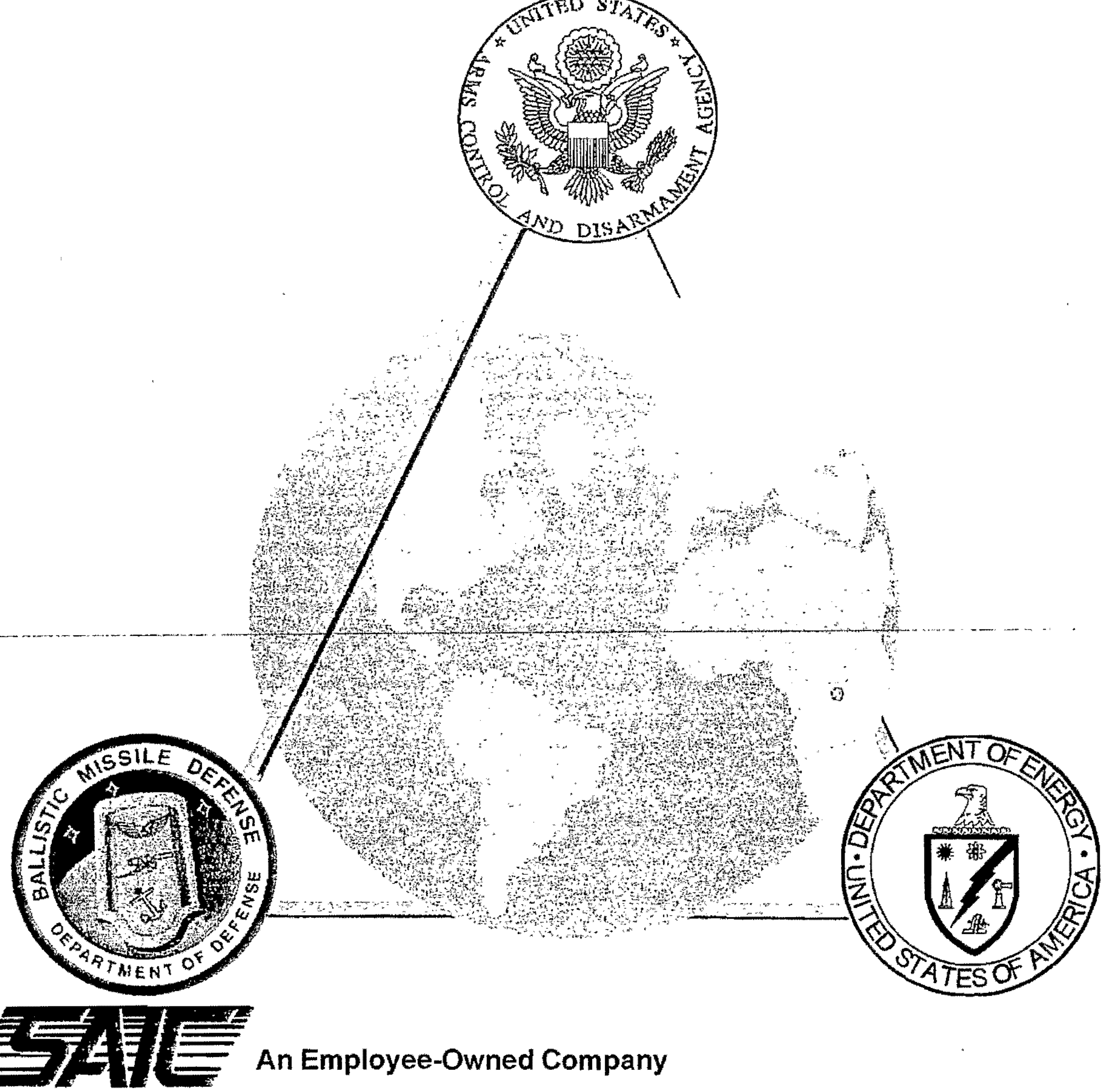
PROGRAM ON STABILITY AND THE OFFENSE/DEFENSE RELATIONSHIP

Final Report

Stability Implications of Open-Market Availability of Space-Based Sensor and Navigation Information (U)

9 November 1995

SAIC, McLean Virginia



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SEMINAR EXECUTIVE SUMMARY: STABILITY IMPLICATIONS OF OPEN-MARKET AVAILABILITY OF SPACE-BASED SENSOR AND NAVIGATION INFORMATION

9 November 1995

On November 9, 1995, SAIC conducted a seminar for the Arms Control and Disarmament Agency, the Department of Energy, and the Ballistic Missile Defense Organization which focused on the stability implications of the increasingly widespread and growing availability of higher resolution satellite imagery and more accurate space-based navigation data (GPS). Participants included government, academic, and industry experts.

Dr. Vipin Gupta of Lawrence Livermore National Laboratory discussed the opportunities and risks inherent in the expanding commercial availability of high-quality satellite imagery data. In the past, the U.S. and USSR held an almost exclusive monopoly on higher resolution satellite imagery. Consequently, it was possible to make a clear technical distinction between civil and military satellites and imagery based on the technical capabilities of the satellite platforms. In the future, the commercial availability of imagery with resolutions closely approaching those formerly found only on classified imagery, will erase that distinction. Therefore, the U.S. must be aware of the security implications of the sale of high-resolution imaging satellites and imagery. The dissemination of this capability represents opportunity as well as risk. On the plus side, states without an independent technical imaging capability could use commercially available imagery to verify arms control agreements, manage crises and assist peacekeeping operations, thus broadening international participation in such efforts. On the negative side, the development of a large market for imagery potentially can place a strain on alliances, complicate crisis management, and foster commercial competition for imagery market share. There is a risk that the major power in a given region (for example, India) could monopolize or retain exclusive rights to all commercial satellite imagery over their region, thus creating asymmetries that are dangerous for regional stability. It is likely that more states (including Japan, India, Brazil, China, and Germany) will make imagery commercially available. As this occurs, U.S. forces may be increasingly exposed to overhead observation. As a consequence, military strategies involving some level of surprise, pre-emption, or counteroffense will become harder to carry out.

Dr. Steven Lambakis of National Security Research, Inc. focused on the increasing commercial and military use of space and the implications for U.S. security. Dr. Lambakis discussed "space power," which he defined as the competitive struggle for the use of space to a state's advantage. The control of space will alter the way in which future warfare will be waged. Information age warfare will provide enhanced quantity and quality of information to all decisionmakers with access to space-based data. The U.S. must consider quickly the strategic and warfighting implications of this development. Because Operation Desert Storm involved the extensive use of space-based information, Lambakis suggested it can be characterized as the first "space war." Based on the Desert Storm experience, it is clear that in the future information gained from and disseminated via satellites will play an increasingly important role in both deterrence and warfighting. Consequently, the United States must establish early and reliable control over the space environment, since the control of space-based assets will be a vital and early combat objective. Maintaining the ability to regenerate on-orbit capabilities and to destroy the space-based assets of hostile, and even neutral, providers of space-based imagery and navigation data may be important to future strategic stability in crisis situations or open hostilities. The creation of a long-term national space policy will be a key step in this process.

