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# A study on the commercialization of space-based remote sensing in the twenty-first century and its implications to United States National Security

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# NAVAL POSTGRADUATE SCHOOL

**MONTEREY, CALIFORNIA**

# THESIS

**A STUDY ON THE COMMERCIALIZATION OF SPACE-BASED REMOTE SENSING IN THE TWENTY-FIRST CENTURYAND ITS IMPLICATIONS TO UNITED STATES NATIONAL SECURITY**

by

Carrey A. Chin

June 2011

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Remote sensing from space provides critical data for many commercial space applications. Due to global market demand, it has undergone tremendous growth since the early 1990s. The purpose of this thesis is to assess how the commercialization of space imagery, since the end of the Cold War, has led to increased intelligence gathering by adversaries, and created a new series of threats against United States overseas and domestic targets. The research performed involves an analysis of the proliferation history of space imaging for growing civilian use, and the threats created by its widely available dissemination and accessibility. The analysis results, together with the findings from a review of commercial programs, initiatives, and remote sensing policy, will be used to develop trends that formulate recommendations in this thesis. Specifically, in order to further develop and protect commercial space imaging capability in the future, remote sensing policy makers, systems engineers, and industry analysts must be aware of the implications to United States National Security.


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# ABSTRACT

Remote sensing from space provides critical data for many commercial space applications. Due to global market demand, it has undergone tremendous growth since the early 1990s. The purpose of this thesis is to assess how the commercialization of space imagery, since the end of the Cold War, has led to increased intelligence gathering by adversaries, and created a new series of threats against United States overseas and domestic targets. The research performed involves an analysis of the proliferation history of space imaging for growing civilian use, and the threats created by its widely available dissemination and accessibility. The analysis results, together with the findings from a review of commercial programs, initiatives, and remote sensing policy, will be used to develop trends that formulate recommendations in this thesis. Specifically, in order to further develop and protect commercial space imaging capability in the future, remote sensing policy makers, systems engineers, and industry analysts must be aware of the implications to United States National Security.

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# I. INTRODUCTION

## A. BACKGROUND

During the 1960s, the Cold War between the United States and the Soviet Union set the stage for the greatest period of advancement in space-based imaging technology. The race for obtaining the most advanced military intelligence transitioned the reconnaissance world from airborne sensing to space-based sensing. Both superpowers closely guarded their own reconnaissance capabilities and technologies, fearful that the other might discover the extent of their spying capability. However, the end of the Cold War and the fall of the Soviet Union in the early 1990s changed this environment. As regulatory pressures weakened due to a diminishing Soviet threat, opportunities began to emerge for aerospace companies looking to enter the commercial space imaging market. During the same period, the United States had an established space program and was looking to space technology for growing both civilian and military systems. Soon thereafter, both United States and international companies started developing space-based imaging capabilities, and thus began a huge movement in commercialized space-based imaging products and capabilities.

This trend has undoubtedly advanced space-based imaging technology and capability to levels not seen before. The open commercialization, commoditization of commercial space-based imagery, and global marketing of these imaging technologies and products have created widely available information that may threaten United States National Security. The creation of the Internet and such publicly available imaging applications, such as Google Earth, have given global access to space-based imagery data, covering almost every square mile of the world. Adversaries, warring nations, and rogue organizations could possibly exploit this data for intelligence gathering, offensive targeting, and other military applications. This transparency also holds other secondary implications that affect United States National Security. This thesis discusses the types and uses of imaging data currently available on the commercial markets, their implications to United States National Security, the effectiveness of United States policy in addressing these concerns, and recommendations to further develop and protect commercial space imaging capability in the future.

## B. PURPOSE

This research is intended to provide an understanding of the issues related to the commercialization of space-based remote sensing in order to assist policy makers, systems engineers, and data analysts with their efforts to further develop and protect future commercial space imaging capability in the future. This research will help define the important role space policy plays in the global trend towards transparency, the proliferation of the commercial remote sensing industry, and the protection of United States National Security. The intention for this research is to identify any policy issues associated with space-based remote sensing and understand how these issues create vulnerabilities to both United States domestic and overseas assets. The objective of this research is to analyze the past and current policies of space-based remote sensing for growing civilian use and the threats created by its widely available dissemination and accessibility. These findings formulate the basis for specific recommendations that attempt to sustain continued growth for space-based remote sensing data and products as well as protect the privacy of United States sensitive imagery data.

## C. RESEARCH QUESTIONS

This thesis attempts to answer the strategic question: What United States security-based implications have emerged due to the transparency brought about by the proliferation of commercial remote sensing satellites? The answer to this question is obtained through a complete investigation of the specific research questions:

1. How does domestic and international remote sensing policy protect United States National Security?

2. How effectively are United States government agencies organized to police these policies?

3. What infrastructure and processes are in place for the commercial providers of remote sensing systems to protect United States National Security?

4. What threats and protections does current technology present to United States National Security?

5. What types of countermeasures are available and can be developed for protecting United States National Security?

## D. BENEFITS OF STUDY

This thesis provides recommendations pertaining to the above issue that can be leveraged by the United States commercial remote sensing industry, commercial remote sensing policy makers, and the space-based imaging community.

## E. SCOPE

This thesis pertains to the current state of publicly available remote sensing information and the potential vulnerabilities it presents to United States national security. This work analyzes international and domestic remote sensing policy, discusses the advantages and disadvantages of a commercialized remote sensing industry, discusses the military uses for remote sensing information, and assesses these potential vulnerabilities. This thesis makes specific recommendations on how to assist with resolving the issues that threaten United States National Security.

## F. METHODOLOGY

1. Conduct a brief review of space-based imaging history and current commercial and global trends.

2. Conduct a detailed review of commercial space-based imaging vendors, their technologies, and their customers/markets.

3. Conduct a detailed review of former and current United States policies on commercial space-based imaging.

4. Correlate information gathered from this research to formulate detailed findings.

5. Utilize the findings and analysis from this research to develop specific recommendations for developing and protecting future commercial space imaging capability.

## G. THESIS ORGANIZATION

Chapter I contains general information that includes the purpose of the thesis, a description/background of the issue, and introduces the research questions that are answered in this thesis. Chapter II contains a review of space-based remote sensing, providing a brief history of the three milestone satellite programs from which today's commercial remote sensing satellite programs originate. It also provides a summary of the recent data utilization and industry trends in the commercial remote sensing, both critical for a complete understanding of the issue. This chapter also gives a detailed description of the issue topic and cites several specific events that provide evidence of the issue at hand. Chapter III is a literature review intended to provide background on: 1) several commercial remote sensing programs and initiatives and 2) several significant United States remote sensing policies. Chapter IV summarizes the research findings as related to the thesis research questions identified in Chapter I. Finally, Chapter V contains the thesis conclusions and recommendations that are formulated from the research and interview findings.

# II. REVIEW OF SPACE-BASED IMAGING ARCHITECTURE AND POLICY

## A. INTRODUCTION

In order to understand the issues related to space remote sensing, the term must first be defined. The term “remote sensing” is used “to describe the science—and art—of identifying, observing, and measuring an object without coming into direct contact with it” (NASA, 2010). Sensors measure the levels of radiation of different wavelengths that are reflected or emitted from objects or materials on the Earth’s surface by which they may be identified and categorized by “class/type, substance, and spatial distribution” (NASA 2010). The data acquired by these sensors is fed into a wide array of mapping and other services for air and land based applications. The International Society for Photogrammetry and Remote Sensing (ISPRS) lists the primary uses and markets for this data:

- disaster monitoring and assessment services
- emergency services
- tracking hazardous activities
- fire and hazards detection
- disease detection (agricultural)
- disease monitoring (agricultural and human)
- real estate appraisal, taxation and permitting
- city and urban planning
- financial and insurance services
- retail marketing
- facilities placement
- facilities monitoring
- peacekeeping and treaty monitoring

- law enforcement
- news services
- environmental protection
- global monitoring
- resource assessment (natural and renewable)
- resource monitoring (natural and renewable)
- archaeological and architectural site preservation
- cadastral survey and land registration
- trends analysis and prediction services
- navigation safety
- utilities management
- reconnaissance, detection and surveillance
- demographics
- tourism and recreation
- entertainment

Remote sensing data is divided into three main categories for specific users: civil, commercial, and military. All three communities pursue environmental remote sensing activities, but these communities are driven by different needs and objectives. Civil institutions tend to focus on problems such as "monitoring and predicting global climate change, weather patterns, natural disasters, land and ocean resource usage, ozone depletion, and pollution" (Glackin, 2007). Commercial organizations typically "invest in systems with higher spatial resolution whose imagery can support applications such as mapping, precision agriculture, urban planning, roadway route selection, disaster assessment and emergency response, pipeline and power-line monitoring, real-estate visualization, and even virtual tourism" (Glackin, 2007). Military users generally focus on "weather monitoring and prediction as it directly supports military operations and high-resolution imagery, and they have become the primary customer for commercial imagery at resolutions of one meter or better" (Glackin, 2007).

