainties*: length of time required to reach U.S. licensing and export decisions, as well as how company proprietary data is handled.

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[60] Landsat 7 Data Policy (September 19, 1997); and U.S. Geological Survey, "Landsat 7 Data Prices Announced," October 31, 1997.

[61] The discussion of perceived risks in this subsection is based on RAND staff assessments of the views of senior managers among the leading U.S. commercial remote sensing satellite firms. These assessments were informed by RAND reviews of their public statements over the past several years, as well as several in-depth interviews conducted during 2000.

- *Internal advocacy*: lack of a strong internal advocate for the commercial remote sensing satellite firms within the U.S. government's policymaking process.

Performance Restrictions

U.S. commercial remote sensing firms are concerned about government-imposed restrictions on the imaging capabilities of their satellite systems. Managers at U.S. firms have expressed concern that performance restrictions on next generation commercial observation satellites will inhibit their ability to produce and sell satellite imagery products that will satisfy customer demand, particularly given the alternatives available from aerial imagery or foreign satellite imaging providers.

Operational Restrictions

Another major concern is the uncertainty that arises from operational restrictions imposed on U.S. firms as part of their licensing obligations. Senior managers at these firms contend that the shutter controls provisions derived from PDD-23 diminish their ability to attract investors and partners. Uncertainties concerning how and when shutter controls might be imposed can discourage potential investors, and particularly foreign partners, because of the risks that the commercial satellite imaging operations could be unexpectedly interrupted, revenues lost, and the business reputation of the U.S. firms damaged. Although recognizing the government's legitimate need to impose operational controls on U.S. commercial remote sensing satellite operations if a national emergency arises, the industry managers view the current U.S. government formulation of shutter controls as essentially a "blank check" to interrupt their business operations. Concerns also exist that foreign competitors are actively taking advantage of this situation to attract away potential international customers.

Policymaking Process Concerns

Another concern focuses on the U.S. government's policymaking process for license applications and amendments to existing licenses. The process is viewed as much too slow and uncertain for firms attempting to compete effectively in the commercial marketplace. In one instance, it reportedly took nearly 32 months to receive a licensing amendment approval. Such delays give rise to industry concerns that too many opportunities exist within the complicated interagency process for delaying the consideration of license applications.

Concern also exists over whether proprietary data, which the firms provide as part of their licensing applications, is being appropriately handled within the U.S. government. Because of the unclassified nature of this information, the possibility exists that the information is being broadly circulated among government officials and their nongovernmental support staffs despite the risk that sensitive propriety information (launch schedules for planned imaging satellites, sensor performance capabilities, company marketing strategies, etc.), could be inadvertently revealed to commercial competitors.

Internal Advocacy

Finally, some senior company managers have expressed concern over the lack of a strong internal advocate for the U.S. commercial remote sensing firms within the U.S. government's policymaking process. They view the current process as placing the Commerce Department in the ambivalent position of serving as both a regulator of and an advocate for the U.S. commercial remote sensing satellite firms. Unlike their domestic and international competitors, U.S. commercial remote sensing satellite firms are subject to substantial U.S. government regulations. In addition, the commercial prospects for the emerging remote sensing satellite firms are substantially influenced by U.S. government policies because federal agencies are likely to be the largest potential customer for these imaging data providers over the near-term. Hence, the managers contend that a strong internal advocate is needed within the U.S. policymaking process to ensure that the emerging firms are not placed at a disadvantage compared with their unregulated competitors.

PLACING THE EVOLVING POLICY AND REGULATORY ENVIRONMENT INTO PERSPECTIVE

Some of the concerns expressed by managers of the U.S. commercial remote sensing firms appear well founded while others seem to be based more on concerns over possible negative consequences rather than known instances where U.S. government policies and decisions have detrimentally affected the business prospects of the commercial firms. In assessing industry concerns, it is important to distinguish between those concerns directed at specific elements of U.S. government policies and those focused on the nature of the American policymaking process.

Policy Concerns

A broader perspective suggests that some real improvements in the policy and regulatory environment have occurred since the PDD-23 policy was announced in March 1994. Although the PDD-23 policy set forth

guidelines encouraging U.S. private firms to enter the commercial remote sensing satellite business, the burden of translating some difficult policy issues into specific regulations was left to the implementation process. The resulting licensing and export controls have greatly clarified the U.S. policy guidelines for U.S. firms seeking to develop, operate, or export commercial remote sensing satellites.

In particular, the newest version of the NOAA licensing regulations (publicly released on July 31, 2000) includes several revised provisions that are more favorable to the business operations of U.S. firms compared with earlier provisions. These provisions include the following:

- *Foreign business relationships.* The revised licensing regulations reduced the impediments facing U.S. firms in attracting foreign investors by dropping the specific investment limits previously placed on foreign investors. This change is reflected in the shifted focus to the question of operational control rather than the percentage of foreign ownership.

- *Data policy obligations.* Another change in the revised licensing regulations is a NOAA interpretation that gives U.S. commercial firms greater leeway in setting different prices for their imagery data while still honoring the U.S. government's commitment to providing the governments of sensed states with "reasonable" nondiscriminatory access to unenhanced remote sensing data of their territory.

- *Israel restrictions.* The revised licensing regulations also indicate that the Commerce Department will annually assess the government's restriction on U.S. commercial firms not to collect or disseminate precise satellite images of Israel. This commits the Commerce Department to determining whether higher resolution imagery is readily and consistently available in sufficient quantities from non-U.S. commercial sources.

While these revisions in licensing regulations are generally considered more favorable for the U.S. commercial remote sensing firms, other regulatory issues continue to pose greater risks to their domestic and global competitiveness.

Performance Restrictions

A particularly challenging regulatory issue concerns restrictions on the performance characteristics of the next generation commercial remote sensing satellite systems. The initial licensing applications for high-resolution electro-optical (EO) imaging satellites were approved with relatively few restrictions on the technical performance of the imaging satellites, thus allowing U.S. firms to become world leaders in collecting satellite imagery with resolutions better than 1 meter. In

considering the licensing applications of various firms for the first generation of high-resolution imaging satellites, U.S. government officials not only considered the business plans of the American firms but also weighed the broader U.S. national security concerns and the expected availability of imagery with comparable qualities from non-U.S. sources. The resulting licensing decisions reflected the government's judgment that both U.S. national security and commercial competitiveness benefited from approving licenses from U.S. commercial remote sensing satellite firms to develop and operate high-resolution satellite imaging satellites.

However, a tougher set of issues has arisen for subsequent licensing applications. Several applications (or amendments) for more advanced sensors have received U.S. government approval, although contingent on accepting a broader set of performance and operating restrictions. These advanced imaging sensors have involved imaging radars and hyperspectral sensors, as well as second-generation applications for EO sensors with sub-meter resolutions (i.e., electro-optical sensors capable of producing images with resolutions better than 1-meter). The prospect of sub-meter resolution satellite imagery data becoming available on the commercial market could also raise new policy issues associated with the Fourth Amendment rights of individuals to privacy and companies to corporate security.[62]

Compared with the first generation EO satellites, much greater uncertainty exists on the market prospects for these new imaging satellite systems. In addition, a substantially higher degree of concern exists within the U.S. government over the potential military and intelligence risks that could arise with expanded commercial and public access to these types of imaging satellites. The result has been that several licensing applications and amendments have been approved, provided that the licensees accept certain sensor performance and

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[62] Although satellite and aerial imagery have only limited resolution capabilities for identifying individuals, high-resolution commercial imagery could raise privacy concerns by providing data useful for identifying vehicles, buildings, or land use that can be associated with individuals and companies. The Supreme Court held in Dow Chemical Co. v. United States (1986) that aerial photography commissioned by EPA of an industrial facility did not raise constitutional concerns. However, a recent Supreme Court ruling (*Kyllo v. United States*) on police use of a thermal imaging device poses Fourth Amendment questions over the use of advanced sensor technologies to observe things not visible to the naked eye.

satellite operating constraints, including "two-tiered" licenses.[63] These provisions are part of a risk management strategy used by the U.S. government to minimize possible military or intelligence risks that could arise from foreign access to advanced technology imaging satellite systems. Nonetheless, such performance and operating restrictions can potentially increase the regulatory risks facing U.S. commercial firms by creating additional problems in attracting investors and in satisfying customer demands for their imagery products in a highly competitive global marketplace.