Mr. Wilson Cook of the National Intelligence Council addressed foreign motivations for the acquisition of satellite imaging data, present and future foreign satellite programs, the availability of technology and services, and the challenges and future implications of the spread of satellite imagery technology. Foreign nations are actively seeking their own independent space-based sensor capability, although few countries presently have "advanced" (i.e., U.S.-level) systems. The technology and data for constructing a basic satellite capability are available on the open market as is launch capacity. The implications of these developments in foreign countries are that the satellite imagery "club" is growing larger, and an increasing quantity of information is openly available. For the U.S., control over satellite imagery data, by denying imagery and imagery technology to countries, will soon no longer be an option. Militarily-applicable intelligence will become increasingly available and will contribute to improved planning, targeting, and guidance of even third world weapons systems. The U.S. ultimately will have to develop a framework for balancing military and intelligence concerns with commercial interests with regard to satellite imagery data.

TABLE OF CONTENTS

STABILITY IMPLICATIONS OF OPEN-MARKET AVAILABILITY OF SPACE-BASED SENSOR AND NAVIGATION INFORMATION

9 November 1995
SAIC, McLean, VA

Sponsored by
The Arms Control and Disarmament Agency
The Department of Energy
The Ballistic Missile Defense Organization

INTRODUCTION

On November 9, 1995, SAIC conducted a seminar for governmental, academic, and industry specialists. The seminar focused on the stability implications of the increasingly widespread, open-market availability of high-quality satellite imagery and accurate space-based navigation data. This report summarizes seminar presentations and discussion. It also provides some generalized findings synthesized from the discussion. Consensus on findings was not an objective of the seminar, and participants expressed a range of opinions on the various subjects that were discussed.

The SAIC program chairman opened the meeting by noting that space-based assets were key to continuing and enhancing the U.S. capability to deter adversaries and, should deterrence fail, to fight and win in a strategic environment increasingly dominated by information warfare. In the future, winners and losers may be determined by how well and quickly one can acquire, distribute, and process data. Today, as a result of decades of U.S.-USSR nuclear confrontation, the U.S. possesses the most advanced infrastructure for acquiring, processing, and utilizing space-based sensor and navigation information. However, in a post-Cold War environment dominated by regional tensions other countries need not possess a similar level of technological sophistication, including processing and analytic infrastructure, in order to acquire militarily useful information or to make military use of commercially available information. "Bronze medal" satellite technology and information/imagery is good enough for most third world nations involved in a regional crisis, and "gold medal" imagery and data are now commercially available to them. Given the limited time available, a top-level, policy-relevant assessment of the stability implications of this sea-change, both militarily and commercially, is the goal of the seminar.

NEW SATELLITE IMAGES FOR SALE: THE OPPORTUNITIES AND RISKS AHEAD

Presentation Summary[1]

Dr. Vipin Gupta of Lawrence Livermore National Laboratory opened the session with a discussion of the opportunities and risks inherent in the expanding commercial availability of high-quality satellite imagery data. In the past, it was possible to make a clear technical distinction between civil and military satellites and imagery based on the technical capabilities of the satellite platform. In the future, the availability of images from commercial satellites, with resolutions approaching those formerly found only on classified imagery, will erase that distinction. The U.S. must be aware of the security and stability implications of the sale of high-resolution imaging satellites and their imagery. The dissemination of this capability represents opportunity as well as risk.

Dr. Gupta displayed slides of commercial satellite images that contained militarily valuable intelligence information, including views of hardened shelters at an Israeli airfield and images of the Ain Oussera nuclear research complex in Algeria. While the resolution of the Ain Oussera site is not good enough to allow an observer to identify the complex as a nuclear facility, such an assessment is possible in combination with publicly available collateral information. Dr. Gupta's next commercially-acquired image showed massed ground force emplacements during the Gulf War. On one hand, commercial acquisition of such images could provide the opportunity to help stabilize regions of

[1] Also see http://www.llnl.gov/csts/publications/gupta

The French government, after long opposing the sale of high-resolution imagery, is now willing to consider the sale of imaging satellites to the defense and/or intelligence agencies of friendly governments. While the foreign policy community in France remains opposed to widespread commercial availability of high-resolution imagery, if a market for such imagery develops, France will most likely enter it.

The imagery buyer's requirements are both technical and operational in nature. The technical requirements include high spatial resolution, high revisit frequency, and multiple image acquisition in a single pass of the satellite. The buyer's operational requirements are the degree of control over the satellite, whether or not the satellite provides real-time data transmission, and the size of the satellite's geographic jurisdiction (that is, the exclusive right to use the satellite over a given area).

The development of a widespread market for imagery would create significant opportunities for crisis management and arms control verification. In the area of threat assessment, high-resolution imagery offers a safe, unobtrusive vantage point for monitoring military forces both along borders and deep within an adversary's territory. In addition, it would be possible to obtain regular threat updates from such imagery. Satellite observation could also serve as a subtle means of communication or signaling to other countries to the extent that such nations are aware that an imaging satellite is passing overhead, or is being repositioned in orbit, or even launched to better cover a region.

Widespread availability of high-quality commercial imagery could also provide opportunities for verification of arms control agreements. It would facilitate regional arms control by providing a means of independently compiling and verifying data on a regional opponent's force structure. It would also make it possible to conduct pre-verification exercises and, because commercially-available data is necessarily unclassified, to share data among several states in order to address compliance issues. Widespread availability of such satellite data can introduce new countries into verification regimes and would allow for verification without relying on international organizations or major powers, like the U.S., to serve as intermediaries. Finally, the commercial availability of timely satellite data offers opportunities for peacekeeping. It could, for example, augment aerial reconnaissance, provide tactical intelligence, and allow peacekeepers to conduct surveys of lines of communication in remote, poorly mapped areas.

The development of a large market for satellite imagery also poses risks which revolve around how high-resolution imagery will disseminated. Increased access to high resolution imagery could strain alliances and complicate crisis management. There is a risk that the major power in a given region (for example, India) could monopolize all of the remote sensing capabilities in that region, creating asymmetries that are dangerous for regional stability. The principal actors within a crisis will also be required to deal with more information coming in at a faster rate, which could reduce decision-making time. Satellite information will affect targeting and attack planning, depending on whether the targets are fixed or transportable as revealed by the imagery data. Widespread availability of imagery could also lead to the deployment of expeditionary forces, and access to GPS data could foster improvements in the accuracy of long-range weapons such as ballistic and cruise missiles. This raises the possibility of target databases being leaked, sold to, or traded with hostile states and of hostile responses to overhead observation. As the satellite imagery market develops, so will the need for countermeasures or technical hedges. Potential passive countermeasures include camouflage, concealment and deception, while active countermeasure options could involve ASAT launches or jamming of the satellite uplink or downlink channels. For nations, like the U.S., that are highly dependent on satellites, hedges against active countermeasures also will be needed.

Dr. Gupta concluded his remarks with some observations on the future of the satellite imagery market. More states are likely to enter the imagery market, including Japan, India, Brazil, China, and Germany. As more states offer imagery for sale, U.S.

forces may be increasingly exposed to overhead observation. As a consequence, military strategies involving pre-emption or counteroffensive will become harder to carry out.