## B. HISTORY OF COMMERCIAL SPACE-BASED IMAGING

The concept of collecting aerial-based information about ground-based activities dates back well over one-hundred years. Using balloons and early aircraft, early pioneers of aerial reconnaissance found that information gathered from highly elevated locations contained an immense amount of data on nearby activities and geographical surroundings. By World War I, military forces regularly scanned enemy areas for movement of troops and supplies. In the past fifty years, advancements in space deployment and operations have made it possible to take advantage of the wide coverage and reliability offered by a space environment. Remote sensing is yet another mission area that benefits from this environment (Sibbet, 1997).

During the 1950s, the use of high-altitude reconnaissance aircraft was the technique used by the United States to "obtain information from the Soviet Union, Eastern Europe and China" (Steinberg, 1998). The United States implemented these systems to collect intelligence on Soviet missile development, production, and deployment. Until the end of the Cold War, this tactic was widely used in numerous military applications, and enabled the United States to collect thousands of images of intelligence value (Steinberg, 1998). Both the United States and the Soviet Union used these images to formulate nuclear targeting opportunities and monitor each other's military infrastructure, capabilities, and activities (Steinberg, 1998).

However, there were several disadvantages by using this method of intelligence collection. First, there was the denial of mutual arms control between the United States and Soviet Union in 1958. (Dashora, 2007). Second, these aircraft were vulnerable to ground-based anti-aircraft missiles, as was discovered in 1 May 1960, when U-2 pilot Gary Powers was shot down over the Soviet Union (Steinberg, 1998). This incident was a significant blow to aerial-based reconnaissance by the United States as President Eisenhower was forced to terminate these missions over the Soviet Union (Olsen, 2007). Third, manned missions were limited by aircraft range and dwell time over an area. For both of these reasons, the United States looked to the space environment for alleviating these issues and presenting a viable environment for continuing these reconnaissance missions. Thus, it was a combination of limitations in the aerospace environment and the tacit agreements between the United States and Soviet Union that established the use of remote sensing from Space (Steinberg, 1998). The Sputnik launch in 1957 was the true catalyst that pushed the United States to develop space-based reconnaissance satellites and the first satellite of its type named Corona in 1960 (Steinberg, 1998).

Since Sputnik, four major remote sensing programs have taken the remote sensing industry from its infancy to its widespread acceptance and use in the world today:

**1. Corona**

The concept behind Corona was to "develop an invulnerable space vehicle equipped with a photographic camera that would collect intelligence information as it passed over a foreign territory" (Dashora, 2007). Early imaging resolution was "on the order of 8-10 meters" and " individual images on average covered approximately 10 mi by 120 mi" (Olsen, 2007). By 1972, when the Corona program ended and was replaced by new technology, 95 of 105 satellites had been launched successfully (Dashora, 2007). The satellites took thousands of photographs, "after which retrorockets triggered the reentry of the film capsule, which was recovered either in mid-air, or on the surface of the ocean" (Steinberg, 1998). Over the next thirty years, United States reconnaissance satellites took thousands of images, "covering a wide variety of strategic and tactical targets, including Soviet and Chinese missile locations, the site of the detonation of the first Chinese atomic weapon, submarine ports, aircraft carriers, and combat air bases" (Steinberg, 1998). During this period, the Soviet Union also developed their own remote sensing program (Steinberg, 1998). The Corona program was classified until the end of the Cold War. In 1995, the United States government unclassified the Corona program and its imagery. (Dashora, 2007).

For the past two decades, these remote sensing systems have been "augmented by infra-red and broad spectrum imagery, space-based synthetic-aperture radar, and other technologies to allow for all-weather, all-hours imaging" (Steinberg, 1998). Corona and many follow-on remote sensing satellites became non-intrusive technical means of verification (Steinberg, 1998). Recently released Corona images revealed critically important military intelligence at the time, “including Soviet medium range missiles, intermediate range, ICBM complexes, Soviet submarine classes (from deployment to operational bases), and inventories of Soviet bombers and fighters” (Steinberg, 1998). The Corona program was originally designed for spatial data collection from Space, not for assessing weapons capability of the Soviet Union. Nevertheless, the development of remote sensing systems such as Corona became an important contributor to global stability and mutual deterrence for both the United States and the Soviet Union.

The Corona program stands as the technological pioneer concerning remote sensing from space. It allowed the United States to continue reconnaissance operations against the Soviets during the Cold War. From a technological perspective, the Corona program demonstrated the tremendous capabilities and advantages of space-based remote sensing over traditional aerial-based reconnaissance methods of the time.

### 2. Landsat

In the 1960s, the Apollo Moon-based missions helped inspire public interest in photographing the Earth from space. Support for a remote sensing program for civilian agencies came from the Department of the Interior, the Corps of Engineers, and the Department of Agriculture. All of these groups concluded that imagery data taken from space had the potential to help them perform their respective missions (Mack, 1998). This push toward exploration of the space environment is what inspired the creation of the Landsat program (NASA, 2008). Landsat was the first remote sensing satellite and the program set the stage for the eventual commercialization of the civilian remote sensing industry. Landsat I had a maximum resolution of 30 meters, a multi-spectral imager, and an infrared sensor for detecting ground temperature. Landsat I was launched by the United States in 1972 (Florini, 1999).

However, the beginning of the Landsat program was not without controversy due to the high costs of a dedicated remote sensing program, funded solely by the United States government through NASA. The Bureau of Budget opposed and disapproved budgetary approval for the Landsat program in 1967. The initial costs of the Landsat program were tremendous at $41.5M, at a time when the funding of the Vietnam War had already drained the defense budget (Mack, 1998). NASA had to justify the Landsat program not on the basis of new benefits that the program would bring but on the basis of how much money would be saved through the collection of imagery taken from space.

Eventually, Landsat data proved its value to many users after the launch of the first satellite in 1972. The satellite met all requirements of providing information to scientists in the civil areas of agriculture, geology, land use, and in many other fields (Mack, 1998). Landsat I was considered a success and validated the need for gathering terrestrial imagery from space on everything from “urban growth to ice cover in shipping lanes to the health of vegetation” (Mack, 1998).

The success of the Landsat program inspired a movement for transitioning space-based remote sensing from a strategic and tactical military use to civilian applications. The Landsat program seemed to be ideal for this purpose because its commercial validation had been one of the promises of the early studies: "the original approval for Landsat was predicated on private markets growing to the point of having the capability to fully fund all system cost" (Mack, 1998). President Carter supported the Landsat program with the intention of privatizing the remote sensing data market. He directed government organizations such as NASA and the Department of Commerce to find ways to increase private industry interest and participation in a commercial remote sensing market (Mack, 1998). Following his lead, President Reagan also supported this initiative by passing launch and operational costs to the commercial space sector in an attempt to reduce government spending (Johnston, 2003). This was exercised through the Department of Commerce who requested proposals from private industry to assume responsibility and management of the Landsat program (Mack, 1998). Eventually, the Earth Observation Satellite Company (EOSAT), a joint venture of Hughes and RCA, was awarded the contract and assumed control of the program (Mack, 1998).

While the operational responsibility of Landsat was redirected to the commercial space sector, small government incentives to EOSAT could not support the high operating costs of such a complex satellite program by a private company (Mack, 1998).

Eventually in 1992, the privatization of the Landsat ended because EOSAT could not sustain the program. The government realized that the privatization had failed and the burden of responsibility for running the program needed to be transferred back to the government (Mack, 1998). This was evidence that barriers to market entry were significant due to "high development costs and long build times of satellite systems and the high risks involved in launching and operating such technology" (Mack, 1998). The Land Remote Sensing Act eventually relinquished responsibility of the Landsat program back to NASA and the DoD in 1992. Since then, demand for geographic data increased as more civil and military applications have emerged. Also, the technological developments during the 1990s drastically reduced development and operations costs. This enabled companies to "design smaller and less expensive satellites with similar capabilities," thereby reducing costs (Mack, 1998). By the end of the 1990s, private industry was realizing market opportunities in remote sensing that could be accomplished with little to no government assistance (Mack, 1998)

Despite the failed attempt to commercialize the Landsat program, it is considered the catalyst that birthed the movement towards the privatization of the remote sensing market. The Landsat program made the world aware of the United States government's desire to create an independent commercial remote sensing industry, thus increasing the technological qualities and lowering the purchasing costs of Earth imagery.