Operational Restrictions

Another important regulatory issue is the government's authority to impose operational restrictions, including shutter controls, on the operations of U.S. commercial remote sensing firms. The PDD-23 policy allows for limiting the data collection and/or data distribution activities of U.S. commercial observation satellites in situations where national security, foreign policy, or the international obligations of the United States are at risk. Commercial firms, which are concerned about shutter controls driving away potential investors and foreign partners, have urged the U.S. government to be more specific on the circumstances that could trigger shutter controls. However, even if U.S. officials could specify the contingencies in advance, they are unlikely to give up their policymaking leeway for deciding under which conditions to impose shutter controls. Thus, a natural tension exists between the desire of U.S. commercial firms to reduce the uncertainties that could affect their business operations and the overriding interest of the U.S. government to preserve its policymaking flexibility for employing shutter controls in largely unforeseeable circumstances.

The U.S. government has taken steps to reassure the commercial remote sensing satellite industry and others that shutter control decisions will be made at the highest levels of government (i.e., involving Cabinet-level officials) and that they will be "imposed for the smallest area and for the shortest period necessary"[64] to protect U.S. national security, foreign policy concerns, and international

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[63] A "two-tiered" license would allow a U.S. firm to operate its imaging satellite system at one level of capability, which is available to all users, while reserving the full operational capability for U.S. government users or those receiving U.S. government approval. The "two-tiered" licenses apply to restrictions on Orbimage's OrbView-4 satellite with its hyperspectral sensor, as well as the "sub-meter" imaging satellite systems planned by DigitalGlobe and Space Imaging.

[64] NOAA regulations, *Federal Register*, p.46823.

obligations. Since the initial U.S. high-resolution commercial observation satellite became operational in September 1999, the U.S. government has not invoke shutter controls. Nonetheless, how U.S. policymakers choose to handle decisions on imposing shutter controls when such emergencies periodically arise will probably speak more convincingly than any public statements.

In some respects, the main problem is less in convincing outside observers that shutter controls decisions will be prudently considered and implemented than it is in dealing with the wider perception that American firms are operating under substantially greater constraints than their foreign competitors. This perception is probably misleading given that most governments view imaging satellites as sensitive technologies. Non-U.S. governments are likely to impose similar restrictions on the collection or dissemination of images produced by commercial and civilian observation satellites under their control if a crisis or armed conflict arises that warrants such controls.[65] And some governments, such as Canada's, have already adopted policies and procedures that would permit restrictions to be imposed on Canadian commercial and civilian remote sensing satellite operations if needed.

Policymaking Process Concerns

The February 2000 MOU significantly clarified both the schedules and responsibilities associated with the interagency review process for licensing U.S. commercial remote sensing satellites. Nonetheless, the current policymaking process remains somewhat opaque and unpredictable.

Much of the complexity of the policymaking process arises from the need to weigh rather disparate policy concerns, including national security, intelligence sources and methods, and trade and international competitiveness objectives, in reviewing license applications and amendments. The policymaking questions raised by the first-generation EO imaging satellite applications were not easy. However, applications by U.S. commercial firms for different types of imaging sensors (e.g., imaging radars and hyperspectral sensors) and higher-resolution EO sensors, have proven to be even more challenging because their greater dual-purpose utility raises difficult policy issues within the interagency process. One result has been substantial delays in making

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[65] A good historical example was the willingness of the operators of France's lower resolution SPOT imaging satellite to restrict the distribution of imagery of the Persian Gulf region during the 1990-1991 Gulf War to ensure that Iraq did not enjoy access to their satellite imagery during the fighting.

and announcing government decisions on the licensing applications and amendments. These continuing delays and uncertainties of U.S. policymaking create a significant policy and regulatory risk for the commercial firms that must make business decisions based on their expectations of U.S. government policy decisions. Without greater predictability and transparency in the U.S. policymaking process, U.S. commercial remote sensing satellite firms will find it difficult to make timely and sound decisions on their best options for competing with domestic and foreign competitors.

Internal Advocacy

Another important concern of the U.S. commercial remote sensing satellite firms is that a stronger advocate is needed within the Executive Branch policymaking process. To some degree, this concern is exacerbated by unrealistically high expectations that developed in the mid-1990s in the wake of the PDD-23 decision, which encouraged the idea that the U.S. government was clearly committed to their commercial success. The subsequent complications in the U.S. government's policymaking process, which stem from dual-use issues posed by high-resolution commercial observation satellites, have significantly diminished this expectation.

The commercial prospects for the remote sensing industry are unlikely to be improved if the Commerce Department gives up its responsibility as the industry's "internal advocate" in the policymaking process because no other Executive Branch agency is likely to be a more determined advocate. A better approach is to develop a consensus involving a broad range of U.S. government agencies concerning the importance of developing a viable U.S. commercial remote sensing satellite industry, which occurred in the process leading to the PDD-23 decision in 1994.

Within this context, the Commerce Department can make the strongest contribution to the long-term success of the U.S. commercial remote sensing satellite firms in three ways. First, NOAA should assume the role of being a strong "honest broker" in managing the interagency process on licensing decisions for U.S. private remote sensing satellite firms. A firm hand is needed for keeping government decisionmaking on a timely track consistent with the needs of commercial enterprises to be competitive. This entails giving all applications and amendments a fair hearing from the full range of interested government stakeholders without unduly delaying the decisions. Second, the Commerce Department's International Trade Administration (ITA) has a potentially important role to play in assessing whether foreign governments are using their domestic data policies to limit access to the satellite imagery data and

information products of the U.S. remote sensing satellite firms and their partnership organizations in these countries.[66] Third, the Commerce Department can proceed to establish a federal advisory committee that will give U.S. commercial remote sensing firms a better venue for making their collective concerns known to the Commerce Department.

SUMMARY

The U.S. policy and regulatory environment is an important factor in shaping the choices available to U.S. commercial remote sensing satellite firms, mainly through the impact of government's licensing and export decisions. The government policymaking process is necessarily complex as it considers both the commercial competitiveness and national security implications of the dual-purpose technologies associated with imaging satellite systems. The Executive Branch and Congress have take major steps towards normalizing the policymaking process and encouraging U.S. private firms to become world leaders in developing and operating commercial observation satellites. Despite substantial progress achieved in the past few years, however, more work is needed to sustain this progress by clarifying and bounding the uncertainties that U.S. commercial firms face from policy and regulatory restrictions. In particular, the government's policymaking process has yet to achieve the degree of predictability, timeliness, and transparency that commercial remote sensing firms need if they are expected to operate effectively in a highly competitive and rapidly changing global marketplace. The Commerce Department, and its specific subcomponents, can play an important role in strengthening the U.S. government's policymaking process for commercial remote sensing to better reflect these desired qualities.

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[66] In addition to its responsibilities for assessing potential foreign trade barriers affecting U.S. goods and exports, the ITA maintains an "Advocacy Center" and performs other activities aimed at trade promotion and enhancing the international competitiveness of U.S. industry. These tasks are directly relevant to the efforts of the emerging U.S. commercial remote sensing satellite firms in establishing a significant presence in the global marketplace.

6. CONCLUSIONS AND RECOMMENDATIONS

For almost two decades, the United States has encouraged the commercialization of remote sensing based on the assumption that it would synergistically contribute to both U.S. security and economic growth. Commercial remote sensing was envisioned to serve roles ranging from being a complementary source for the science and intelligence satellite architectures, to offering a new source of innovation in image processing and exploitation, to being a new tool in the information economy. The Land Remote Sensing Policy Act of 1992 and the subsequent PDD-23 policy guidance energized the potential for these various goals to be satisfied, largely based on an approach that encouraged U.S. companies to play a proactive role in expanding the market.

Yet for a variety of reasons, the goals of U.S. policy remain unfulfilled. Continued U.S. government ambivalence about commercialization, as well as the delays and failures of U.S. industry to get to market, have resulted in only marginal progress towards these goals. Beyond this, the expectations about the market for commercial remote sensing have become clearer, based on the overall size of the market and the unique niche that space-based providers must carve out for themselves in a rapidly growing geospatial/geotechnology market. These more realistic expectations include the recognition that the marketplace is characterized by a multitude of competitive data sources, varying degrees of customer adoption, price flexibility, and other market attributes.

Our analysis has identified and discussed the different kinds of risk confronting U.S. firms as they try to find these niches, and compete within the broader market. Table 6.1 highlights key risks in various areas (i.e., technology, market, international, and policy and regulatory), which are discussed in the earlier sections. These risks facing the U.S. commercial remote sensing satellite firms could potentially diminish their chances of succeeding in the marketplace unless they are successfully managed.