Dr. Gupta offered some policy recommendations for managing the commercial imagery market. Providers should sell only the imagery and not the satellite platform itself. They should arrange transactions to allow for confidentiality between the supplier and the consumer of imagery in order to facilitate the use of commercially-available imagery by allies for intelligence-gathering purposes. In addition, Dr. Gupta recommended the abandonment of the concept of an International Satellite Monitoring Agency (ISMA), since market forces that are developing as a result of the growing commercial market for imagery removes the need for, and even the likelihood of, international management of satellite imagery. Some state-specific measures recommended by Dr. Gupta include taking into account the regional balance of power when concluding agreements to provide imagery data, and the exclusion of belligerent states from receiving such data. Providers should also link access to imagery to a state's non-proliferation performance. In sum, Dr. Gupta concluded that a persuasive case exists for a commercial imagery market despite the risks.

Discussion Summary

A participant asked whether the cost of imagery increases as the capability of the satellite platform increases, whether there is an economic limit to commercial imagery acquisition capability, and, if so, what the implications are of using high-technology capabilities for increasing resolution digitally rather than through modification of cameras and lenses. Dr. Gupta replied that the only way to increase the resolution of images is to scale up the optics of the satellite, which makes it heavier and more expensive. As a result, commercial imagery is *de facto* confined to the visible and infrared spectrums at a resolution of approximately one meter. The manner in which data processing affects resolution depends on a number of factors including the shape, orientation and contrast ratio of the target.

Another participant suggested that Dr. Gupta had been proceeding from an unwarranted assumption that the U.S. can control the limit of resolution in the commercial imagery market. He pointed out that Russia was, at one time, ready to sell its high-resolution technology. This fact suggests that, if the money is available, even the most advanced technology and images can be bought. Dr. Gupta replied that the U.S. is a dominant player in the emerging commercial imagery market and is in fact setting the technological pace. He also pointed out that Russian technological capabilities in this field are not comparable to leading-edge U.S. technology. Another participant observed that the distinction between military and commercial information is a false dichotomy, arguing that all such information is militarily applicable. Dr. Gupta agreed with this observation.

A participant asked whether France has a policy like that of the U.S. regarding shutter control and other restrictions. The speaker expressed his doubt that France maintains a similar policy, suggesting that U.S. policy has already been rendered obsolete by the ready availability from competitors of comparable quality imagery without U.S.-type restrictions. Because of shutter controls and associated policies in the U.S., he argued, purchasers will simply buy imagery from France or other equivalent providers. Another discussant mentioned that the French have expressed their willingness to sell an entire system, but would institute shutter controls in the case of such a sale. Israel did recently deploy its first spy satellite, but has not offered any imagery for sale. In the final analysis, Gupta feels the challenge facing the U.S. is to remain aware of what sort of information states will provide to other states, since there is nothing the U.S. can do to control other states' indigenous development of their own systems or their imagery sales policies.

Another participant noted that the expanding commercial applications of imaging will necessarily generate employment and wanted to know if that fact had been included in the commercial imaging cost-benefit analysis. Dr. Gupta responded that the extent to which employment would be generated depends on the mix within the market of

STRATEGIC STABILITY AND SPACE CONTROL: LESSONS FROM DESERT STORM

Presentation Summary

Dr. Steven Lambakis of National Security Research, Inc. focused on implications for U.S. security of the increasing commercial use of space. Dr. Lambakis began his presentation with a discussion of "space power," which he defined as the competitive struggle for the use of space to a state's advantage. The control of space, he held, will alter the way in which future warfare will be waged. Information age warfare will provide enhanced quantity and quality of information to both U.S. and foreign decisionmakers, and the USG soon must consider the strategic and warfighting implications of this development.

Lambakis said that the U.S. is now in the earliest stages of addressing space power issues. Space power occupies a contemporary position analogous to that held by air power in 1918. Satellites and satellite information have gradually been exerting their influence on both deterrence and warfare. As the nature of warfare transforms itself with the onset of the information age, other states will try to adapt quickly to the new environment. An important part of adapting to the new environment will be space control -- that is, which states operate in space and how. The U.S. must therefore establish early and reliable control over the space environment.

The denial of space to hostile states will also be important, but will be made more complicated by widespread availability of commercial imaging and GPS data. Space control will be a vital and early combat objective. As a result of the extensive use of space-based information during Operation Desert Storm, Dr. Lambakis suggested that operation could be thought of as the first "space war." He noted that during Desert Storm, while Iraq had no satellites, their ground links to space assets were promptly targeted in an exercise that involved negotiation and diplomacy, as well as the application of force, culminating in coalition airstrikes against command and control assets. He also noted that Iraq had no anti-satellite (ASAT) weapons to threaten our space dominance. However, Iraq was not entirely cut off from the use of space during Desert Storm, since the leadership had access to CNN throughout which provided vital information as well as a way to influence world opinion against coalition military actions. Space power, he concluded, has the potential to be the biggest factor in future military victories.

The lessons of Desert Storm will not be lost on potential adversaries. In the future, the USG will not have the degree of freedom in the use of space-based assets that it has today. Therefore, the U.S. must ensure that no adversary can use space to the detriment of U.S. national security and strategic stability. In the future, access to and control of space-based assets will play an even larger role in maintaining strategic stability, perhaps eclipsing the central Cold War role played by strategic forces and defenses. The U.S. must develop the capability to degrade an adversary's access to military information from space and to take away an enemies' ability to use space. The U.S. must also use political avenues to disrupt the progress of nascent space powers before their capabilities constitute a threat to the U.S. control of space. Finally, there must be agreement within the USG on the long-term goals of space policy.

Dr. Lambakis suggested that technology controls--on software and data interpretation algorithms, for example--could also help preserve the U.S. technological advantage. Also, the U.S. needs to reach agreement with commercial data providers in order to exercise greater control over what data is commercially available. During wartime or in a crisis, the U.S. could saturate providers with orders for their product to prevent images from being sold to the enemy. Selective degrading or jamming of GPS is also possible, but the U.S. could not do this on an ongoing basis. Most importantly, he argued, there needs to be policy coordination, unity of organization, and agreement on purposes regarding space-based data and the use of space within the USG.

getting lower, and to say that only the U.S. is able to make the requisite economic investment for entry into space is misleading. Similarly, another participant mentioned that the Iraqis were working on ASAT weapons and satellites when the Gulf War started and suggested that perhaps they simply chose not to use them just as they elected not to use chemical and biological weapons. If the U.S. only invests in the commercial aspects of space power, it risks losing control over space.

A discussant suggested that control of space is simply a means to an end: the application of military power on the earth's surface. He suggested that there is a danger that space control may come to be seen as a cheap way of achieving stability, in the same manner that building massive numbers of nuclear weapons was seen in the 1950s and 1960s as a cheap counter to Soviet dominance in European conventional forces. In a similar vein, another participant said that space power is more than simply satellites; it is also political and diplomatic power. The U.S. therefore needs to explore the non-military aspects of political power that can affect space and its use. For example, regional agreements with allies can help to shape space power. The participant also cautioned against giving other countries a commercial "free ride" by allowing them to leverage the commercial space market into military space capability. The U.S. should instead try to make other countries afraid to compete with us in that market because of our technical and cost advantages.