### 3. SPOT

In 1982, the French space agency, Centre National d'Etudes Spatiales (CNES), commissioned the SPOT (Satellite Pour l'Observation de la Terre) program as the first government-developed, commercially operated remote sensing system. This program was "designed to improve the knowledge and management of the Earth by exploring the earth's resources, detecting and forecasting phenomena involving climatology and oceanography, and monitoring human activities and natural phenomena" (GeoImage, 2011). The SPOT satellites capture panchromatic and multispectral imagery in resolutions from 2.5m to 20m (GeoImage, 2011). The initial SPOT satellites were an improvement over the Landsat system with higher resolution images of Earth and shorter revisit times (Florini, 1999). The Landsat system provided the highest resolution of remote sensing imagery for over a decade (Florini, 1999).

In 1986, SPOT Imaging was created as a spin-off of the SPOT program. SPOT Imaging became the commercial worldwide distributor of SPOT data products and services (GeoImage, 2011). Currently, SPOT Imaging has local offices and subsidiaries based in Australia, Brazil, China, United States, Japan, Mexico, Peru, and Singapore that provide geographic information to both public and private sector decision makers worldwide (GeoImage, 2011).

The early success of the SPOT Image venture saw a 42% growth in sales revenues in its first five years of operations, from 1986 to 1991 (Williamson, 1997). By 1989, SPOT Imaging's sales revenues surpassed that of the Landsat program (Florini, 1999). The steady growth rates for SPOT data products demonstrated a rapidly growing market for commercial remote sensing satellite products and services (Mack 2004). In 2002, revenues from SPOT data products and services reached $58M, still demonstrating a sustained trend and attracting more private ventures in the remote sensing market. The SPOT program and SPOT Imaging spin-off demonstrated how a commercial company could not only sustain itself through imagery product and service sales, but also achieve steady growth in a new space-based imaging market. The SPOT program example had a tremendously positive impact on the growth of the private satellite industry within the United States.

#### 4. IKONOS

In 1999, the first commercial IKONOS was launched with the mission to collect high-resolution imagery at 1-meter and 4-meter resolution using both multispectral and panchromatic imagery. One of the major advantages of IKONOS over older generation sensing satellites was its advanced pointing capability which significantly reduced revisit times (GeoEye, 2011). Today, IKONOS provides valuable high-resolution Earth imagery and extracts additional spatial data in the visible and near infrared bands (Goward, 2003).

The IKONOS program was the first to collect remote sensing data for specific civil and research applications. NASA implemented an experimental Scientific Data Purchase (SDP) that collected data requirements from the commercial and government sectors for scientific data collection. The IKONOS SDP proved to be a useful experiment in determining what types of data and data collection were useful and which could have been modified for improvement. The SDP activity took nearly five years and provided many United States and international researchers with key data for their specific civil and research applications. This experiment concluded that an IKONOS-type system is valuable to scientific data collection because it dramatically improves high resolution, multispectral measurements to a level never achieved before (Goward, 2003).

The IKONOS program demonstrated that the United States private space industry was capable of providing high resolution, remote sensing imagery to customers and users (Goward, 2003). This program also proved that the private space industry was able to meet the technical needs of the United States science community by supplying critically needed data that was unavailable from any other sources at the time. The realization that remote sensing data had a high scientific value is what spurred demand for these systems and their data primarily by United States government agencies. Their demand for high resolution, multispectral data was met by the explosive growth of remote sensing systems by private space industry for the next twenty-five years to come (Goward, 2003).

## C. RECENT TRENDS IN SPACE-BASED IMAGING

### 1. Explosive Growth in the Global Space-Based Imaging Industry

The space remote sensing market has witnessed an explosion in the number of companies and initiatives in the last decade. This has been due primarily to the growth of the commercial remote sensing industry as a result of the Landsat and SPOT programs and encouraging United States remote sensing policies. According to Keeley, over 120 market segments and sub-segments have been identified that drive the demand for high-resolution remote sensing imagery (Keeley, 2004). Remote sensing imagery has established itself as a critical need in not just military applications but in a host of civil applications and markets such as environmental monitoring, local government planning, utility facilities management, forestry, and mineral exploration. Emerging applications such as wireless communication, agriculture, insurance, and disaster response will continue to create large demand for more remote sensing technology and capability (Keeley, 2004). In a recent study conducted by Forecast International named “Civil & Commercial Remote Sensing Satellites”, there are projected deliveries of approximately 110 remote sensing satellites worth over $16.3B over the ten years spanning from 2004 to 2014 (Forecast International, 2010). According to Figure 1, the global sales of remote sensing data and products have gone from $2 billion to $6 billion from 2001 to 2010 (Forecast International, 2010).

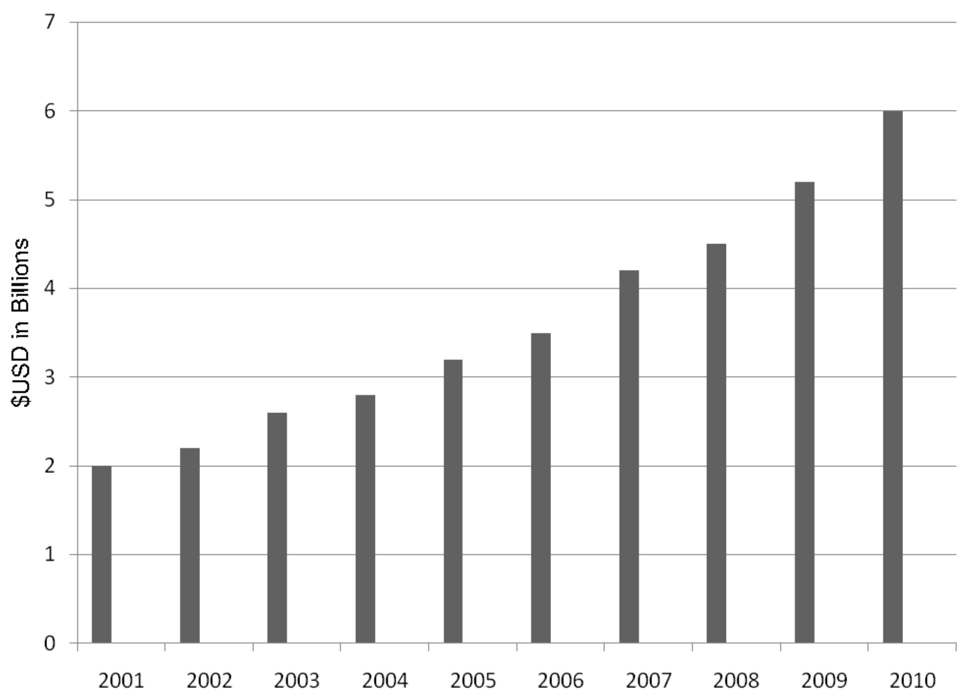


Figure 1. Global Sales for Commercial Remote Sensing Imagery

The recent explosive growth of the commercial remote sensing industry owes its expansion to several political and technological changes that have occurred in the remote sensing industry since the early 1990s. First, the legal framework for licensing and regulating in the commercial remote sensing industry was established in 1984 by the Land Remote Sensing Commercialization Act. However, it was not until the early 1990s when the Land Remote Sensing Policy Act was signed into law that the industry started to flourish. This was due in part to the attempts of the Reagan administration to reduce federal spending and ignoring evidence that suggested that the remote sensing market was not sufficiently mature to sustain itself (Florini, 1999). The implementation of these policies resulted in the development of several private sector ventures with goals to design, develop and operate medium-resolution and high-resolution, earth-observing satellites (Fritz, 1999).

Second, the anticipation of the expanding market for remote sensing data has had a large positive impact on the growth of the private satellite industry within the United States. The potential customers of remote sensing data and products include “farmers, city planners, map makers, environmentalists, emergency response teams, news organizations, surveyors, geologists, mining and oil companies, timber harvesters, and domestic as well as foreign military planners and intelligence organizations” (Florini, 2000). In anticipation and support of this trend, commercial providers now exist in over 20 countries worldwide. The global market for remote sensing technology and products has gone from virtually non-existent in the early 1990s to an estimated $8.2 billion in 2009. Its growth is expected to grow to $11 billion by 2014, a projected 5-year compound growth rate of 6.1% (BCC Research, 2010).

Finally, active United States government support has also encouraged growth of the commercial satellite industry within the United States. Following the failure in the Landsat commercialization, the United States government has taken many measures to encourage the growth of an independent commercial satellite industry in the United States. The implementation of remote sensing policies has loosened restrictions and promoted the space industry to invest in remote sensing technology. Also, the utilization of direct subsidies to commercial companies and guaranteed contracts has further incentivized companies to invest in developing remote sensing systems and products (Florini, 2000).