Table 6.1: Potential Risks Facing U.S. Commercial Remote Sensing Satellite Firms

	Potential Risks for U.S. Firms
Technology area	Launch or spacecraft failures can require added investment and additional insurance expenditures Shortfalls in spacecraft or sensor performance can diminish imagery data quality and market competitiveness Underdeveloped or invalid algorithms and software associated with user technologies for processing, analyzing, and archiving imagery data can discourage potential customers
Market area	Risks that U.S. commercial remote sensing satellite firms will not succeed in: --leveraging the growth of the broader geospatial technology marketplace --adopting new business models that transform the firms from being traditional imagery data providers into information age companies --effectively competing with aerial remote sensing firms in providing overhead imagery products and services --effectively competing with non-U.S. remote sensing (aerial and satellite) firms in supplying imagery products and services in the international marketplace
International competition and cooperation	The risks of competing in the international marketplace with foreign remote sensing enterprises that are fully owned or heavily subsidized by their governments, and thus relatively insensitive to market factors The proliferation of smaller national remote sensing satellites can reduce the foreign demand for U.S. commercial imagery and absorb limited national resources Non-U.S. restrictions on the use of high-resolution satellite imagery can limit U.S. market access
U.S. policy and regulatory area	Protracted and opaque policymaking can complicate future planning and diminish the company's appeal for outside investors Uncertainty over U.S. policy actions can discourage foreign investors and partners Public access to low-cost or free overhead U.S. government imagery can reduce the potential demand for more expensive commercial satellite imagery

This report concludes that the greatest risks for the U.S. firms come from the major challenges stemming from their strong market competitors, a need to master the technical risks associated with imaging satellites, and the complicated demands of international business operations. However, the U.S. policy and regulatory environment also exerts a substantial influence on the choices available to these new firms even if its influence on the emerging commercial remote sensing companies does not emulate the importance of the market, technical, and international factors.

REALIZING BENEFITS FROM A COMMERCIAL REMOTE SENSING SATELLITE INDUSTRY

U.S. national interests in commercial remote sensing go well beyond the commercial success or failure of any particular private remote sensing satellite firm. These benefits include realizing advances in remote sensing applications and technological innovations relevant to civilian and military imagery users, strengthening U.S. international competitiveness in imagery data and information products, and expanding the potential remote sensing capabilities available for addressing national needs in times of emergencies at home or abroad. Some of these benefits are already being realized through the commercial remote sensing industry, which is largely dominated by U.S. aerial data providers. In addition, the United States already possesses a robust value-added industry that is unsurpassed in translating both aerial and satellite imagery data into the types of information products needed by a diverse array of customers.

However, the emerging commercial remote sensing satellite firms could offer some special benefits for the United States. Collectively, these firms will acquire and operate satellite systems with imaging capabilities that can supplement U.S. national capabilities. These capabilities will provide a useful hedge in the event of military contingencies, foreign policy emergencies, or system failures, which could place a serious strain on the finite intelligence and surveillance resources available to the United States and its allies. Equally important, however, the new commercial remote sensing satellite firms potentially provide a window on innovative technologies, applications,

and even best practices in the rapidly advancing commercial sector that are directly or indirectly relevant to many U.S. government agencies responsible for collecting, processing, disseminating, and archiving satellite imagery data.

ASSESSING THE KEY RISK FACTORS

This report has assessed a range of key risk factors that will substantially shape the prospects for success of the U.S. commercial remote sensing satellite firms. As presented in Table 6.2, the authors of this report conclude that the risks to commercial satellite remote sensing firms in key areas affecting their activities are somewhat higher today compared with how they were generally viewed in the 1994 time frame. The changed view of risks stems largely--but not entirely--from a more realistic appreciation of the market competition that U.S. commercial remote sensing satellite firms face at home and abroad, as well as some hard-gained experience with the technical challenges of developing, launching, and operating advanced technology spacecraft.

Technical Risk

The basic technical feasibility of building and operating satellite remote sensing systems is well established. However, all space systems entail a level of technical risk. U.S. and foreign government remote sensing programs generally rely on extensive documentation, rigorous testing, and redundancy to constrain technical risks, sometimes at the expense of program cost and schedule. Still, even these government programs experience some launch failures and on-orbit failures. Commercial satellite remote sensing firms are seeking to build, launch, and operate imagery satellites under a commercial procurement paradigm. One of the key goals of this paradigm is cost containment. At the same time, these firms have relatively limited organizational expertise in managing the building, launching, and operating of high-performance imaging satellite systems compared with relevant U.S. government organizations.

Table 6.2: Comparison of Perceived Risks: 1994 vs. 2001

Risk Factor	1994 Perceived Risk	2001 Perceived Risk (relative to 1994)
Technical	Low	Higher
Market	Low	Higher
Policy & Regulatory	Medium	Lower
Foreign Competition	Medium	Higher

The demonstrated record of the U.S. commercial remote sensing firms in bringing their satellite systems to market using their current procurement practices is mixed at best. Of four launches of commercial remote sensing satellites since 1997, two have resulted in launch failures, one suffered an on-orbit failure of the satellite within a few days of launch, and only one achieved a successful launch and imaging operations of the satellite. Our research suggests that these failures probably stem more from programmatic risk factors than from intrinsic technological risks or lack of knowledge. Some, indeed, may be nothing more than bad luck. Nonetheless, it remains incumbent on the private remote sensing firms to demonstrate that they can bring to bear the resources, technical expertise, and management skills required for successfully placing a fully operational imaging satellite system into orbit based on a commercial model for system acquisition and operations.

Market Risk

The underlying question of whether a robust market exists for commercial satellite remote sensing products and services remains unanswered at this point. While the geospatial technology market is rapidly expanding, satellite remote sensing is presently only a small part of that market. For commercial remote sensing satellite firms to succeed, they must adopt new business models that focus on providing users with information that can be readily used in making management decisions, rather than focusing only on providing imagery data. Although the U.S. firms generally recognize this need and are attempting to respond to it, their ability to successfully transform into information technology firms remains to be demonstrated.

Table 6.2 highlights the assessment of the authors of this report that market risks are substantially higher than during the mid-1990s. This changed assessment largely stems from a better appreciation of the complex marketplace and the continuing strength of the potential competition. Commercial remote sensing satellite firms face stiff competition from aerial remote sensing firms. In recent years, many aerial firms have upgraded to digital cameras, incorporated improved inertial systems and GPS, and reduced processing time to provide imagery information products that compete favorably with satellite-derived products. As discussed below, the satellite firms also face strong competition from foreign satellite systems.

Significant uncertainties concerning the robustness of demand for satellite-derived products, the need to restructure business models, and strong competition from aerial systems and foreign satellite systems all combine to make market risk the greatest challenge currently facing the U.S. commercial satellite remote sensing firms.

Policy and Regulatory Risks

The U.S. policy and regulatory environment is an important—but not dominant—factor in shaping the choices available to U.S. commercial remote sensing satellite firms through the government's licensing and export decisions. The government policymaking process must consider both the competitiveness and national security implications of the dual-

purpose technologies associated with imaging satellite systems. The resulting government policies are necessarily complex because of the multiple roles that government plays as regulator, customer, patron, and potential competitor in shaping the environment for the U.S. commercial remote sensing industry. They are also complex because of large number of government stakeholders (e.g., Commerce, Defense, Intelligence Community, NASA, NIMA, NRO, NSC, OMB, OSTP, State, USGS, and various congressional committees) that possess legitimate concerns and equities related to commercial remote sensing policy issues.

As shown in Table 6.2, a key finding is our assessment that the risks for U.S. satellite firms arising from U.S. government policies and regulations are actually lower today than when PDD-23, the primary U.S. Executive branch policy decision, was made in 1994. While operating within the policy and regulatory regime remains challenging and frustrating at times for U.S. firms, we assess that substantial progress has been achieved over the past seven years in diminishing the policy and regulatory uncertainties that previously had stalled the development of the U.S. commercial remote sensing satellite firms.

Furthermore, U.S. commercial remote sensing firms are not unique in being subjected to close government scrutiny and regulation. Canada has imposed explicit regulations on its own commercial remote sensing satellite activities, with U.S. government encouragement. Other countries are believed to have similar regulations even if these national restrictions are not being made public.

Nonetheless, substantial improvements still are required in clarifying and bounding the uncertainties that U.S. commercial firms face from policy and regulatory restrictions. The government's policymaking process has yet to achieve the degree of predictability, timeliness, and transparency that commercial remote sensing firms need if they are expected to operate effectively in a highly competitive and rapidly changing global marketplace. The Department of Commerce, and its specific agencies, can play an important role in strengthening the U.S. government's policymaking process for commercial remote sensing to better reflect these desired qualities.