Returning to the issue of Iraq's space assets during the Gulf War, a participant commented that, contrary to an earlier comment, there are indications that the Iraqis considered developing ASAT weapons before the war, but there is no evidence that they had actually acquired them. The participant then asked what steps Dr. Lambakis would recommend to ameliorate U.S. vulnerabilities regarding space control. Lambakis replied that although there is no single clear answer, the U.S. must achieve a coherent space policy and develop an improved launch and on-orbit asset regeneration capability. Another participant suggested that the U.S. should encourage private sector research and development in space-based imagery and use it as a lever for improving national security capabilities in that area.

A participant noted that one must not overstate the strategic significance of imagery access during wartime. He felt, as a practical matter, it would be impossible to make massive force movements, on the scale of the Desert Storm flanking movement, without some asset observing and reporting it. Satellite imagery was not the only source for that sort of information. Another participant disagreed any assessment that down-graded the strategic significance of imagery during wartime. Satellite imagery, he argued, can reveal what is behind a front or beyond a hill--information that may be impossible to obtain from the ground in a timely manner. Satellite imagery would also be valuable for determining the location of nuclear, biological, and chemical weapons which may be more important than troop movements or the massing of forces. The speaker also reminded discussants that satellites are most useful when used strategically during peacetime and in the time period just before the beginning of hostilities. Once the shooting starts, he argued, events may move too rapidly for satellites to provide useful tactical information, an observation which calls into question the utility of making large investments in ASAT weapons.

Another discussant drew an analogy between stability issues and the efficient market theory. An efficient market has total freedom of information; if it does not, then the market exhibits a lot more volatility. If nations have the power to deny satellite information to one another, then the U.S. cannot be sure how the resulting volatility will affect the dynamics of interstate relations. Dr. Lambakis questioned the utility of that analogy, stating that the U.S. would not want its enemies to have information that would be useful to them. Another participant noted that transparency does not always lead to restraint.

FOREIGN EFFORTS TO DEVELOP SPACE-BASED SENSORS: CAPABILITIES, AVAILABILITY, MOTIVATION, AND FUTURE IMPLICATIONS

Presentation Summary

Mr. Wilson Cook, Deputy National Intelligence Officer for Science and Technology, National Intelligence Council, focused on foreign motivations for acquisition of satellite imaging data, present and future foreign satellite programs, the availability of technology and services, and the challenges and future implications of the spread of satellite imagery technology. In sum, he noted that foreign nations are actively seeking their own independent space-based sensor capability, although few countries presently have "advanced"--that is, U.S.-level--systems. The technology and data for constructing a basic satellite capability are available on the open market.

Mr. Cook cited some of the motivations behind foreign acquisition of satellite imagery capabilities. First, there is a keen awareness internationally of the extent and benefits of the U.S. and Russia's use of satellite reconnaissance. The role of satellite imagery in Operations Desert Shield and Desert Storm constituted a dramatic demonstration of the benefits of possessing satellite imagery data. Foreign countries would like to gain critical intelligence information through satellite sensor use and would also like to break the U.S. monopoly on satellite sensor use.

Mr. Cook next summarized the programs of various countries that are actively seeking to develop their own satellite architecture. Russia and China both have multiple advanced capabilities. France has deployed the SPOT and, more recently, the Helios satellite, the latter having a resolution capability of one meter or better. Italy and Spain both have shares in the Helios satellite. Israel has recently put up the Offeq 3 satellite, which has capabilities surpassing those that are commercially available. Japan has intelligence will become increasingly available and will contribute to improved planning, targeting and guidance of third country weapons systems. Finally, the U.S. will have to develop a framework for balancing military concerns and commercial interests with regard to satellite imagery data.

Discussion Summary

A participant suggested that the U.S. should be concerned about and devote attention to the prospect of Russian scientists selling imagery technology, in the same way the U.S. has taken action regarding the possibility of the sale of Russian nuclear technology. Mr. Cook replied that this is the reason that Russia is selling its imagery data as a preventive measure to stop the sale of the underlying technology and that Russia is currently implementing policies to stem any satellite technology "brain drain." Another discussant asked whether the sale of imagery was turning out to be profitable for Russia or for any of the providers. Mr. Cook replied that there have not been a lot of sales yet and that the sales that have taken place have not been particularly profitable. Russia, he said, is simply trying to undercut other providers. Another participant offered the observation that SPOT and Landsat sales have also been sparse, and that the builders of the SPOT satellite have not yet recouped their costs.

Roundtable Discussion Summary

The moderator opened the roundtable discussion period by noting that wider access to satellite imaging data is neither a panacea for arms control and stability nor is it a disaster for U.S. national security that will limit our freedom of action. He suggested that any analysis of the risk to national security posed by the growing availability of this information must take into consideration the intentions of the countries that have access to the data and the data's potential negative effect on our long-term strategic and economic interests. While imagery is a useful source of technical intelligence, much information related to intentions will never show up in a timely manner on any form of imagery. Another participant observed that the sunk costs which went into constructing the U.S. satellite architecture over the past thirty years included a large amount of money that was spent for secrecy. He noted that commercial imagery interests presumably would not have to pay for secrecy and, therefore, would not be expected to incur comparable costs in constructing a purely commercial satellite architecture.

A participant pointed out that much of the discussion of space strategy is in technical terms, and suggested that it is important not to overlook at the geopolitical impact of U.S. space capabilities and leadership. He also noted that the strategic advantage of possessing satellites is conferred by possessing a constellation of satellites, not individual satellites. A participant also made the point that image processing, interpretation, and dissemination has become much easier as computer capabilities have exploded. Consequently, much of the technical capability resident in the U.S. imagery community, that cost the U.S. billions of dollars to develop over many years, is now commercially available at a much lower cost.

Someone suggested that there is a disconnect between the demonstrated utility of the Landsat satellite imaging service and the projected demand for commercial satellite images, and wondered how it is possible to predict an enormous market for such data given the limited market for Landsat images. A participant replied that consumers were unhappy with Landsat's capabilities and pricing, which caused sluggish sales. He did not feel the Landsat experience will be representative of the future imaging market. In addition, the future market will involve other services apart from imaging. Finally, a participant suggested that some attention should be given to the assertion and protection of U.S. commercial property rights in satellite imaging.

SEMINAR FINDINGS

Although consensus was not an objective of the seminar, a number of common themes can be synthesized from the presentations and ensuing discussion:

- **Commercial satellite imagery data will inevitably provide information that has some degree of military utility.** Just as any technology could conceivably have military applications, commercial imagery technology will provide militarily useful information to consumers, especially given that satellite technology has advanced to the point where distinctions between military and civilian levels of sophistication are increasingly meaningless. While this will have some effect on strategic stability, it will have a greater effect on regional stability.

- **The relative risk of widespread dissemination of satellite imagery data depends upon the intentions of the recipient state, for which U.S. assessments will nearly always reflect a certain degree of uncertainty.** Whether or not the spread of commercially-available satellite imagery data is a positive development for stability depends on how the intentions of the recipient state are evaluated. Intentions cannot always be clearly determined from imagery. Differences in the evaluation of a state's intentions can yield diametrically opposed policy recommendations, making it difficult to institute blanket policies regarding control of satellite imagery data.

- **Efforts to control dissemination of satellite imagery will have to balance U.S. national security interests with its commercial interests.** Assuming the commercial imagery market expands, which seems problematic, the U.S. will have an ever-increasing economic stake in the health of that market. It will be essential to develop a means of resolving any conflicts between the U.S. interest in cultivating the imagery market and potential national security threats arising from that market's success. Moreover, since much imagery technology is now widely available at relatively low cost, there may be very little the U.S. can do to limit dissemination.