### 2. Reduced Costs for Commercial Remote Sensing Imagery

Over the last decade, rising levels of competition in commercial space imaging have significantly reduced the costs associated with sourcing remote sensing imagery. As demand has increased with more users purchasing these products, basic image costs, without considering elements such as additional processing, have dropped to under $600 for Landsat imagery in some cases (Keeley, 2004). In the last decade, numerous international companies have emerged as providers of remote imagery or remote imagery products on the global market. In addition, advances in image exploitation technology have improved imagery measurement and extraction from raw data. This has also reduced the costs of data significantly by improving performance in image collection systems.

### 3. Advances in Remote Sensing Sensor Technology and Distribution

Advances in imaging sensor technology (panchromatic, multispectral, and hyperspectral imaging), data storage, and data processing along with the ability to quickly and efficiently transfer such data files electronically has furthered the growth of the remote sensing industry. Significant developments in sensor technology have made it possible to extract huge amounts of information by breaking apart an image into separate infrared bands for detailed analysis. For example, useful information such as temperature changes in the environment, the growth of vegetation, carbon monoxide pollution levels, and alterations in terrain are now all made possible through advanced sensors and data processing. As stated by foreign policy expert Ann Florini,

> Since the 1980s, the development of the powerful personal computers capable of processing large amounts of data, the development of geographic information system (GIS) applications, and the growth of data dissemination methods such as CD-ROM disks and the Internet have all promoted the accessibility, marketing and demand for satellite imagery, (Florini, 1999)

This, in turn, has enabled the remote sensing industry to flourish into an $5.2 billion per year industry as of 2009.

### 4. Advances in Geographic Information Systems (GIS)

A GIS is a computer-based tool or application for storing, handling, and manipulating geographic-related information. It serves as the framework for transforming overhead imagery into useful data for numerous applications. For example, geospatial information is necessary for “numerous government and business functions, including transportation, understanding market conditions and demographics, analyzing environmental conditions, agriculture, and construction, mining, maintenance and design of buildings” (O’Connell, 2001). Over the last decade, the demand for geospatial data has resulted in the rapid development of GIS technology and applications. Applications such as Mapquest or Microsoft’s business mapping software, MapPoint both use widely available GIS applications. According to a report by Daratech, a research firm that tracks GIS and geospatial data, federal agencies spent $4.4 billion on GIS in 2010 and are estimated to spend $5 billion in 2011 (Daratech, 2010). Even though military applications for GIS data are a small portion of the total market, this overwhelming trend demonstrates the global demand for GIS technology and products.

### 5. Commercialization of High-Resolution Systems

In the United States, three primary commercially owned companies provide remote sensing satellites to both government and domestic markets, and foreign commercial markets such as GeoEye (formerly known as Space Imaging), Digital Globe (formerly known as EarthWatch), and Orbital Sciences. Due to an aggressive buildup of the commercial industry over the last two decades, the total revenue from the North American remote sensing market alone is estimated at $1.68 billion per year (Spaceref, 2011). The demand for this data has been clearly established in many commercial markets such as environmental protection, peacekeeping, treaty monitoring, disaster assessment, where the details captured in high-resolution imagery are necessary. Since the mid-1990s, promotion for a commercial remote sensing industry, technological advances in space launch, and sensor technology have all made remote sensing imagery a source of huge profits for an entire commercial industry.

In addition to the United States, many foreign governments and commercial companies have developed remote sensing programs in the past fifteen years. France's SPOT, Canada's RADARSAT, European Space Agency's ERS radar imaging satellites, Japan's JERS and India's IRS-1C and 1D satellite are major remote sensing programs (O'Connell, 2001). According to Figure 2, the commercial remote sensing industry has grown from five countries, developing remote sensing systems in 1980, to twenty-two countries in present day (O'Connell, 2001).

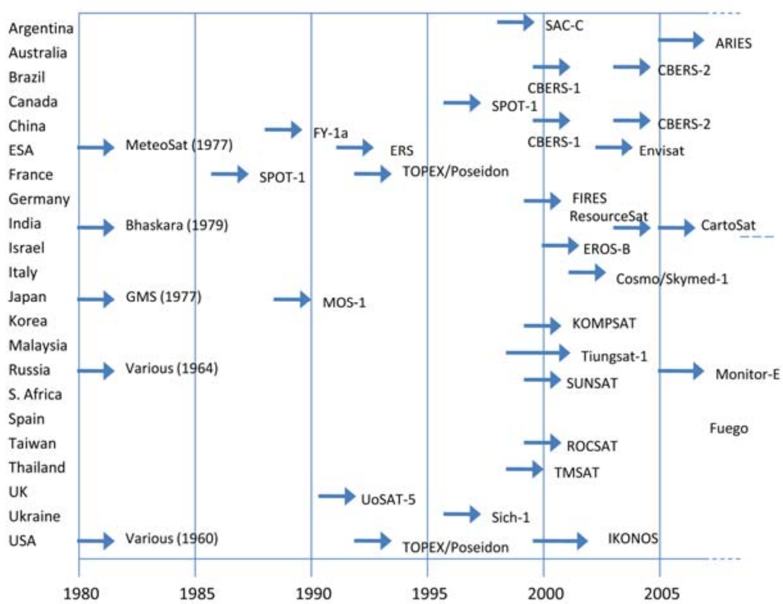


Figure 2. Remote Sensing Programs Worldwide (1980–2007)

Most of these foreign governments allow their civilian satellite imagery to be sold on the commercial market and to be available to almost anyone on a commercial basis (O'Connell, 2001).

### 6. Reduction in Satellite Size

The number of remote sensing satellites in the 100–500-kg range, also known as "minisats," has increased significantly in the last decade. Because of their small size and use of Commercial Off-The-Shelf (COTS) technology, the development and launch costs for this satellite classification have been reduced significantly (Kramer, 2008). For example, French SPOT satellite engineers estimate that the smaller 500-kg 3S satellites that will replace the 2000kg SPOT satellites will cost on the order of 200 million francs as opposed to 2.6 billion francs, a 92% reduction in cost (Glackin, 1999). When applied to the remote sensing market, this trend has made it easier for countries and commercial industry to develop remote sensing programs. Some remote sensing programs have even developed "microsats" in the 10–100-kg range. Many foreign countries such as South Korea, Israel, Germany, South Africa, Thailand, Chile, Pakistan, and Malaysia either have or are developing miniaturized remote sensing systems (Glackin, 1999).

#### 7. Smaller Instruments

In the last fifteen years, dramatic improvements have been made in decreasing the size and reduce the weight of remote sensing instrumentation. This comes as a result of the industry demand for "smaller, faster, cheaper" space hardware which is challenged with increasing mission capabilities and requirements. For many remote sensing systems, basic physics dictates the size of key components such as electro-optics and telescope length (Glackin, 1999). However, computer components and system circuitry have been miniaturized. According to expert David Glackin, "smaller and lighter instruments means smaller and lighter spacecraft, which in turn mean smaller launch vehicles, and can result in dramatic cost savings" (Glackin, 1999). These large cost savings make remote sensing data more accessible to customers and organizations to use and integrate in their daily operations.

### D. ISSUES

Since the fielding of the Landsat program in 1972, United States policy on remote sensing has loosened restrictions for the "passage of satellites over national territory and for unimpeded distribution of the imagery flowing from civilian satellites" (Florini, 1999). Thus, the ongoing legitimacy of remote sensing satellites is part of a global trend towards transparency, where people are more informed about news and events occurring in other parts of the world. This increasing "transparency" combined with the worldwide proliferation and accessibility of the Internet has resulted in an enormous amount of detailed geographical information of the Earth made widely available to global users

(Florini, 1999). The availability of high-resolution imagery introduces scenarios that threaten United States National Security.

### 1. Compromises to Military Operations Security (OPSEC) and Civilian Targeting

Open source imagery applications such as Google's Google Earth and Microsoft's Windows Local Live give users geospatial data down to 6 inches in resolution in some areas. However, with the increases in "transparency," not all uses of this information are benign. In a testimony to the United States Senate Armed Services titled "Current and Projected National Security Threats to the United States," Lieutenant General Michael D. Maples stated (Maples, 2008),

> The proliferation and potential use of Weapons of Mass Destruction (WMD) against United States forces, the American people, our allies and interests remains a grave, enduring and evolving threat. Non-state terrorist networks continue to seek this capability while nation-states expand their WMD capabilities and the survivability, accuracy and range of the associated delivery systems.
>
> The most significant terrorist threat to United States interests worldwide, Al-Qaida remains committed to using violence to displace Western influences across the Islamic world with its own interpretation of Islamic rule. Al-Qaida continues efforts to obtain chemical, biological, radiological and nuclear capabilities.