Foreign Competition

U.S. commercial satellite remote sensing firms are facing somewhat stronger competition from foreign satellite enterprises compared with the expectations of the mid-1990s. At the time, only a few foreign countries (e.g., Russia, France) were believed capable of offering commercial satellite imagery on the international marketplace of comparable quality to projected U.S. commercial imaging satellites.

Most governments have a diverse set of motives for pursuing remote sensing capabilities, whether to gain international prestige, nurture a high-tech industrial base, or better enable government functions from national security to resource management. These motives exist regardless of whether the approach to remote sensing is done by traditional government programs or through commercialization, a concept that varies widely in its implementation from one country to another. Therefore, foreign satellite systems generally enjoy a substantial level of government financial backing and support. This government involvement affords foreign systems more protection from the market forces that otherwise affect U.S. commercial firms. As a result, foreign systems may have greater staying power in the face of launch failures or slow-to-develop markets than may be the case for their U.S. commercial counterparts. At the same time, foreign enterprises could eventually match the technical performance of first-generation U.S. commercial imagery systems, which could diminish the sustained advantages for U.S. commercial firms from being first-to-market with higher resolution imaging satellites.

The growing availability of small remote sensing satellites provides a low-cost alternative for satellite imagery, hence reducing entry barriers for new service providers. This will further expand the number of systems with which U.S. firms must compete, and will introduce unconventional system operators into the market. Some of these new operators, such as universities, may have incentives to provide very inexpensive or free products, putting price pressures on U.S. and other suppliers. Thus, these new satellite systems are wild cards in any assessment of the risks present in the commercial remote sensing marketplace because of uncertainties about their ultimate numbers and

potential role as direct or indirect competitors to commercial remote sensing firms.

Although foreign government attempts to limit access to high-resolution satellite imagery have been measured to date, U.S. commercial remote sensing firms could face some significant market access issues if more governments decide to impose or enforce government restrictions on domestic access to higher resolution satellite imagery data. India and South Korea, for example, already have various restrictions on the open distribution or export of satellite imagery even though each of these countries is pursuing its own higher resolution imaging satellite system with at least some intention of making available or selling satellite imagery data. U.S. government monitoring of such restrictions and possible intervention to ensure fair market access may be necessary.

CONCLUDING OBSERVATIONS

The risks identified in this report have implications for the U.S. government and industry as they try to advance the goal the commercialization of satellite remote sensing. Our view is that the goals associated with commercialization—both in the economic and security domains—remain valid, yet their realization is put at risk by the continuing ambivalence in the implementation of U.S. policy and strategy, thereby creating the suboptimal outcome that currently exists.

Our broadest recommendation, directed throughout the U.S. government, is that it is time that the U.S. strategy laid out in PDD-23, or whatever its successor in the new administration, is implemented in coherent and earnest manner. Moreover, because of the diverse government stakeholders with issues and equities in remote sensing, which creates substantial opportunities for policymaking debates and delays, the U.S. government must move quickly to be more agile in responding to the external dynamics—both at home and abroad—that can curtail U.S. competitiveness in the emerging global marketplace. Further, government agency heads must be cognizant of the various roles that their agencies play in influencing the commercial remote sensing market, and manage them synergistically, rather than have the effect of

supporting—by virtue of the failure to manage them—competing aims within or goals contrary to the PDD-23 regime.

Numerous other studies and commissions have also spoken to the need to take advantage of a commercial remote sensing industry, especially in the field of U.S. national security. Three national commissions—one on NIMA, one on the NRO, and one on Space Management and Organization—spoke critically of the progress thus far in incorporating commercial remote sensing products and services into the broader national security architecture, and challenged government agencies to be more creative and enlightened in how they do so.

RECOMMENDATIONS FOR THE DEPARTMENT OF COMMERCE

The Department of Commerce itself holds multiple, and at times, conflicting roles with regard to commercial remote sensing, such as its potential role as customer and regulator. This report concludes that the Department of Commerce (DOC) can best fulfill its role of promoting the U.S. commercial remote sensing industry, and encouraging the international competitiveness of new private imaging satellite firms by adopting the following recommendations aimed at strengthening its leadership role in implementing U.S. government policies for licensing and regulating commercial remote sensing satellite firms:

Recommendation: DOC should continue to create a policy and regulatory environment for encouraging U.S. commercial satellite remote sensing firms consistent with the fundamental PDD-23 concept. U.S. policy assumes that a synergy exists between promoting American industrial competitiveness in remote sensing space capabilities and protecting U.S. national security and foreign policy interests. However, to realize these goals, the Department of Commerce must assume a greater leadership role in setting the tone for a responsive policy and regulatory environment as well as helping to manage the interagency process to become more agile in addressing both policy concerns and commercial needs.

Recommendation: DOC should continue the normalization of the regulatory process for commercial satellite remote sensing systems. Although we conclude that the U.S. policy and regulatory processes are becoming relatively clearer, they are still less than transparent to all parties nor complete in scope. This situation unnecessarily adds to the uncertainties that are inhibiting U.S. commercial remote sensing firms

and their potential investors from proceeding to the next generation of commercial remote sensing satellite systems. Policy restrictions on U.S. firms should be clarified and well bounded, including the issue of operational controls (i.e., shutter controls). DOC must play a strong and credible role in ensuring the integrity and efficacy of the interagency decisionmaking process for licensing applications and amendments by U.S. commercial firms.

Recommendation: DOC should keep abreast of the changing relationship between aerial and satellite remote sensing firms. Part of the Department's advocacy role on commercial remote sensing should be to provide, in an open and impartial fashion, a government perspective on how remote sensing markets are evolving. Any market assessment must begin by recognizing that the aerial firms account for a substantially larger portion of the remote sensing market compared with the commercial remote sensing satellite firms. This situation is unlikely to change soon because many aerial firms are adopting digital products and other advanced imaging and processing technologies that enhance their competitiveness with satellite-derived products. Satellite imagery data providers and aerial firms are also beginning to enter into commercial alliances. Hence, DOC needs to take a broader perspective on understanding the evolving relationship between the satellite and aerial components of remote sensing to ensure that these dynamics are adequately considered in U.S. policy and regulatory decisions that affect the remote sensing industry.

Recommendation: DOC should monitor developments in the broader geospatial and information technology services industries for their relevance to commercial remote sensing. Beyond understanding trends in remote sensing, DOC must strive to understand how the potential for commercial remote sensing are is affected by trends in the broader geospatial and IT market. Many remote sensing firms are seeking to become providers of information products and services within the broader emerging geospatial technology marketplace. The long-term health of the remote sensing industry strongly depends on the future growth of the geospatial and information technology services industries. DOC must ensure that policies and regulations for satellite remote sensing do not unduly constrain the ability of remote sensing firms as they position themselves to capitalize on that growth.

Recommendation: DOC should monitor foreign actions that could reflect efforts to restrict market access by U.S. commercial remote

sensing firms. DOC needs to have a good understanding the broader foreign dynamics, including non-U.S. domestic regulations on access to commercial satellite imagery data and services, in order to ensure fair market access for U.S. firms. Whether drawing on its own information sources, or working with the State Department and the Intelligence Community, DOC needs to distinguish between outdated regulations and cases where such domestic regulations are being unfairly exploited to impose trade barriers for protecting national remote sensing programs. Both formal or informal barriers can have the effect of limiting the access of U.S. firms, both satellite and aerial remote sensing companies, to foreign markets for geospatial information products and services.

Recommendation: DOC should dedicate more resources to undertaking its responsibilities in supporting the licensing and regulation of U.S. commercial remote sensing satellites, as well as should better leverage the broad range of U.S. government resources and expertise that are available in this area. Although DOC is the lead agency for licensing and regulating U.S. commercial remote sensing satellite firms, it has a relatively small amount of resources devoted to carrying out its multiple responsibilities, including the advocacy and regulatory roles. DOC needs to dedicate more internal resources, as well as take greater advantage of the substantial expertise available within the U.S. government, to ensure that the best assessments are available to policymakers in considering future licensing and regulatory decisions for second generation imaging satellite systems. An important element in these assessments will be to include forward-looking analyses of non-U.S. capabilities, plans, and motives rather than basing U.S. policy decisions only on the current capabilities of operational foreign remote sensing satellite systems.