- **The emerging post-Cold War strategic environment suggests that access to, or control of, space-based imagery or navigational information will be both more difficult and more important.** The development of a space policy that recognizes and balances the need to compete commercially in space while also ensuring U.S. strategic dominance of space should be a high priority. Moreover, while the U.S. is the technological leader in space-based assets, its cutting edge capability may be more than many regional powers need, want, or can afford. Nonetheless, if the U.S. is to remain a world leader in the emerging era of information warfare, it must maintain its edge in space-based assets and be able to defend that edge both physically, on orbit, and in the marketplace. Maintaining U.S. space leadership may be key to ensuring long-term strategic stability in the post-nuclear age.

- **We are evolving into a strategic environment where the balance of power is defined less in terms of offensive and defensive forces and more in terms of information access, processing, and analysis.** Consequently, the whole issue of what constitutes the most important factors contributing to strategic stability and the offense-defense relationship in a post-nuclear era should be analyzed. While we will continue to need strong and modern conventional and nuclear deterrent forces, maintaining our leadership in space and in processing, analyzing, and sharing data acquired on orbit, may greatly reduce the likelihood that those forces will need to be used.

STABILITY IMPLICATIONS OF OPEN-MARKET AVAILABILITY OF SPACE-BASED SENSOR AND NAVIGATION INFORMATION

An Introduction to Topics and Issues

30 October 1995

Ms. Marjorie Robertson

Introduction

Since the launch of the Corona series of photoreconnaissance satellites and the discovery of the alleged "Missile Gap" in the 1960s, to the acquisition of real-time, space-based sensor and navigation data during the Persian Gulf conflict, military space systems and advanced technology have become increasingly important to maintaining strategic stability. Today, the virtual U.S.-Russian monopoly in this area is ending. These capabilities are becoming widely available to developing nations which, in turn, increasingly view access to sophisticated space-based technology as fundamental to the advancement of their national interests. Consequently, while much attention has been focused on the potential spread of weapons of mass destruction and ballistic missiles in developing countries, the sale of space technology to the same countries is no less important.

As with ballistic missiles, space technology is spreading through several channels including the purchase of space systems and data from industrialized countries, and the development of systems using foreign technology and expertise. Currently, only seven nations, the United States, Russia, China, France, Japan, India and Israel, have indigenous space-launch capabilities, yet still others have arranged for satellite launches by states with the capability. All nations have access to high quality commercial satellite imagery and GPS data. The competitive economic pressures that drive both U.S. and foreign companies to more widespread sales of launch capacity, space-based technology, and data (including communications transmissions, photography and GPS information) likely will increase in the future. As this happens, the line between commercial and the military application of space-based sensor information will become increasing less clear. Consequently, the use of space militarily and commercially by an ever increasing number of nations has important implications for U.S. national security policy that could affect the methods of warfare and future geopolitical scenarios, thereby reshaping U.S. interests and strategic response options.

Military and Commercial Photoreconnaissance

Background. For three decades, the traditional space powers, the United States and Russia, have been able to exercise a degree of control over other states through their monopoly over the building and launching of satellites. This leverage is diminishing as new suppliers of space services and militarily relevant space technology enter the market. The dissemination of high quality space-based images to the highest bidder means that it may soon be impossible to deny space data, or even access to space, to a developing state. Other states, including France, China, Brazil, Great Britain, India, Israel, South Africa and Japan. have or are acquiring advanced military space systems, often under the guise of peaceful space systems, to strengthen their regional security and commercial interests. Still others, such as Iran, Pakistan, and Libya, are allegedly able to purchase missile technology and full-up ballistic missile systems from supplier states.

While several states have intelligence-sharing agreements with established space powers, such arrangements place client states in a dependent situation. An indigenous space reconnaissance ability would provide a state with an independent observation capability with tactical applications. Commercial and military satellite imagery would disclose aggressive intentions of an adversary before a crisis and subsequently allow a country's military forces to operate more effectively.

The United States and Russia have been using photoreconnaissance satellites for many years to monitor each other's military buildups, weapons testing and deployments. Other states may now do the same by purchasing detailed imagery "over the counter," courtesy of commercial observation satellites, thereby making it more difficult for any nation to hide military and even commercial activities. Conversely, if a state is aware of overhead observation by a foreign power, it could communicate quietly, but clearly, its aggressive intentions through imagery from those satellites.

Proliferation of Capabilities. Currently, virtually any state in the developing world can gain access to satellite data with military applications, because satellite imagery is commercially available. Imagery of ten to thirty meters is available directly from EOSAT, the operator of Landsat, and SPOT Image, the operator of SPOT. Thus, while the resolution quality may be poor by current U.S. military imagery standards, even states that lack the technology to build, or the funds to purchase their own satellites do have access to militarily useful satellite data. In addition, states such as Argentina, Brazil, South Africa, India, Pakistan, and Indonesia operate ground stations to receive SPOT and Landsat data on their territory. While imagery is supposed to be available on a non-discriminatory basis, states that operate ground stations have the ability to process data in a timely manner.

Presidential Directive (PD) 23, issued by President Clinton on March 10, 1994, encourages the U.S. private sector to develop and operate high-resolution imaging satellites. It also allows private companies to sell the imagery at, as of yet, an undetermined resolution. High-resolution imagery produced and sold by U.S. firms is expected to be available commercially within a few years. This decision follows a precedent set by the Russians who have been selling 2-meter resolution imagery to any government or individual for several years. France has announced that it will follow suit, but will limit its clients to allies and national governments. It is estimated that within the next twenty years, a significant number of other countries will acquire indigenous space-based imaging capabilities to enhance their military operations, such as Iraq, Brazil, India, Israel, Pakistan, Indonesia, Taiwan, South Korea, and South Africa.

Significantly, civilian systems can be used for military purposes, and as the resolution of civilian systems improves, they will prove ever more useful for military purposes. Several civilian satellites already have the capability to attain resolution of five meters or less if they were placed in the low-earth orbits (200 kilometers) of military reconnaissance satellites. Moreover, in combination with a communications satellite data and voice transmission capability, any nation can improve the connectivity between the national command and military commanders. In general, as such capabilities spread, efforts to undercut competitors by supplying more accurate, near-real time data at lower prices will grow.

While the resolutions of current commercial observation satellites do not provide imagery that is accurate enough to identify small ground units or individual aircraft, they can detect a number of militarily relevant objects. Consequently, reconnaissance and surveillance missions of interest to developing states could be accomplished using imagery from commercial satellites. Moreover, with sufficient funds, commercial-quality imagery can be improved by electronic enhancement and the use of trained imagery interpreters. As the resolution of commercially available imagery improves, processing times will decrease, thereby allowing more states with timely intelligence data.

As regional powers increase the use of satellite data as a means of supporting and enhancing military operations, they may also attempt to develop countermeasures against the space-based systems of their adversaries. Earth observation and reconnaissance satellites are particularly vulnerable to ground-based anti-satellite (ASAT) weapons because they are deployed in low-earth orbit (LEO). Future advancement in the development of sensors, computation and propulsion may place higher-altitude satellites at risk as well. Many states have ballistic missile programs which could provide the foundation for the development and deployment of ASAT weapons. While ASATs may require some sophisticated technology, several states (such as China, Israel, or India) may be capable of deploying ASATs within the next twenty years. These states not only enjoy advanced domestic technological capabilities, but they have access to sophisticated computer and tracking technology from the United States and Europe.