The threats discussed here refer to targeting capabilities and tactics that could lead up to an adversary launching an offensive attack against U.S domestic and/or overseas interests. These threats can be organized groups with intelligence gathering capabilities to hostile governments with a full access to advanced weapons and intelligence gathering methods. Several incidents alert us to the potential that United States and other foreign adversaries, warring nations, and rogue organizations may utilize widely available remote sensing imagery to aid in their offensive planning:

- February 2009 – Updated imagery on Google Earth reveals a previously unknown piece of Britain's defense infrastructure: a nuclear submarine base located in Faslane, Scotland. Satellite pictures also revealed the exact location of two Vanguard Class submarines, SAS sleeping quarters, office blocks, bunkers and parade grounds. (Haines, 2009)

- December 2008 – The Jerusalem Post reports that a documentary called "The Field of Death" posted on the Hamas military wing's website showed terrorists using Google Earth to plot a rocket attack on a fuel depot inside Israel in April 2008 that killed two men. (Harvey, 2009)

- November 2008 – Islamic terrorists from Pakistan launched over 10 coordinated shooting and bombing attacks across Mumbai, India, killing over 175 people. The sole gunman who survived said that the attackers used Google Earth to familiarize themselves with the locations of buildings and synchronize the attacks. (Irani, 2009)

- In 2007, insurgents operating in Basra, Iraq, were caught with printouts of Google Earth imagery showing detail of buildings, vehicles, tents, and bathroom facilities inside British military bases in Basra and other vulnerable areas. British security services are concerned with Internet viewing access to sensitive infrastructure such as electricity stations, military bases, and their own headquarters in London. (Telegraph, 2007)

- August 2007, imagery of Bangor, Maine, that appeared on Microsoft's Mapping Tool, Virtual Earth, reveals the Trident ballistic submarine's secret propulsion system. The imagery showed clear images of the propeller design, a key to the submarine's ability to deploy and remain undetected. (Seattle Times, 2007)

- In 2007, satellite photographs were released on Google Earth that clearly shows sites viewed by the government as sensitive such as Israel's classified nuclear research station in the city of Dimona, the headquarters of the Mossad spy agency, Israeli Air Force Bases, the location of the Aiirow missile defense system, and the central military headquarters and Defense Ministry compound in Tel Aviv. The resolution was one pixel to 2.4 sq yards. (Nissenbaum, 2007)

- Since 1999, Venezuelan President Hugo Chavez made multiple attempts to purchase a major stake in ImageSat International (ISI), a United States based satellite imagery company. In 2002, Venezuela had set aside funding for the exclusive rights to a high-resolution image footprint encircling a Venezuelan ground station. President Chavez is a socialist, has created an alliance with Fidel Castro, and considers the United States a threat. (Miami Herald, 2008)

In each one of these incidents, widely available satellite imagery either compromised military intelligence or aided in the planning of an insurgent attack. The availability of imagery data through openly available sources such as the Internet has made it extremely easy and fast for anyone to obtain useful intelligence and data from anywhere in the world. It can be argued that imagery and mapping alternatives exist that could have been substituted for imagery, leading to the same outcomes of each of these incidents. However, the availability of “detailed-enough” commercial and public imagery data on the Internet does play a role in insurgents gathering intelligence and planning attacks. Allowing this imagery data to be accessed openly and globally may pose a threat to the safety and operational security of United States military and civilian targets.

### 2. Lack of Control of the Distribution of Commercial Space Imagery

One of the major innovations in conventional warfare is the ability for military forces to receive detailed images from the battlefield and distribute them (or the analysis) directly and immediately to the commanders in the theater. Space-based imaging also provides useful intelligence from the planning of military operations to evaluating post-attack damage assessments. Almost every aspect of the military mission from the tactical to the strategic levels is made possible by high-resolution imagery that allows the military to operate in an environment of always knowing what lies ahead. In fact, former Secretary of Defense William J. Perry has acknowledged the importance of all space-based capabilities in his statement that "Space forces are fundamental to modern military operations" (Perry, 2009).

However, if regional powers, rogue states, or terrorist groups have access to this data and capability, they will be able to exploit it to obtain the same advantages as our military. Thus, the widespread availability of high-resolution imaging presents a vulnerability to United States military and civilian targets. If high-resolution imagery were to be collected and controlled solely by the United States military, the danger of this intelligence falling into the wrong hands would be minimal. However, 45% of high-resolution imagery in existence is owned and controlled by three commercial companies located in the United States and several commercial companies and governments in foreign countries, well away from close United States government monitoring and control (BCC Research, 2009). This situation was created by the loosening of restrictions on commercial licensing of high-resolution satellites systems in the 1980s in an effort for the United States government to encourage commercial industry development. These commercial companies are given the large and critical responsibility of protecting vital data that could fall into the wrong hands. Currently, only a few United States government policies and international laws exist which limit the distribution of high-resolution data to certain countries and customers. However, without adequate government control and/or oversight of this data, there is a risk of this data being used for purposes that can compromise United States National Security and place critical military and civilian targets at risk.

### 3. Risk of Decline of the Commercial Imagery Industry Due to Government Intervention

Since the development of the Landsat imaging satellite in the early 1980s, the United States government has actively shaped the space imaging commercial industry through numerous civil remote sensing policies. These programs have been owned and operated by commercial companies that have grown and profited because of the United States government's encouragement to procure expensive high-resolution imagery. The result has been the development of a $8.2 billion (as of 2009) commercial industry that today owns, controls, and distributes data products to customers all over the world, including the United States military (Williamson, 2004; BCC Research, 2011). Because of the almost complete commercialization of the remote sensing industry, there is a risk that too much regulation through government could upset the profitability and health of the industry. With many remote sensing providers assuming all costs of their operations from satellite launch to data distribution, the financial health of these companies may be at risk if healthy profitability is not maintained. For the United States government, the element of profitability simply does not exist when dealing with any of its own programs. This makes regulation and policy much easier to implement on internal government programs. However, with a growing number of vulnerabilities to United States National Security present, it is critical that United States policymakers achieve a proper balance in developing and implementing remote sensing policies that protect United States military and civil targets without hurting the commercial imagery industry (Williamson, 2004).

## E. SUMMARY

The United States government has grown the commercial space imagery industry into a $7 billion-per-year industry. The United States government has benefited immensely and received large cost savings by incentivizing private industry to bear the technological development and satellite launch costs. Today, the United States government remains the largest customer of commercial space imagery. Numerous civil agencies have used commercial space imagery to improve their operations and customer products. However, the cost of providing this capability is the high reliance many of these agencies have on commercial space imagery in order to carry out their job functions and missions. The United States government needs to provide the proper policies and adequately manage the issues that present risks to commercial space imagery in order to maintain an industry that remains healthy, profitable, and contains protections for United States National Security.

# III. LITERATURE REVIEW

## A. INTRODUCTION

During the Cold War between the United States and the Soviet Union, the technology available for high-resolution remote sensing was strictly controlled by the both countries. Each other's technical capabilities and the photographed images were highly classified in fear of intelligence leaks that would expose how much was known about the other side. All matters having to do with remote sensing from space were never publicized or released to the public, including satellite launches and acknowledgement of remote sensing programs. These restrictions began to diminish the mid 1980s, with the commercialization of the Landsat program and the competitive response to the development of SPOT. Several policies issued since the early 1990s have led to the explosive growth in the commercial remote sensing industry over the last 20 years.

## B. U.S. REMOTE SENSING POLICY REVIEW

### 1. Presidential Directive 54 (1979)

In an effort to expand the user base for Landsat data and set the stage for the eventual commercialization of the civilian remote sensing industry, the Carter administration issued Presidential Decision Directive (PDD) 54 in July 1979. The PDD transferred the flight operations of the Landsat systems to the National Oceanic and Atmospheric Administration (NOAA) and the Department of Commerce (DOC) and directed NOAA to "seek ways to further private sector opportunities in civil land remote sensing activities … with the goal of eventual operations of these activities by the private sector" (Florini 1999). PDD 54 encouraged the private space industry to take over the management of the existing Landsat satellites as well as the development and operations of future remote sensing systems. Large government subsidies were set aside by the Carter for this purpose to bridge the high space costs at the time. The goal was to bring in a few major private companies into the remote sensing marketplace. This would eventually decrease the data costs to the customers and further incentivize private industry to develop more programs and products (Florini, 1999).