RECOMMENDATIONS FOR INDUSTRY

This research report on the risks to the U.S. commercial remote sensing industry also offers several insights that industry might find useful to enhancing their own competitiveness within the broader geospatial and geotechnology markets. We offer the following recommendations to the satellite remote sensing firms trying to compete in these markets:

The first recommendation is the most fundamental, and even in the face of the risks identified in this report, central to commercial success:

Recommendation: Commercial remote sensing firms must continue to adapt their business models away from the role of satellite data providers toward a provider of information products and services. The early days of U.S. commercial remote sensing have, by the very nature of the business, focused on the satellite acquisition and ground station development, with an extreme emphasis on the space aspects of the business. However, as the leadership of each of the U.S. firms is aware, a commercially viable business will emerge only when remote sensing firms are producers of various types of information, drawing on multiple data sources (including non-space sources) and focused directly on customer needs. That space-based remote sensing may be an essential part of that information may not be of interest, per se, to the user.

Our other recommendations address specific aspects of the commercial remote sensing business:

Recommendation: Commercial remote sensing satellite firms must effectively compete in the broader geospatial technology marketplace. One challenge that has emerged during the early years of commercial remote sensing has been an explosion in geospatial information sources (and the tools to use them) that effectively compete with commercial remote sensing firms. Satellite firms face stiff competition within the broader geospatial marketplace from established aerial and terrestrial data providers. As reflected above, satellite companies should concentrate on providing the geospatial information that customers desire rather than providing imagery data, which could involve added costs and time to process into the desired information. U.S. satellite companies must continue to develop vertical market expertise either through partnerships or by acquisitions to enable their remote sensing data to be useful information in user demanded products.

Recommendation: Satellite and aerial remote sensing firms should expand their partnerships. U.S. satellite firms originally expected to enter the commercial remote sensing marketplace at the expense of the aerial photography companies, and their well-established market. This has not occurred for several reasons, including technological improvements in airborne imaging platforms, and sensors, and improved data management practices by the aerial firms. While aerial and space imaging do compete within certain parameters, they are more likely considered best as complementary sources of information. Given the potential synergies and the strengths of the aerial and satellite imaging, satellite companies have much to gain from forming and expanding partnerships with aerial remote sensing firms, as well as the value-added firms that have long worked with aerial firms. Some of this is already occurring, but should be expanded.

Recommendation: Satellite imagery firms must adopt creative financial approaches for selling their products and services. To compete in a marketplace with declining geospatial data prices and strong aerial and international competition, U.S. commercial remote sensing satellite companies must be creative in how they earn their profits. Offering greater flexibility in licensing access to their imagery data, as well as considering creative financial mechanisms, such as offering subscription services or selling older imagery data at substantially lower prices, will strengthen the ability of commercial remote sensing satellite firms to penetrate the geospatial data marketplace.

Recommendation: U.S. satellite imagery firms should take a proactive role in identifying foreign restrictions on their ability to sell imagery data and services. The international environment for remote sensing will be extremely competitive, including competition with foreign "commercial" commercial providers that are heavily subsidized. U.S. satellite firms must be able to sell their products and services worldwide if they are to benefit from providing global imaging coverage. However, there is concern that some countries may restrict or limit the sale of U.S. imagery products within their borders. Although some countries have done this on the basis of a national security argument, others may attempt to use restrictions to protect the domestic imagery

market for that country's own satellite imaging system. U.S. satellite firms, and their foreign vendors, can assist the DOC in identifying specific policy and regulatory levers, as well as less formal measures, in foreign countries that are restricting domestic access to U.S. commercial imagery data sales and services mainly to avoid competition. In addition, the commercial remote sensing satellite firms should identify impediments, both U.S. and foreign, that constrain their ability to develop innovative partnerships with the foreign entities that are essential to gaining access to foreign markets.

FINAL NOTE

The conclusions and recommendations offered in this report proceed from the assumption that government and industry must work together in developing and sustaining a viable U.S. commercial remote sensing industry that includes commercial satellite firms. Although this report concludes that the policy and regulatory environment is not the predominant risk factor in shaping the long-term viability of the new U.S. commercial remote sensing satellite firms, the U.S. government continues to play important, multiple roles that affect the opportunities and choices available to private companies. Thus, eventually realizing the potential national benefits of having a robust satellite component within the larger commercial remote sensing industry requires that the U.S. government must continue to play a proactive role in both promoting and regulating these firms without placing them at a substantial disadvantage compared with their domestic and international competitors.

APPENDIX A

EMERGING U.S. COMMERCIAL REMOTE SENSING SATELLITE FIRMS: AN OVERVIEW

The commercial remote sensing industry consists of both aerial and satellite remote sensing firms. Aerial remote sensing has been a commercial industry in the U.S. for more than half a century. Originally, aircraft were flown over rural and urban areas with people taking photographs to be used for a variety of geospatial applications, such as transportation and urban planning. The photographs were used directly in such planning; in fact, aerial remote sensing was instrumental in the development of the U.S. interstate highway system in the mid-1900s. Since the 1980s, aerial photographs have also been digitized for use in computerized systems. In the last few years some aerial remote sensing firms have started using digital cameras and taking advantage of latest computer, sensing, and processing technologies industry.

In comparison, the time frame for the emerging U.S. commercial remote sensing satellite firms is measured in less than one decade. U.S. private firms interested in developing and operating commercial remote sensing satellite systems were strongly encouraged by the Land Remote Sensing Policy Act of 1992, which created the legal basis for the private sector to become operators of imaging satellites (see Appendix B). The 1992 Act made the Secretary of Commerce responsible for licensing private remote sensing space systems. As noted in Table A.1, the Department of Commerce awarded the first license on January 4, 1993, to the WorldView Imaging Corporation, which subsequently became DigitalGlobe as part of a merger.

Presidential Decision Directive 23 (PDD-23), signed in 1994, further clarified the Executive Branch process and conditions for the licensing of commercial remote sensing satellite operations. PDD-23 sets forth the government's specific guidelines for foreign sales of imagery data, sensitive technologies, and even complete turnkey observation satellite systems. Between 1993 and 2000, the Department of Commerce, through the National Oceanic and Atmospheric Administration (NOAA), issued 17 commercial remote sensing licenses to nearly a dozen different U.S. firms (Table A.1), although not all of these firms have proceeded to develop, produce, and launch a commercial remote sensing satellite system. The U.S. firms with the most advanced programs are:

Table A.1: U.S. Commercial Remote Sensing Licenses, 1993 to 2000

U.S. Company	Date License Issued by Commerce Department	Planned Imaging Satellite Program	Company Web Site
DigitalGlobe	1/4/93	EarlyBird	www.digitalglobe.com
Space Imaging	6/17/93	NA	www.spaceimaging.com
Space Imaging	4/22/94	IKONOS	www.spaceaging.com
OrbImage	5/5/94	OrbView-3 & -4	www.orbimage.com
OrbImage	7/1/94	OrbView-2	www.orbimage.com
DigitalGlobe	9/2/94	QuickBird	www.digitalglobe.com
AstroVision Int.	1/23/95	NA	www.astrovision.com
GDE Systems Imaging	7/14/95	NA	www.marconi-is.com
Motorola	8/1/95	NA	NA
Boeing Commercial Space	5/16/96	Resource 21	www.boeing.com/defense-space/space/
CTA Corp.	1/9/97	NA	NA
RDL Corp.	6/16/98	RADAR-1	NA
Space Technology Development Corp.	3/26/99	NEMO	www.earthsearch.com
Ball Aerospace	11/21/00	NA	www.ball.com/aerospace/batchp.html
DigitalGlobe	12/6/00	NA	www.digitalglobe.com
Space Imaging	12/6/00	IKONOS follow-on	www.spaceimaging.com
DigitalGlobe	12/14/00	NA	www.digitalglobe.com

[NA = not available. Sources: Department of Commerce, NOAA website at http://www.licensing.noaa.gov/list.htm; and company webpages.]

- *Space Imaging, Inc.*, was founded in December 1994. Following an initial launch failure in April 1999, it successfully launched a second IKONOS commercial remote sensing satellite in September

1999, marking the start of the world's first high-resolution commercial observation satellite operations. The IKONOS imaging satellite collects both 1-meter panchromatic (black and white) imagery and 4-meter multispectral imagery. Space Imaging has received U.S. government approval to develop and operate a new generation of commercial observation satellites capable of collecting imagery data with higher spatial resolution. Space Imaging acquired the Earth Observation Satellite Company (EOSAT) in late 1996. Similar to other satellite imagery data providers, it sells imagery data produced by a variety of U.S. and foreign civilian remote sensing satellites.