Implications for U.S. interests. In a world of satellite data proliferation, the ability of the United States to act independently and unquestioned may be severely undermined. In such a strategic environment, the potential use of intelligence by countries hostile to the United States to uncover U.S. military operations and activities also is of great concern. In the Persian Gulf War, coalition forces were able to deceive Iraqi troops and move one-hundred miles through the desert to outflank Iraqi defensive positions, a move that would likely have been impossible if Iraq had received images from its own observation satellite or from a U.S. adversary. In a future scenario, even a U.S. ally may be more inclined to share imagery, for financial reasons, with states that are antithetical to U.S. interests.

The creation of multiple sources of satellite information will ensure alternative sources of supply to regional powers at market prices. As a result, easy access to satellite imagery could reduce U.S. influence and flexibility in a crisis. Nonetheless, the acquisition of space capabilities is expected to be uneven and potentially regionally destabilizing. States with relatively sophisticated indigenous science, technology, and national space programs will be at an advantage vis-à-vis neighbors that lack the technology or resources to develop these assets.

Moreover, the availability of multiple sources of high-quality commercial satellite data could allow a "friendly" state to acquire imagery that would facilitate the planning of operations that the U.S. would prefer it not undertake. Regional powers may also be able to obtain observation data from commercial suppliers, confusing a distinction between belligerent and neutral states. Finally, the acquisition of ballistic missiles (regardless of how they are armed), space assets, and possibly antisatellite weapons by regional powers means that they are acquiring a military capability that will allow them to exert more control over future regional conflicts than is currently possible.

The Global Positioning System

Background. Two decades ago, the United States initiated work on a military satellite system intended to improve navigation of its ships, aircraft, and vehicles, and to target weapons more accurately on the battlefield. Although the system was developed by the Department of Defense, it was also expected to serve civilian needs. The resulting Global Positioning System (GPS) has revolutionized the way the world moves people and goods, and is affecting the global flow of information. Today, GPS is an essential element of the U.S. national security posture. It has been widely deployed in military units and systems, and is expected to become an integral part of all major weapons platforms (planes, ships, and land vehicles) over the next decade.

In the early stages of GPS development, military requirements drove the evolution of the satellite system. The commercial demand for GPS products and services now, however, overshadows military demand. GPS is user-passive and free. Its civil signal is unencrypted, making it readily available to anyone anywhere with a GPS receiver. Terminals permitting the use of highly accurate navigation satellite data are available worldwide at relatively low cost. Commercial applications and technologies are leading their military counterparts, and raising new concerns about the future of GPS. Worldwide revenue from GPS-related products and services, currently at $2 billion, is expected to exceed $30 billion annually by 2005.

Balancing the commercial advantages of widespread civilian access to reliable GPS positioning data and the national security interests, however has been a major concern. The notion that a military adversary could use GPS technology against the United States led the Department of Defense to separate military and civilian GPS signals and then intentionally to downgrade the latter using Selective Availability (SA) when it seemed more accurate than expected. (SA introduces intentional errors in timing and positioning data into the civilian GPS signal.) Civilian users responded to a forced decrease in accuracy by pushing the commercial development of differential GPS (DGPS), which can circumvent the effects of SA. As DGPS becomes more popular, the utility of SA eventually will likely be undermined.

Military thinking about GPS has focused on securing the precision military GPS signal through encryption and denial of a highly accurate civilian signal to potential adversaries through SA. Since most military receivers require acquisition of the civilian signal prior to gaining access to the more accurate military signal, jamming of the civilian signal can currently affect the military's access adversely.

Implications of the proliferation of GPS-related technology. Technological improvements are being made to the basic GPS system to provide higher levels of accuracy, integrity, and availability. As a result, GPS data will likely be used increasingly by civilians in the future, nationally as well as internationally. Foreign manufacturers and service providers interested in capturing these markets are urging their governments to demand U.S. assurance of continued GPS signal availability and for international participation in system management. Unease with reliance on a U.S. military-controlled system may give foreign governments an incentive to develop a competing global navigation system. The United States may need to consider establishing a governance and management framework capable of balancing the national goals set for GPS.

Use of GPS by foreign military forces may be expected to greatly increase in the near future. Foreign military use proceeded slowly until GPS demonstrated its utility in the Gulf War, although members of NATO signed a memorandum of understanding on the use of GPS as early as 1978. An updated agreement, signed in December 1993, permits all NATO allies to use the military Precise Positioning Service (PPS) signal. (PPS, known as the Y-code, is an encrypted code for authorized users of GPS data.) This agreement also allows NATO allies to purchase and manufacture PPS user equipment. Several non-NATO countries have also entered into formal agreements with DOD concerning use of PPS including Australia, Israel, Japan, New Zealand, and South Korea. Each of the agreements with the non-NATO countries differs in some ways, but all provide PPS access and decryption device procurement from the United States via the foreign military sales (FMS) program.

Current DOD planning for GPS is focused on three objectives: meeting the congressionally mandated deadline of 2000 to equip major military platforms with GPS; completing production and beginning launch of the new Block IIR generation of twenty-one satellites, already covered under an existing multi-year contract; and initiating acquisition of up to fifty-one follow-on Block IIF satellites. Improvements to increase the resistance to jamming of military GPS receivers are also under development in DOD. but decisions on proceeding with procurement have been deferred.

The commercial availability of data from the Global Positioning System (GPS) and Russian GLONASS navigation satellite networks have serious military implications, as such data could be used for aircraft and missile guidance, and for command and control purposes. Access to commercial GPS data may now allow commercial users of the differential GPS (DGPS) technique to determine locations to within five meters which can provide users a militarily significant targeting and guidance capability. In the long term, the availability of accurate positioning capabilities may pose an increased threat to U.S. and allied military interests and have a negative impact on strategic stability.

Potential risks. The increasing number of GPS applications within the armed forces of the United States and its allies greatly increases its importance and the dependence of those armed forces on the system. This dependence, in turn, increases the need for effective anti-jamming and anti-spoofing capabilities. The low power of both the military and the civilian signals make them highly vulnerable to line-of-sight jamming, even by low-power sources. Both technological and tactical options exist that can minimize this type of interference

The most immediate impetus to the proliferation of DGPS services is the civilian and commercial demand for greater accuracy that is intentionally denied to the civilian users through the imposition of SA. With the increasing expansion of wide-area differential systems, SA will not longer be effective in denying potential adversaries the accuracies inherent in GPS. Whatever deterrent effect SA currently has will rapidly disappear as differential systems proliferate. Over the long term, continued use of SA may be ineffective and could be counterproductive.

Considering the U.S. commercial interest in encouraging wider use of GPS, the United States might benefit from turning the SA to zero and deactivating it after a number of years. Improvements in the civilian signal that would result from turning SA to zero may, however, encourage potential adversaries to integrate this technology into major weapons systems. Foreign militaries might then have to be concerned that the United States could deny them the use of GPS in a wartime or crisis situation through jamming, encryption, and spoofing techniques.