In addition, the United States government believed that future availability of 30-meter resolution imagery from future Landsats 4 and 5 would dramatically increase the revenue from sales of Landsat imagery to government and private customers. The PDD utilized these two measures to create an affordable and robust market for high-resolution, space imaging data. In turn, this would spur the growth of a commercial satellite industry that would develop and operate remote sensing systems for an established and growing customer base while being profitable (Florini, 1999). This led to a 1985 contract with EOSAT Corporation to operate and manage Landsat (Fritz, 1999).

### 2. Land Remote Sensing Policy (1992)

The Land Remote Sensing Policy further clarified the guidelines for NOAA to license commercial remote sensing systems that were originally established under the 1984 Land Remote Sensing Commercialization Act (Johnson, 2003). The Act captured an important concept, "the continuous collection and utilization of land remote sensing data from space are of major benefit in studying and understanding human impacts on the global environment, in managing the Earth's natural resources, in carrying out national security functions, and in planning and conducting many other activities of scientific, economic, and social importance" (NASA, 1992). This policy advocated three different initiatives: (1) allowing export sales of the satellites themselves to foreign countries, (2) enabling export of imagery, and (3) committing the United States government to sales agreements with domestic space capability providers. The push for this was for the United States to maintain technological competition with the French remote sensing Satellite SPOT-3, scheduled to launch in 1993 (Keeley, 2004). At this time, the French were already developing SPOT-4 with twice the resolution of SPOT-3. Also, countries such as Israel, Japan, South Africa, and China were developing medium resolution space systems (Keeley, 2004).

The Act enabled private companies to develop their own customer base while accommodating the interests of foreign countries that wanted protected distribution of their own sensitive data. Soon thereafter, the Department of Commerce (DOC) issued the first commercial remote sensing license in January 1993 (Johnston, 2003). Over the next eight years, seventeen licenses for operating commercial remote sensing satellites were issued to both United States and international private companies (Johnson, 2003).

The Policy also established protections for United States national security and foreign policy interests. It executed this protection in multiple ways. First, commercial systems were required to use data encryption systems provided or approved by the United States government with allowable monitoring during data transmissions. Second, the concept of shutter control was established which allowed discontinuing of imaging during periods of crisis. The Policy also reduced the threshold for commercial imagery to 1-meter resolution (Keeley, 2004).

The Land Remote Sensing Policy resulted in the establishment of several private industry ventures for high and medium resolution Earth observing satellites. These ventures were initiated using private investment funding rather than government grants and subsidies (Fritz, 1999). The Act was considered a success because it incentivized private companies to start their own programs, established licensing of remote sensing programs on an international level, and recognized remote sensing data products as a valuable scientific data.

### 3. U.S. Commercial Remote Sensing Policy

The United States Commercial Remote Sensing Policy, issued by President Bush in 2003, provided justification for United States government agencies sourcing high-resolution imagery for civil and military applications (Office of the President of the U.S., 2003). It encouraged civil agencies to incorporate high-resolution remote sensing data into their daily operations. It also established the guidelines for access to remote sensing data by international customers. The fundamental goal of the United States commercial remote sensing space policy is "to advance and protect United States national security and foreign policy interests by maintaining the nation's leadership in remote sensing space activities, and by sustaining and enhancing the United States remote sensing industry. Doing so will also foster economic growth, contribute to environmental stewardship, and enable scientific and technological excellence" (Whitehouse.gov, 2011).

In support of this goal, the United States government will:

> Rely to the maximum practical extent on United States commercial remote sensing space capabilities for filling imagery and geospatial needs for military, intelligence, foreign policy, homeland security, and civil users (Whitehouse.gov, 2011);
>
> Focus United States Government remote sensing space systems on meeting needs that cannot be effectively, affordably, and reliably satisfied by commercial providers because of economic factors, civil mission needs, national security concerns, or foreign policy concerns (Whitehouse.gov, 2011);
>
> Develop a long-term, sustainable relationship between the United States Government and the United States commercial remote sensing space industry (Whitehouse.gov, 2011);
>
> Provide a timely and responsive regulatory environment for licensing the operations and exports of commercial remote sensing space systems (Whitehouse.gov, 2011);
>
> Enable United States industry to compete successfully as a provider of remote sensing space capabilities for foreign governments and foreign commercial users, while ensuring appropriate measures are implemented to protect United States national security and foreign policy interests (Whitehouse.gov, 2011).

## C. SUMMARY

The purpose of initial United States remote sensing policy, following the end of the Cold War, was primarily to pass launch and acquisition costs on to the commercial space industry. The Land Remote Sensing Act of 1992 was instrumental in shaping the growth of the commercial remote sensing industry; however, it was not until the 1990s, when the value of remote sensing data was discovered by civil agencies. Since then, the commercial remote sensing industry has experienced annual growth rates of 8–10%, demonstrating the massive desire and dependency for remote sensing data and products. However, it was not until the late 1990s that remote sensing policy identified the goal of protecting national security. This was due mainly to the growing reliance on remote sensing data by civil agencies. The next step was for the United States government to formulate and field measures that would adequately protect national security.

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# IV. RESEARCH ANALYSIS

## A. RESEARCH FINDINGS

### 1. Current Remote Sensing Policy

#### *a. International Regulations on Remote Imagery Distribution*

The international control of remote sensing collection by countries and private companies falls under the Outer Space Treaty, established in 1967. Article I, paragraph 2 of this Treaty states that: "Outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law" (Department of State, 1967). Since remote sensing is conducted from space, it falls under the Treaty's jurisdiction even though this type of space operation involves the detailed imagery collection of a country or state. This is dissimilar to remote sensing by aircraft, in which a country's airspace is protected and governed by sovereign law. The collection of remote imagery from space presents a large vulnerability because any country or individual is free to launch and collect any type of imagery from any location in space without discrimination of any kind.

Since little to no limitations exist for countries taking detailed imagery of each other, one must look to international laws for protective measures for the distribution of remote data of another country's territory. The distribution of space remote imagery falls under Principle IV of the United Nations General Assembly Resolution concerning remote sensing from space. It states that remote sensing activities

> shall be conducted on the basis of respect for the principle of full and permanent sovereignty of all States (countries) and peoples over their own wealth and natural resources, with due regard to the rights and interest of other States (country)….Such activities shall not be conducted in a manner detrimental to the legitimate rights and interests of the sensed State (country), (United Nations, 1986).

The resolution does not state that prior consent or authorization is required by a country before distribution or sale of their imagery occurs. This can be problematic because the need to verify and gain consent for imagery taken of a country is left to the subjectivity of the imagery's owner, leaving the issue with little to no formal procedure in place. In addition, the collector of remote data of another country's territory is entitled to full ownership and use of that data, despite authorized distribution or not. In summary, neither a country's airspace nor distribution of its imagery is protected by international law.

#### *b. U.S. Regulations for International and Domestic Providers*

In October 2000, the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce issued regulations regarding to the licensing, monitoring, and compliance of commercial providers of remote sensing systems that are affiliated with the United States (NOAA, 2003). These regulations outlined the modes of collection and distribution of remote imagery and included United States national security interests, foreign policy, and international obligations. Important provisions that must be followed include the licensee being required to maintain operational control from a domestic location at all times, the ability to override commands, the licensee is required to limit data collection and distribution. In addition, each licensee must comply with the Land Remote Sensing Act of 1992, which was purposely written with no definitions of such terms as "significant national security" and "significant foreign policy concerns" (NASA, 1992). Verbal ambiguity in this regulation is assumed to be for the purposes of political convenience and flexibility for the United States government to take action where it sees fit.

### 2. Implementation of Policy

#### *a. International Policy*

With little international policy or legal obstacles to prevent satellite observation of one's country or territory or by another, even countries that object to remote observation can do very little about it. For them, the distribution and release of space imagery by another country or foreign provider is not much better protected. International law governing the international distribution of remote imagery, such as Principle IV of the United Nations General Assembly Resolution, is written very loosely and leaves obtaining authorization prior to release of imagery up to the country or foreign provider that owns the data (United Nations, 1986). The burden of requesting particular imagery be removed is on the country that has been observed. They can make international requests to have the particular imagery removed or degraded. However, they are left with the consequences that this imagery has already been distributed, and, in most cases, damage to a country's national security has already occurred. Furthermore, countries that have poor relations with others may not feel obligated to obtain consent for taken imagery prior to its release.