- *DigitalGlobe*, which was the early leader in receiving U.S. government approval of its commercial observation satellite plans. However, this pioneering firm suffered a major setback in December 1997 with the in-orbit failure of its EarlyBird satellite, which would have provided 3-meter panchromatic imagery. More recently, in November 2000, DigitalGlobe suffered another setback when its QuickBird 1 satellite, which was to provide 1-meter panchromatic imagery and 4-meter multispectral imagery, was lost in a launch failure of its Russian Cosmos launch vehicle. However, DigitalGlobe succeeded in launching its QuickBird 2 satellite in October 2001. It will operate this satellite at a lower orbital altitude to achieve 0.7-meter resolution for panchromatic imagery and 2.8-meter resolution for multispectral imagery.

- *OrbImage (Orbital Imaging Corporation)* is building on the successful launch and operation of its OrbView-2 ocean monitoring satellite, known as Seastar/SeaWiFS, which was partially built with NASA funding. OrbImage is a subsidiary of Orbital Science Corp., a space launch and technology firm that produces small launchers. OrbImage planned to launch two high-resolution satellites: OrbView-3, which will collect 1-meter panchromatic and 4-meter multispectral imagery, and OrbView-4, which will have the same sensors plus a hyperspectral sensor being funded by the U.S. Air Force Warfighter program. However, OrbView-4 was lost in a launch failure on September 21, 2001. A launch for OrbView-3 is planned for 2002.

Other U.S. commercial remote sensing firms with plans to develop and launch satellite systems include:

- *Earth Search Sciences, Inc.*, is an aerial remote sensing firm planning to field a hyperspectral satellite remote sensing system. ESSI has acquired the Space Technology Development Corporation, which has been working with the Naval Research Laboratory (NRL) to fly a hyperspectral imager as part of the Naval EarthMap Observer (NEMO) program.

- *Resource21,* is a company dedicated to developing a multispectral observation satellite system that would be focused mainly on agricultural applications. Its owners include Boeing, BAE Systems, and Farmland Industries. It has plans for one or two medium-resolution, multispectral imaging satellite focused on the commercial agricultural market with some plans for addressing the Landsat Data Continuity Mission.

- *AstroVision International* plans to develop and launch the AVSTAR constellation of five geostationary satellites that would provide continuous, lower resolution, color imagery coverage of the Earth, starting with the initial satellite launches in late 2003. This satellite constellation will provide "true color" images of the Earth at spatial resolutions of 1 to 4 km for environmental monitoring purposes.

Finally, it is worth noting that most U.S. commercial satellite remote sensing firms tend to have extensive relationships with both domestic aerial imagery firms and value-added firms. In addition, several of the U.S. firms have business relationships with foreign firms and governmental organizations related to the use of ground stations for receiving raw satellite imagery data, distribution networks for reselling images, value-added products, and services, and various financial relationships including foreign partners and investors.

APPENDIX B

TITLE II OF THE LAND REMOTE SENSING POLICY ACT OF 1992

The Land Remote Sensing Policy Act of 1992 (P.L. 102-555) was legislated by the 102nd Congress and signed into law on October 28, 1992, by President George Bush. The main focus of the Act was to expedite government development of the Landsat 7 remote sensing satellite program, ensure data continuity following the launch failure of Landsat 6, as well as to repeal the Land Remote Sensing Commercialization Act of 1984 (P.L. 98-365), which had earlier encouraged the private sector to take a prominent role in running the Landsat satellite program and managing data sales. In addition, Title II of the 1992 Act authorized the Secretary of Commerce to license private U.S. companies as operators of remote sensing space systems. The following excerpt of the 1992 Act presents the Title II provisions:

TITLE II--LICENSING OF PRIVATE REMOTE SENSING SPACE SYSTEMS

SEC. 201. GENERAL LICENSING AUTHORITY.

(a) LICENSING AUTHORITY OF SECRETARY- (1) In consultation with other appropriate United States Government agencies, the Secretary is authorized to license private sector parties to operate private remote sensing space systems for such period as the Secretary may specify and in accordance with the provisions of this title.[67]

(2) In the case of a private space system that is used for remote sensing and other purposes, the authority of the Secretary under this title shall be limited only to the remote sensing operations of such space system.

(b) COMPLIANCE WITH THE LAW, REGULATIONS, INTERNATIONAL OBLIGATIONS, AND NATIONAL SECURITY- No license shall be granted by the Secretary unless the Secretary determines in writing that the applicant will comply with the requirements of this Act, any regulations issued pursuant to this Act, and any applicable international obligations and national security concerns of the United States.

(c) DEADLINE FOR ACTION ON APPLICATION- The Secretary shall review any application and make a determination thereon within 120 days of the receipt of such application. If final action has not occurred within such time, the Secretary shall inform the applicant of any pending issues and of actions required to resolve them.

(d) IMPROPER BASIS FOR DENIAL- The Secretary shall not deny such license in order to protect any existing licensee from competition.

(e) REQUIREMENT TO PROVIDE UNENHANCED DATA- (1) The Secretary, in consultation with other appropriate United States Government agencies

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[67] In this Act, the term 'Secretary' means the Secretary of Commerce.

and pursuant to paragraph (2), shall designate in a license issued pursuant to this title any unenhanced data required to be provided by the licensee under section 202(b)(3).

(2) The Secretary shall make a designation under paragraph (1) after determining that--

(A) such data are generated by a system for which all or a substantial part of the development, fabrication, launch, or operations costs have been or will be directly funded by the United States Government; or

(B) it is in the interest of the United States to require such data to be provided by the licensee consistent with section 202(b)(3), after considering the impact on the licensee and the importance of promoting widespread access to remote sensing data from United States and foreign systems.

(3) A designation made by the Secretary under paragraph (1) shall not be inconsistent with any contract or other arrangement entered into between a United States Government agency and the licensee.

SEC. 202. CONDITIONS FOR OPERATION.

(a) LICENSE REQUIRED FOR OPERATION- No person who is subject to the jurisdiction or control of the United States may, directly or through any subsidiary or affiliate, operate any private remote sensing space system without a license pursuant to section 201.

(b) LICENSING REQUIREMENTS- Any license issued pursuant to this title shall specify that the licensee shall comply with all of the requirements of this Act and shall--

(1) operate the system in such manner as to preserve the national security of the United States and to observe the international obligations of the United States in accordance with section 506;

(2) make available to the government of any country (including the United States) unenhanced data collected by the system concerning the territory under the jurisdiction of such government as soon as such data are available and on reasonable terms and conditions;

(3) make unenhanced data designated by the Secretary in the license pursuant to section 201(e) available in accordance with section 501;

(4) upon termination of operations under the license, make disposition of any satellites in space in a manner satisfactory to the President;

(5) furnish the Secretary with complete orbit and data collection characteristics of the system, and inform the Secretary immediately of any deviation; and

(6) notify the Secretary of any agreement the licensee intends to enter with a foreign nation, entity, or consortium involving foreign nations or entities.

(c) ADDITIONAL LICENSING REQUIREMENTS FOR LANDSAT 6 CONTRACTOR- In addition to the requirements of paragraph (b), any license issued pursuant to this title to the Landsat 6 contractor shall specify that the Landsat 6 contractor shall--

(1) notify the Secretary of any value added activities (as defined by the Secretary by regulation) that will be conducted by the Landsat 6 contractor or by a subsidiary or affiliate; and

(2) if such activities are to be conducted, provide the Secretary with a plan for compliance with section 501 of this Act.

SEC. 203. ADMINISTRATIVE AUTHORITY OF THE SECRETARY.

(a) FUNCTIONS- In order to carry out the responsibilities specified in this title, the Secretary may--

(1) grant, condition, or transfer licenses under this Act;

(2) seek an order of injunction or similar judicial determination from a United States District Court with personal jurisdiction over the licensee to terminate, modify, or suspend licenses under this title and to terminate licensed operations on an immediate basis, if the Secretary determines that the licensee has substantially failed to comply with any provisions of this Act, with any terms, conditions, or restrictions of such license, or with any international obligations or national security concerns of the United States.

(3) provide penalties for noncompliance with the requirements of licenses or regulations issued under this title, including civil penalties not to exceed $10,000 (each day of operation in violation of such licenses or regulations constituting a separate violation);

(4) compromise, modify, or remit any such civil penalty;

(5) issue subpoenas for any materials, documents, or records, or for the attendance and testimony of witnesses for the purpose of conducting a hearing under this section;

(6) seize any object, record, or report pursuant to a warrant from a magistrate based on a showing of probable cause to believe that such object, record, or report was used, is being used, or is likely to be used in violation of this Act or the requirements of a license or regulation issued thereunder; and

(7) make investigations and inquiries and administer to or take from any person an oath, affirmation, or affidavit concerning any matter relating to the enforcement of this Act.