Some analysts suggest that DOD keep the civil GPS signal free of a direct user charge and available to all. It may even be useful to broaden civil agency participation in GPS management. These ideas appear to reflect the realization that access to militarily accurate GPS data or competing satellite navigation systems will soon be a reality. Some suggest that a private company take over management of the civil signal as a service. Such a company would have to market an encrypted signal, and then restrict and control the use of the signal and charge a fee for it. But this would violate a basic doctrine of GPS operations that all system changes be "backward compatible." Greater private sector involvement might, however, improve system performance, economy, and efficiency.

Summary

The availability of commercial space-based imagery and accurate GPS data, in combination with the development of Third World missile and space programs and WMD proliferation, is creating new geopolitical relationships in which the United States may have reduced influence over its adversaries or even its allies. The spread of this technology has removed the political and military leverage that was inherent in the ability of the original space-powers to control the flow of satellite information and space technology. To ensure continued strategic stability, it may be essential for the United States to prepare now for a variety of scenarios resulting from the commercial availability of high-resolution satellite imagery and GPS positional and guidance information. The acquisition of missile and space capabilities and the use of GPS by regional powers antithetical to U.S. interests may alter both the strategic and tactical circumstances U.S. forces face when operating abroad. U.S. commercial and strategic policies that address responses, countermeasures, and safeguarding issues may eventually allow the United States to retain some influence and advantages in what promises to remain a changing strategic environment as access to space-based imagery and GPS data becomes more common.

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Stability Implications of Open-Market Availability of Space-Based Sensor and Navigation Information

Thursday, 9 November 1995
Science Applications International Corporation
1710 Goodridge Drive McLean, Virginia 22102: Tower 1, First Floor Conference Facility

AGENDA

0900	**Check-in** (Coffee and Pastry available)
0915	**Welcome, Purpose, Format** [Jim Reams, SAIC Seminar Program Chairman]
0920	**New Satellite Images for Sale: The Opportunities and Risks Ahead** [Dr. Vipin Gupta - Center for Security and Technology Studies, Lawrence Livermore National Laboratory]
0945	**Discussion**
1015	**Break**
1030	**Strategic Stability and Space Control: Lessons from Desert Storm** [Steven Lambakis - National Security Research Inc.]
1055	**Discussion**
1130	**Space-Based Sensor and Navigation Information: Capabilities, Availability, Motivation, and Future Implications** [Wilson Cook - Deputy National Intelligence Officer for Science and Technology, National Intelligence Council]
1155	**Discussion**
1225	**Roundtable Discussion: Stability Implications of Open-Market Availability of Space-Based Sensor and Navigation Information**
1300	**Wrap-up**

ACDA Seminar on the Stability Implications of Open-Market Availability of Space-Based Sensor and Navigation Information
Thursday, 9 November 1995
Tower 1, Conference Room B/C

Attendees

Mr. C. Frederick Horr
Hughes Aircraft Co.

Mr. James Linder
NSR Inc.

Ambassador James Sweeney
ACDA

Mr. Allen Lewis
Lockheed Martin

Ms. Joy Speicher
TRW

Mr. Jeffrey Richelson
Author

Ms. Susan Oliver
CIA/ACIS

Mr. Mark Bitterman
Orbital Sciences

Dr. Steve Lambakis
NSR Inc.

Ms. Marjorie Robertson
SAIC

Mr. James Reams
SAIC

Mr. John Ball
Department of Commerce

Dr. Edward Lacey
ACDA/IVI

Mr. Joseph Maccone
CIA

Mr. Nasir Khan
NSR Inc.

Dr. Richard Speier
Consultant

Mr. Bruce Berkowitz
Consultant

Mr. Terry Schilling
Orbital Sciences

Mr. Wilson Cook
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Mr. Raffi Gregorian
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Mr. Allen Thomson
SAIC

Dr. Scott Pace
RAND

Dr. Fred Giessler
NDU

Dr. Gary Stradling
OSD/A&T(CCI&C)

Colonel Gilbert Siegert
USAPACECOM

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Ms. Julia Kortum
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Dr. George Pitman
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Mr. Gene Madding
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Ms. Mary Engebreth
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Mr. Art Grant
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Dr. Vipin Gupta
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Mr. Thomas Marshall
SAIC

Ms. Terri Westerfeldt
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Mr. Scott Carlson
SAIC

New Satellite Images for Sale

Vipin Gupta

Satellite remote sensing began as a tool of the Cold War. With the mutual desire to monitor and target each other, the United States and the Soviet Union designed remote sensing satellites that would overfly each other's national airspace and acquire high-resolution images (less than 5 meters GSD) of each other's territory.[1] Developed in the 1950s and deployed in the 1960s, U.S. and Soviet spy satellites quickly became a unique classified source of militarily useful information.

As satellite imaging for the U.S. and Soviet classified domains advanced during the 1970s and 1980s, satellite remote sensing slowly began to emerge in another arena—the commercial market. The emergence of a commercial market began with NASA's deployment of Landsat-1 in 1972 and Landsat-2 in 1975. These two satellites carried multispectral sensors that acquired low-resolution images (80 meter GSD) of the earth's surface. Given that these sensors could not generally detect objects smaller than a football field, the images were principally used by academic institutions, multinational companies, and national governments for large-scale civil applications such as environmental monitoring and resource management.

During the 1980s, the U.S. and French governments constructed and deployed more advanced remote sensing satellites for the commercial market. The primary U.S. contribution consisted of Landsat-4 (1982) and Landsat-5 (1984); each carried multispectral sensors that acquired more detailed images (30 meter GSD) of the earth's surface. France launched SPOT-1 in 1986 and

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1. Like Georges Seurat's pointillist paintings, a digital image consists of many square dots or "pixels." For this article, a high-resolution image is defined as a digital picture where the length and width of each pixel represents a ground distance of less than five meters. The ground extent of the pixel is expressed in terms of GSD—ground sample distance (in meters). Images captured on film are described at an equivalent GSD. See Peter Zimmerman, "A New Resource for Arms Control," *New Scientist*, Vol. 123, No. 1683 (September 23, 1989), p. 40; M.R.B. Forshaw, A. Haskell, P.F. Miller, D.J. Stanley, and J.R.G. Townshend, "Spatial Resolution of Remotely Sensed Imagery: A Review Paper," *International Journal of Remote Sensing*, Vol. 4, No. 3 (1983), pp. 497–520.

International Security, Vol. 20, No. 1 (Summer 1995), pp. 94–125

SPOT-2 in 1990, placing a 20-meter GSD multispectral sensor and a 10-meter GSD panchromatic sensor on each satellite.[2] These four satellites became the principal source of imagery for civil applications as well as a new source of information for surveillance and defense mapping.

Commercial satellite remote sensing is now expanding into a new area that encroaches on the classified domain—high-resolution imagery. Examples are shown in Figures 1 and 2. While such images were once controlled solely by the U.S. and Soviet governments, the end of the Cold War effectively removed the superpowers' rationale for keeping high-resolution satellite imaging to themselves. The subsequent decline in defense budgets has also created economic incentives within private industry and government in Russia and the United States to sell high-resolution satellite imagery for profit to the many states, institutions, and individuals who have been denied access to this source of information. Remote sensing companies that developed imaging technologies for classified use have already begun using their know-how to build and operate new satellites that will provide high-resolution imagery to the commercial market.