### *b. U.S. Remote Sensing Policy*

Remote sensing policy is a two-sided issue that needs to provide two seemingly conflicting objectives of growing the commercial remote sensing industry and protecting United States National Security. The objective for many of the stakeholders and users for remote sensing data is to obtain the most capability and maximum information possible for their applications at the lowest cost. The United States government's position is to protect national security, foreign policy, and international obligations. The National and Mapping Agency (NIMA) as relegated by the Commercial Remote Sensing Space Policy of 2003 is the sole agent or primary responsibility for acquisition and dissemination of all commercial remote sensing space products and services all national security government organizations (NOAA, 2003). Civil remote sensing space capabilities are managed by the Secretaries of Commerce and the Interior and NASA in consultation with other United States government agencies. Delegated from the Secretary of Commerce, NOAA is responsible for regulating the operations of United States commercial providers of remote sensing data. They administer the licensing, their adherence to licensing obligations, and enforce their compliance. Other government agencies such as the Departments of Defense, State, and Interior and the intelligence community have important roles in interagency review (O'Connell, 2001). National Security Council and the Office of Science and Technology both play important roles in coordinating interagency policymaking process on United States providers.

### 3. Commercial Industry

#### *a. Security Protection for Remote Sensing Data*

Many imaging providers use the Internet as a means of distribution for their products. This heightens the ease and likelihood of theft of imaging data or proprietary applications falling into the wrong hands. Because of the enormous data amounts and the need to leave raw data untouched for customer processing, remote sensing data is difficult to protect through any type of encryption or security that exists today. However, customers spend large amounts of money to develop the many data products such as geographic information system (GIS) data and remote sensing applications that are derived using purchased remote sensing data. Thus, an urgent need exists for adequate security measures against data compromise both for customers' interests and in order to protect national security. Unfortunately, the development of web technology and the increase of network communication bandwidth over the last decade have not been matched with the adequate security means possible to protect remote sensing data.

According to requirements outlined by NOAA of the Department of Commerce, commercial providers are responsible for policing the distribution of remote sensing data to customers (NOAA, 2003). Most commercial space imagery providers have established their own security guidelines for pre-screening customers for security issues prior to granting access to their data and products. However, each provider's policy is different and only broad security guidelines are provided by NOAA upon the issuance of a license. In addition, requirements and protocol on how each provider is to protect the data on its distribution systems are not specified by NOAA. It is very possible that some providers' websites or distribution systems could be illegally hacked and high-resolution data could be compromised in that manner. Thus, the responsibility of securing critical data is left completely to the commercial provider, absent of any government oversight or specific requirements.

### 4. Technology

#### *a. Widespread Public and Commercial Availability of Remote Sensing Data*

Technological advances in the areas of computing power and the growth of data transmission systems such as the Internet have removed many of the barriers that once limited the access of remote sensing data to governments and large corporations. Today, the use of the Internet and advanced GIS software such as Google Earth has enabled remote sensing data to be accessed anywhere in the world, at anytime, and by anyone. For the example of Google Earth, the majority of the world's land areas available are viewed with 15 meters of resolution with select metropolitan areas available in Google Earth's highest resolution of 6 inches (Wikipedia). Images on Google Earth are taken at the same time, but are generally current to within three years. In the past, Google Earth has honored United States and international requests to pixelate or downgrade the resolution of landmark images that were available for public viewing. However, these high-resolution photos and aerial surveys of areas would be readily available on the Internet elsewhere. Once sensitive data is published on the Internet and becomes widespread among various websites, policing it is virtually impossible.

In addition to the public distribution of remote imagery data, almost all commercial remote imagery providers have made their data products available on their Internet websites for marketing and ease-of-distribution purposes. These commercial data products provide raw, high-resolution imagery that is available for purchase to corporate, private, government, and international customers. In addition, many of these data products are combined with advanced graphic information system (GIS) software that allows the user to integrate layers of information and manipulate them with ease. Customers must receive conditions that firms must accept to receive approval for undertaking foreign sales.

Another widely available source of remote sensing data is United States government websites. A survey done in 2004 identified 465 offices or initiatives at 30 different federal agencies that make GIS data publicly accessible on the Internet and other easily viewed information sources (Baker, 2004). Some of these sources provide critical data such as maps of roadways, floor plans, and facility infrastructure details of potential terrorist targets such as nuclear power plants, dams, and chemical facilities. Some local and state governments have established guidelines on what sensitive information is allowed to be published on their websites. However, there is little to no standardization of rules and regulations between state and local governments.

#### *b. The Use of Graphic Information Systems (GIS) as a Military Planning and Decision-Making Tool*

With significant improvements in the area of graphic information systems (GIS) over the last decade, the U.S military has developed systems such as the Combat Terrain Information Systems (CTIS) that is designed to provide Army and Joint commanders with essential time-sensitive geospatial information and analysis for battle planning and management (U.S. Army Corps of Engineers, 2009). This capability is made possible through advancements in United States weapons systems technology combined with the availability of real-time, high-resolution imagery. Currently, GIS technology only allows for applications that involve educating or decision making. However, an advanced adversary with full access to advanced intelligence gathering methods may already have a GIS-based systems more advanced than those used by United States intelligence, empowered by the availability of the same real-time, high-resolution imagery used in United States systems. Another possibility is an adversary developing the technology to use GIS for offensive weapon targeting. Thus, the availability of high-resolution imagery does provide a potential adversary with much of the same raw data feeds used for advanced military applications by United States Armed Forces.

### 5. Countermeasures

#### *a. Shutter Control*

Shutter Control is a PDD-23 provision for interrupting commercial service or remote sensing for United States-based satellite imagery providers. It is intended for use during times of political or military conflict or "when national security or international obligations and/or foreign policies may be compromised as defined by the United States Secretary of State or Secretary of Defense" (Florini, 1999). The 1991 Gulf War highlighted the importance of this application applied to United States satellite imaging providers. During the conflict, shutter control was exercised and Iraq and general commercial access was denied to Landsat and SPOT imagery while Coalition countries used this imagery to update maps and plan battle campaigns. In this manner, detailed ground imagery of Iraq that could have aided adversaries was removed just prior to the initial United States and coalition strike.

Shutter control has remained a controversial topic since it was first introduced in 1998. Opposition to this policy argues that shutter control violates First Amendment rights and the Freedom of Information Act and any plans to exercise it need to first be presented and ruled on by the United States Supreme Court. Because of this legal controversy, shutter control has only been exercised once since the concept was proposed. Instead, alternative forms of limiting remote sensing distribution such as purchasing exclusive data rights to commercial imagery have been utilized. Even today, the government remains reluctant to exercise shutter control unless all other alternatives have been exhausted. However, shutter control remains an exercisable option for protecting national defense as provided in PDD-23.

#### *b. Spoofing or Concealment*

A technique for evading detection from overhead space imaging satellites is spoofing, which is also known as camouflaging or concealing a building, object, or area using an assortment of techniques. This concept has been around for centuries, for the purpose of protecting one's critical assets from detection by enemy intelligence.

When interpreting imagery from air or space, analysts use manual or computer pattern recognition to interpret what they are looking at. Most structures and objects can be identified by general characteristics such as fencing, location, shape, size, access points, weaponry, vehicles, etc. One example of a facility designed to spoof space satellites is Iran's Natanz Uranium Enrichment Plant (Solodov, 2007). The original enrichment plant was built above ground and contained several centrifuge facilities for testing and buildings for training personnel. The facility was then expanded underground with additional hallways and large rooms, which were quickly concealed with dirt and trees. A topographic look at the site shows several buildings, a security fence and piles of dirt, leaving the majority of the underground complex undetected.

Spoofing is also currently used in objects such as radar communications dishes to mask the pointing location, thus masking the location of the satellite the dish is communicating with. The USAF's Air Force Satellite Control Network (AFSCN) uses radar domes on all of their ground stations to cloak the pointing direction of their ground stations from detection by remote sensing satellites. The primary limitation of spoofing is hiding large objects such as a large complex of buildings or an airplane runway. Also, the improved sensing capability of today's multispectral sensors requires measures to be taken for reducing or removing infrared or thermal signatures. However, spoofing remains an effective and non-controversial option for making critical objects and assets more difficult to detect.

#### *c. Export Controls*

Export controls are a series of United States laws and regulations that control the export of information, goods and services from the United States to foreign countries or to foreign individuals within the United States Under export control laws, remote sensing imagery taken by PDD-23 licensees is subject to removal at the discretion of the United States Department of Commerce and the International Traffic in Arms Regulations (ITAR). In 1997, export control laws were exercised when Amendment 4321 was added to the 1997 Defense Authorization Act to prevent the collection and sale of high-resolution satellite photographs of Israel by United States companies. Imagery of

Israel was removed on the grounds that it could adversely affect Israel's national security interests. The argument for restricting Israel is that it could compromise their national defense and physical security. However, export control has been challenged by activists who believe it is a violation of First Amendment rights. Export control laws do offer strong protections for what imagery the United States government considers may compromise national security before it is made available on the commercial market.