(b) REVIEW OF AGENCY ACTION- Any applicant or licensee who makes a timely request for review of an adverse action pursuant to subsection (a)(1),(a)(3), (a)(5), or (a)(6) shall be entitled to adjudication by the Secretary on the record after an opportunity for any agency hearing with respect to such adverse action. Any final action by the Secretary under this subsection shall be subject to judicial review under chapter 7 of title 5, United States Code.

SEC. 204. REGULATORY AUTHORITY OF THE SECRETARY.

The Secretary may issue regulations to carry out this title. Such regulations shall be promulgated only after public notice and comment in accordance with the provisions of section 553 of title 5, United States Code.

SEC. 205. AGENCY ACTIVITIES.

(a) LICENSE APPLICATION AND ISSUANCE- A private sector party may apply for a license to operate a private remote sensing space system which utilizes, on a space-available basis, a civilian United States Government satellite or vehicle as a platform for such system. The Secretary, pursuant to this title, may license such system if it meets all conditions of this title and--

(1) the system operator agrees to reimburse the Government in a timely manner for all related costs incurred with respect to such utilization, including a reasonable and proportionate share of fixed, platform, data transmission, and launch costs; and

(2) such utilization would not interfere with or otherwise compromise intended civilian Government missions, as determined by the agency responsible for such civilian platform.

(b) ASSISTANCE- The Secretary may offer assistance to private sector parties in finding appropriate opportunities for such utilization.

(c) AGREEMENTS- To the extent provided in advance by appropriation Acts, any United States Government agency may enter into agreements for such utilization if such agreements are consistent with such agency's mission and statutory authority, and if such remote sensing space system is licensed by the Secretary before commencing operation.

(d) APPLICABILITY- This section does not apply to activities carried out under title III.

(e) EFFECT ON FCC AUTHORITY- Nothing in this title shall affect the authority of the Federal Communications Commission pursuant to the Communications Act of 1934 (47 U.S.C. 151 et seq.).

APPENDIX C: U.S. STATEMENT ON FOREIGN ACCESS TO REMOTE SENSING SPACE CAPABILITIES (MARCH 1994)

THE WHITE HOUSE

Office of the Press Secretary

March 10, 1994

FACT SHEET

FOREIGN ACCESS TO REMOTE SENSING SPACE CAPABILITIES

Background

Remote sensing from space provides scientific, industrial, civil governmental, military and individual users with the capacity to gather data for a variety of useful purposes. The US Government operates very high-resolution space-based reconnaissance systems for intelligence and military purposes.

These systems are among the most valuable US national security assets because of their high quality data collection, timeliness, and coverage and the capability they provide to monitor events around the world on a near real-time basis. More nations have discovered the value of these satellites and are developing their own indigenous capabilities, or are seeking the purchase of data or systems.

Policy Goal

The fundamental goal of our policy is to support and to enhance US industrial competitiveness in the field of remote sensing space capabilities while at the same time protecting US national security and foreign policy interests. Success in this endeavor will contribute to maintaining our critical industrial base, advancing US technology, creating economic opportunities, strengthening the US balance of payments, enhancing national influence, and promoting regional stability.

Scope of Policy

The policy covers foreign access to remote sensing space systems, technology, products, and data. With respect to commercial licenses, this would include operating licenses granted under the Land Remote Sensing Policy Act of 1992 and export licenses for certain items controlled on the US Munitions List (USML). While the policy will define certain restrictions for export of items on the USML, export of items on either the USML or the Commerce Control List (CCL) would continue to be licensed in accord with existing law and regulations.

Licensing and Operation of Private Remote Sensing Systems

License requests by US firms to operate private remote sensing space systems will be reviewed on a case-by-case basis in accordance with the Land Remote Sensing

Policy Act of 1992 (the Act). There is a presumption that remote sensing space systems whose performance capabilities and imagery quality characteristics are available or are planned for availability in the world marketplace (e.g., SPOT, Landsat, etc.) will be favorably considered, and that the following conditions will apply to any US entity that receives an operating license under the Act.

1. The licensee will be required to maintain a record of all satellite tasking for the previous year and to allow the USG access to this record.

2. The licensee will not change the operational characteristics of the satellite system from the application as submitted without formal notification and approval of the Department of Commerce, which would coordinate with other interested agencies.

3. The license being granted does not relieve the licensee of the obligation to obtain export license(s) pursuant to applicable statutes.

4. The license is valid only for a finite period, and is neither transferable nor subject to foreign ownership, above a specified threshold, without the explicit permission of the Secretary of Commerce.

5. All encryption devices must be approved by the US Government for the purpose of denying unauthorized access to others during periods when national security, international obligations and/or foreign policies may be compromised as provided for in the Act.

6. A licensee must use a data downlink format that allows the US Government access and use of the data during periods when national security, international obligations and/or foreign policies may be compromised as provided for in the Act.

7. During periods when national security or international obligations and/or foreign policies may be compromised, as defined by the Secretary of Defense or the Secretary of State, respectively, the Secretary of Commerce may, after consultation with the appropriate agency(ies), require the licensee to limit data collection and/or distribution by the system to the extent necessitated by the given situation. Decisions to impose such limits only will be made by the Secretary of Commerce in consultation with the Secretary of Defense or the Secretary of State, as appropriate. Disagreements between Cabinet Secretaries may be appealed to the President. The Secretaries of State, Defense and Commerce shall develop their own internal mechanisms to enable them to carry out their statutory responsibilities.

8. Pursuant to the Act, the US Government requires US companies that have been issued operating licenses under the Act to notify the US Government of its intent to enter into significant or substantial agreements with new foreign customers. Interested agencies shall be given advance notice of such agreements to allow them the opportunity to review the proposed agreement in light of the national security, international obligations and foreign policy concerns of the US Government. The definition of a significant or substantial agreement, as well as the time frames and other details of this process, will be defined in later Commerce regulations in consultation with appropriate agencies.

Transfer of Advanced Remote Sensing Capabilities

1. Advanced Remote Sensing System Exports: The United States will consider requests to export advanced remote sensing systems whose performance capabilities and imagery quality characteristics are available or are planned for availability in the world marketplace on a case-by-case basis.

   The details of these potential sales should take into account the following:

   the proposed foreign recipient's willingness and ability to accept commitments to the US Government concerning sharing, protection, and denial of products and data; and

   constraints on resolution, geographic coverage, timeliness, spectral coverage, data processing and exploitation techniques, tasking capabilities, and ground architectures.

   Approval of requests for exports of systems would also require certain diplomatic steps be taken, such as informing other close friends in the region of the request, and the conditions we would likely attach to any sale; and informing the recipient of our decision and the conditions we would require as part of the sale.

   Any system made available to a foreign government or other foreign entity may be subject to a formal government-to-government agreement.

Transfer of Sensitive Technology

The United States will consider applications to export sensitive components, subsystems, and information concerning remote sensing space capabilities on a restricted basis. Sensitive technology in this situation consists of items of technology on

the US Munitions List necessary to develop or to support advanced remote sensing space capabilities and which are uniquely available in the United States. Such sensitive technology shall be made available to foreign entities only on the basis of a government-to-government agreement. This agreement may be in the form of end-use and retransfer assurances which can be tailored to ensure the protection of US technology.

Government-to-Government Intelligence and Defense Partnerships

Proposals for intelligence or defense partnerships with foreign countries regarding remote sensing that would raise questions about US Government competition with the private sector or would change the US Government's use of funds generated pursuant to a US-foreign government partnership arrangement shall be submitted for interagency review.

# # #

APPENDIX D

GIS AND GEOSPATIAL TECHNOLOGIES MERGING INTO BROADER IT MARKETPLACE

As discussed in Section 3, the imagery data and services provided by the emerging U.S. commercial remote sensing satellite firms are best understood against the backdrop of the broader geospatial technology marketplace. This is particularly true because remote sensing is a subset of the broader geospatial technology market and therefore influenced by the broader market developments. Similarly, geospatial technologies and capabilities are merging into the information technology (IT) industry and beginning to be influenced by IT trends. This appendix offers a more in-depth discussion of some of the key trends as GIS and geospatial technologies merge within the broader IT marketplace.

Marketplace Moving from Geospatial Technologies to Information Services

An important trend within the geospatial technology industry is the movement from geospatial technologies to services. Namely, the industry is increasingly focused on providing geospatial information and services directly to end users. The development of the applications for nontraditional business users and consumers are areas that show movement towards more services. To illustrate this point, look at the development of the business sector called "L-commerce" or "location-based services." Location-based services are where business and consumer users receive service information based on physical locations. Such services include location-sensitive advertising and concierge services, roadside assistance, and mobile services. Such services tend to be based on the integration of technologies such as wireless communication, Global Positioning System (GPS), GIS, personal digital assistants (PDAs), Webphones, and the Internet. For example, in Japan, cellular operator J-Phone, is introducing a Short Message Service system wherein a user can find the nearest gas station, restaurant, or business location by querying a map-based interface on his or her cell phone.[68]

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[68] These two examples are from Reid, Hal, and Joe Francica, May 2000.