## B. SUMMARY

Many of the findings discussed in this chapter are not new. In fact, many of these topics have been identified and discussed between numerous United States government agencies and international governments and remain highly controversial even today. The United States government is seemingly faced with a conundrum of supporting two seemingly conflicting policies: 1) encouraging growth in the commercial remote sensing industry and 2) protecting United States national security. Both of these policies need to be addressed and protected, and neither one can be compromised. The challenge for the United States government in managing the current state of affairs lies in making policy choices that maintain the careful balance of the two. The recommendations in the next chapter are based on careful analysis of Chapters III and IV in an attempt to achieve this goal.

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# V. CONCLUSIONS AND RECOMMENDATIONS

## A. SPECIFIC RECOMMENDATIONS

### 1. Current Remote Sensing Policy

Over the past twenty years, the policies set forth by the United States government have encouraged the space community to grow into the multi-billion dollar industry it is today. Commercial providers in the United States absorb all program costs including launch, data collection, and sensor and data interface development. This industry is completely self-funded, self-sustaining, and dependent on civil and military customer markets for survival. However, the growing dependency on the commercial remote sensing by government agencies has developed into vulnerability where providers may make business decisions that endanger the interests of their customers. Thus, the following recommendation is made to the United States government:

- Establish business partnerships with commercial providers

Most foreign commercial providers of remote sensing are either government-owned or partnered with the government to allow for greater management oversight and pricing control. In some cases such as Canada's Radarsat 2 program, the commercial entity funds a minority portion of the capital costs (about 25%) and the remaining balance is funded by the government. The Canadian government benefits from pre-established pricing of data products, insight into the management of the program, and an opportunity to influence company decisions. The drawback to the government is the initial capital costs. However some of this cost will be recovered through negotiated pricing of imagery products as opposed to purchasing on the open market. Although costly in the near term, this approach will assist the government in controlling long-term data costs, mitigate risks of program mismanagement, and reduce the risk of a program failure due to capital funding issues.

As discussed in Part 4b, Chapter IV, a widely available source of remote sensing data is found on local, state, and federal government websites. Since the September 11 attacks, some government agencies have restricted remote sensing data and GIS data on their websites. However, many policies are not clear in outlining what types of data should be allowed on government websites and many inconsistencies exist concerning publicly accessible geospatial information on many local and state government websites. Hence, the following recommendation is made:

- Develop a process and requirements for regulating potentially sensitive information on government websites

Hundreds of United States government websites offer information on their respective industries, covering an assortment of unrelated industries from forestry to public utilities to nuclear power. With a definitive process and requirements in place for policing sensitive GIS and other information, easily obtainable government information could be protected. Much of the information available today might aid an adversary's mission for data collection and attack planning. The removal or limiting of this information from government websites would not completely protect these resources from being utilized by an adversary. However, it would make intelligence collecting on critical targets more difficult, since the Internet makes data collection easy and available from any location with a connection to it.

### 2. Implementation of Policy

International law does not require prior consent by a country that has been surveyed before imagery is released on a provider's website. As mentioned in Chapter IV, international law regarding this topic is written so loosely that the need for a provider to obtain consent for imagery about to be released is subject to the provider's interpretation of a need to do so. As a result, the following recommendation is made:

- Organize an international consortium of imagery providers and individual countries that agree to share remote sensing data prior to its release to customers

Currently, the global remote sensing community interfaces at international conferences around the world set up by such organizations as the Geoscience and Remote Sensing Society (GRSS) and the International Commission on Remote Sensing (ICRS). However, these events are generally where customers and providers exchange information on market trends, new products, and technologies in an attempt to increase market exposure and generate sales. An international consortium (with voluntary membership) composed of commercial providers and countries with an interest in remote sensing would bring several benefits to the parties involved. The purpose of this consortium would be for customers, providers, and countries to discuss concerns over imaged areas and issues prior to release of remote sensing data. Through this consortium, commercial industry would be given an opportunity to develop business relationships with customers, thereby increasing exposure and sales. In turn, countries or governments with interests in remote sensing would have an opportunity to interface with commercial providers and voice concerns of the imaging of sensitive areas or any other political issues. The creation of such a consortium presents no guarantee that issues regarding the release of imagery will be eliminated. However, it does provides a forum where willing, international participants can work together to resolve issues.

### 3. Commercial Industry

Technical advances in computers and the Internet such as increased processing power, improved data speeds, and the miniaturization of hardware have kept the availability and utilization of information at high levels. However, data and software security has not kept up with this trend in order to provide adequate levels of protection for computer systems and data of today. Remote sensing data is especially vulnerable to stealing and piracy where critical data could be compromised. Many commercial providers of remote sensing products use the Internet as a distribution medium to customers, which introduces the risk of information falling into the wrong hands. Currently, most commercially available remote sensing remains unprotected due to the enormous size of the files. Hence, the following recommendation is made:

- Invest in the development of adequate security protections for remote sensing information and other sensitive data products

Data encryption would provide a protection measure to maintain the integrity, confidentiality and privacy of remote sensing data. Technical papers have been written that propose encryption techniques for the protection and transmission of remote sensing data (Yin, 2008). Encryption or another simple security measure would not absolutely prevent data compromise but would make it more difficult for an adversary to steal or obtain critical data or information.

**4. Technology**

The advancement of remote sensor technology and graphic information systems (GIS) over the last decade has had profound results for providing useful information from remote sensing data as discussed in Sec II, Part C. GIS provide such high levels of useful information that data providers, customers, and users are developing these systems. In addition to civil applications, GIS is used widely for military intelligence collection by the United States and many foreign countries. With remote sensing data providing such large amounts of data on global subjects, if an adversary were to develop a new sensor that provided new forms of intelligence, United States national security could be threatened. The United States military needs to be aware of the capabilities of foreign nations, providers, and users so that it can properly identify threats and formulate adequate defense measures. Thus, the following recommendation is made:

- Monitor developments in sensor technology and graphic information systems (GIS) to quickly identify threats and vulnerabilities

This recommendation allows for better preparation of United States military defenses and provides an opportunity to prepare if a potential adversary develops a breakthrough in technology or capability. It is important that GIS developments on foreign entities are monitored so that the United States can properly focus and develop technology areas that are lacking or require development to reach the next level of technology.

### 5. Countermeasures

Very few DoD requirements currently exist which call for protective measures from remote sensing detection in the procurement of new defense systems. As mentioned in Sec II, Part D, 2007 satellite imagery of Norfolk, VA, appeared on the Internet revealing the Trident submarine's secret propulsion system, a key to the submarine's ability to remain undetected. Remote sensing imagery can also reveal details on ground structures such as a complex of buildings and exemplified in 2007 when images of Britain's secret nuclear submarine in Faslane, Scotland, were revealed on Google Earth, showing detail of submarines, SAS sleeping quarters, office blocks, bunkers and parade grounds. In both cases, protective measures factored in during the acquisition process could have prevented the exposure of important military assets. Based on this, the following recommendation is stated:

- Establish remote sensing protection requirements for DoD systems and facilities during the Acquisition Process

Protective measures considered early in a system's design will greatly reduce the potential for an incident involving a compromise of intelligence. Requirements for protection from overhead surveillance should be discussed in the Pre-Systems Acquisition phase well before a detailed design is agreed upon. This will allow the DoD to minimize the cost impacts of these requirements, help further operational security, and reduce the potential for an adversary gathering useful intelligence on our systems and facilities.

## B. SUMMARY

The widespread availability of high-resolution commercial space imaging data has undoubtedly benefited many military and civil applications that depend on these products. The global desire for more available open-source data has been widely improved by the imagery products that are widely dispersed on information mediums such as the Internet. The military, civil, and transparency benefits have shaped our society and the world today. The widespread availability of high-resolution imagery has created a world culture that depends on this and other space-related data for civil and military operations every second of every day, and has created a world culture where detailed information is available almost anytime and anywhere.

However, global dependence on high-resolution imagery does place United States national security at risk from adversarial threats. Measures for dealing with these vulnerabilities need to be addressed through not only U.S commercial remote sensing policy, but also proactive methods as recommended in this chapter. The growing global dependence on remote sensing information and applications is relatively new, having occurred mostly in the last decade. Despite an unprotected, international remote sensing policy, and absence of state and local government regulation of GIS data, the current global atmosphere remains relatively unexploited for now. However, this situation could change dramatically as adversaries develop more technology and methods for exploiting remote sensing data. Thus, the United States needs to take active measures to advance and protect United States national security and foreign policy interests by maintaining world leadership in remote sensing space activities.

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