Such an emphasis on information services is affecting how geospatial and other technology firms are evolving and will likely affect remote sensing firms as well.

Geospatial Technologies Are Integrated More for User Applications

Different technologies that facilitate geospatial applications are becoming more and more integrated. Geospatial technologies are merging in applications and merging into the broader IT infrastructure. Such technologies as GIS, GPS, remote sensing, simultaneous multisensor measurements, Internet, wireless and mobile devices, 3D visualization technologies, and CAD are being integrated for more efficient and new uses in geospatial applications. For example, 3-D imaging technologies are being integrated with GIS technologies and remote sensing data in new geospatial applications. Such integration is opening the doors for new GIS and other geospatial applications in which that extra dimension of information can help in understanding relationships. For example, a Seattle company, Integral GIS, used GIS, remote sensing data, and 3-D imaging as a management tool during the construction on the Safeco Field baseball stadium. This system helped with logistics planning to visualize outcomes from subcontractor schedules. GIS was used as a living record of the facility's construction, including the ability to assign responsibility if schedules were not met.[69] This trend helps create new applications and demand for remote sensing data. It also has implications for remote sensing companies' business models, such as creating more partnerships with other geospatial technology companies.

Users Want Seamless Applications

Another important theme for the future direction of the geospatial technology industry is the integration of the technologies into applications that are seamless to the user. For example, using a personal digital assistant (PDA) to look at real-time traffic updates and show alternative routes in your car depends on the integration of GPS technology (to provide an accurate position of the vehicle), and GIS (to show the map and calculate alternative routes), and the wireless

[69] Hodges, Mark, May 2000.

technology (using the PDA as an integrating platform to transmit and display the information). Seamless applications help facilitate market penetration into a tremendously large marketplace, the broader nontechnical business users and consumer marketplace. U.S. commercial remote sensing satellite companies, like other geospatial technology companies, want to tap into this larger market.

Distributed Yet Integrated Applications Through the WWW

An important development helping drive integration and the move toward seamless applications is users' desire to conduct geospatial activities through the Web to access data from distributed systems across organizations and integrate them into user products. This development requires interoperable systems accessible from anywhere through the Web. Geospatial data also becomes transparent to the user. Such applications are some of the fastest growing areas for the development of new and innovative geospatial products delivered directly to customers. It is important to note that such applications, especially consumer-oriented ones, often involve very low geospatial data prices. Again, U.S. commercial remote sensing satellite companies expect to benefit from this broader geospatial market trend as it develops. In addition, the companies are beginning to recognize that low data prices have implications for their changing business models.

In this appendix, we have only briefly touched on the broader geospatial technology and IT trends and their implications for remote sensing. Such trends further illustrate how complex, dynamic, and unpredictable the marketplace for remote sensing is at this time.

BIBLIOGRAPHY

Akaka, Sen. Daniel (D-HI), "Security and Commercial Satellite Imagery," Congressional Record (May 11, 2000), S3908-3909.

Baker, John C., Kevin M. O'Connell, and Ray A. Williamson, Commercial Observation Satellites: At the Leading Edge of Global Transparency. RAND, Santa Monica, Calif., and the American Society for Photogrammetry and Remote Sensing (ASPRS), 2001.

Bates, Jason, "DigitalGlobe Alters Quickbird 2 Plans," Space News, March 26, 2001.

____, "U.S. Decision Clears Way for Ikonos Half-Meter Satellite," Space News, January 8, 2001.

Divis, Dee Ann, "Access Locally, Digitize Globally," Geospatial Solutions, July 2000.

Elwood, John P. "High Court to Decide Whether Warrantless Thermal Imaging Violates Fourth Amendment," Privacy Officers Advisor (POA), February 2001, 11.

Francica, Joe, "MapQuest.com Serves Maps to the Masses," Business Geographics, www.geoplace.com, May 2000.

Frost & Sullivan, World Remote-Sensing Data and GIS Software Markets, Mountain View, Calif., 1999.

Gabbard, C. Bryan, Kevin M. O'Connell, George S. Park, and Peter J. E. Stan, Emerging Markets of the Information Age: A Case Study in Remote Sensing Data and Technology. RAND, Santa Monica, Calif., 1996.

Gabrynowicz, Joanne Irene. "The work of the US National Satellite Land Remote Sensing Data Archive Advisory Committee: 1998-2000," Space Policy, Vol. 17, 2001, 49-53.

Hodges, Mark, "See Data In-Depth," COMPUTER GRAPHICS WORLD, May 2000.

Jordon, Lawrie, "Web Accessible 3D Viewing Next Step for GIS: Virtualising the 3D Real World (4)," GIM International, July 2000.

Kastens, Terry L., and Heather Nivens, "Precision Agriculture: Is it Time to Get Involve?," Risk and Profit Conference, Kansas State University, Manhatten, Kansas, August 20-21, 1998.

Korzeniowski, Paul, "Utilities explore a brave new world of maps," Utility Business, July 1999.

Lachman, Beth, E., Public-Private Partnerships for Data Sharing: A Dynamic Environment, RAND, DRU-2259-NASA/OSTP, Santa Monica, Calif., April 2000.

National Academy of Public Administration (NAPA), Geographic Information for the 21st Century, Washington, D.C., January 1998.

Petrocchi, Andrea, "Slick Sensing: Monitoring Oil Spills with Satellite Imagery," Geo Info Systems, May 2000.

Pratt, Timothy, "Dealing with Disasters," GEOWorld, July 2000.

Reid, Hal, and Joe Francica, "Go 'Thin': Corporations Take Mapping to the Masses with Internet Clients," Business Geographics, May 2000.

Report of the Commission to Assess United States National Security Space Management and Organization, January 11, 2001. [http://www.space.gov]

Report of The Independent Commission on the National Imagery and Mapping Agency, The Information Edge: Imagery Intelligence and Geospatial Information in an Evolving National Security Environment, December 2000. [http://www.space.gov]

Report of The National Commission for the Review of the National Reconnaissance Office, The NRO At The Crossroads, November 1, 2000. [http://www.space.gov]

Roberts, Paula, "NIMA Embraces Commercial Imagery,"Imaging Notes September/October 2000, 24-25.

Sapeta, Krysia, "Have You Seen the Light? LIDAR Technology is Creating Believers," GEOWorld, October 2000.

Sarsfield, Liam, The Cosmos on a Shoestring: Small Spacecraft for Space and Earth Science, RAND, MR-864-OSTP, Santa Monica, Calif., 1998.

Sommers, Rebecca, "FRAMEWORK: Introduction and Guide," Federal Geographic Data Committee, Washington, D.C., 1997.

Sommers, Rebecca, "FRAMEWORK DATA SURVEY: Preliminary Report," A Supplement to GeoInfo Systems, September, 1999.

Space Imaging, "Space Imaging Signs on ESRI as a Master Reseller," Press Release Newswire, October 17, 2000.

Stadd, Courtney A., and Ronald J. Birk, "No Strings Attached?," *Imaging Notes*, July/August 1999, 20-22.

Texas Department of Information Resources, "TGIC: TEXAS GEOGRAPHIC INFORMATION COUNCIL," http://www.tgic.state.tx.us/, January 21, 2000, last accessed January 24, 2000.

Texas Geographic Information Council, "Geographic Information Framework for Texas: Resolutions for Action," Austin, Texas, January 1999.

Texas Water Development Board, "Texas Natural Resources Information System," http://www.tnris.state.tx.us/about.htm, December 3, 1999, last accessed January 24, 2000.

Thrall, Grant Ian, "Demographic ring study reports with GIS technology," Journal of Real Estate Literature, July 1999.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, "Licensing of Private Remote-Sensing Space Systems (Rules and Regulations)," Federal Register, Vol. 65, No. 147 (July 31, 2000), 15 CFR Part 960, 46822-46837.

____, "Licensing of Private Land Remote-Sensing Space Systems (Proposed Rules)," Federal Register, Vol. 62, No. 212 (November 3, 1997), 15 CFR Part 960, 59317-59331.

The White House, Office of the Press Secretary, "Foreign Access to Remote Sensing Space Capabilities," Washington, D.C., March 10, 1994.

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