If the security implications associated with the proliferation of high-resolution imagery are to be addressed, it will need to be done before the deployment of new high-resolution imaging satellites over the next few years. Given that this imaging capability was originally developed for U.S. and Soviet defense planning and intelligence gathering, it is important to consider what security impact high-resolution imaging will have when it is used by an expanded group of states and political entities for similar purposes.

This article addresses several technical and political questions to determine the security benefits and costs associated with this new remote sensing enterprise: What will be the technical capabilities of the high-resolution imaging satellites under development? What kinds of imaging satellites would be most suitable for defense planning and intelligence gathering? How could commercial high-resolution imaging be used to enhance national, regional, and international security? What detrimental consequences could result from the use of this technology? And finally, what conditions, if any, should be placed on the export of high-resolution imagery?

2. A multispectral sensor acquires a separate image of the viewed area for each narrow wavelength band of light it is designed to detect. A panchromatic sensor acquires a single image of the viewed area by collecting light over a wide wavelength band.

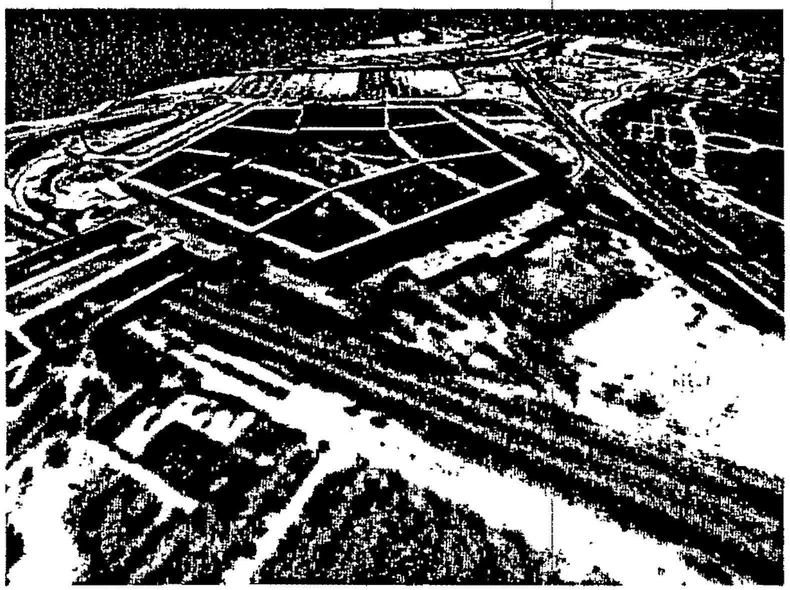

Figure 1. Russian KVR-1000 image of the Pentagon, rendered as a perspective view (image provided courtesy of SPOT Image Corporation; processing by Planetary Visions/University College, London).

Since the supply of high-resolution images to the commercial market will not be fully realized for another year or two, there is still time to answer these important questions and implement policies at the corporate, national, and multilateral levels that address the security aspects of this new competition. If image suppliers and buyers are subject to such policies, commercial high-resolution imaging could, on the whole, act as a stabilizing factor within interstate politics.

After providing the necessary policy background on the sale of high-resolution images, this article briefly describes the technical capabilities and deployment schedules of the competing commercial high-resolution imaging satellites. It then compares the capabilities of these satellites with the prospective customers' technical and operational demands for defense planning and intelligence gathering. Following the technical review, the article describes the

Figure 2. Russian KVR-1000 image of the Shirley Highway, Washington, D.C. (image provided courtesy of SPOT Image Corporation; processing by Planetary Visions/University College, London).

opportunities and security risks associated with the sale of high-resolution imagery. It concludes with an assessment of future trends, and a series of recommendations for maximizing the opportunities for enhancing national, regional, and international security while minimizing the risks.

Policy Developments in the Sale of High-Resolution Satellite Images

Three states have dominated the debate over the wisdom of selling high-resolution satellite images: Russia, the United States, and France. The outcome of this debate in each of these states has shaped not only its own remote sensing policies, but also each other's remote sensing policies. Each of these states has taken a distinct position on the sale of high-resolution imagery. Israel has not yet devised an official national policy, but is considering deployment of a commercial high-resolution imaging satellite.

RUSSIA

Russia officially inaugurated the sale of high-resolution satellite imagery in early 1992 by allowing two Russian firms—Sovinformsputnik and Priroda—to sell 2-meter GSD images. The images were acquired by a camera designated KVR-1000, designed and used by the Russian intelligence community.[3] The commercial availability of KVR-1000 data established Russia as the sole global source of high-resolution satellite imagery and paved the way for future international competition in this area.

However, while Russia is presently the leader of the pack, its policy on the sale of high-resolution imagery has not been operationally coherent because of conflicts between intelligence and commerce. Although images have reached the public domain, requests for lists of available images and image orders have been denied, delayed, and canceled in the name of national secrecy.[4] The difficulties have been particularly acute for inquiries on images acquired before 1992, when the former Soviet intelligence community was the exclusive customer.

Russia's schizophrenic policy on high-resolution imagery has hurt its sales and provided a degree of comfort to the developing competition. Nonetheless, Russia remains committed to the export of high-resolution imagery. KVR-1000 distributors in the United States assert that Russia is prepared to permit the sale of better than 2-meter GSD images in the future if comparable data becomes available from other commercial sources.[5] Whether Russia eventually allows the sale of such imagery from their more advanced imaging satellites will depend largely on U.S. policy developments on this issue.

THE UNITED STATES

The United States became a key player in the commercial sale of high-resolution imagery on March 10, 1994. On that day, President Clinton issued Presidential Directive (PD) 23, a new policy that encouraged the U.S. private sector to develop and operate high-resolution imaging satellites as well as sell the acquired data. The rationale for the new policy was principally economic: "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."[6] The policy stems from a recognition of projected growth in the remote sensing market and an appreciation for U.S. technological strength in high-resolution imaging from space.

The Department of Commerce licenses U.S. companies to construct and operate private remote sensing satellites. Applications for proposed systems with technical capabilities that are presently available or expected in the international market are "favorably considered." To account for national security concerns, the new U.S. policy contains a series of conditions that allow the government to oversee and restrict the operation of licensed remote sensing systems. U.S. companies are required to account for all images that were acquired over the previous year and allow the U.S. government access to the list of acquired images; use only data encryption devices approved by the U.S. government; select a downlink data format that can be accessed and used by the U.S. government; and notify the U.S. government of the intent to enter "significant or substantial" accords with new foreign customers.

If a situation arises where the operation of a private remote sensing system is deemed to jeopardize national security, international obligations, or foreign policies, the Secretary of Commerce, in consultation with the Secretaries of State and Defense, has the authority to limit data collection and distribution for as long as necessary. During wartime, these rules could permit priority U.S. government use of the private remote sensing systems.

As no high-resolution imaging satellites have been deployed since this policy was declared, the practicality of the regulations remains unknown. The line has yet to be drawn distinguishing acceptable from unacceptable private remote sensing systems, and between acceptable and unacceptable foreign customers. All options have been kept open—including the possibility of exporting complete remote sensing systems to other states.

FRANCE

With the successful operation of its SPOT satellites and the planned deployment of its first military intelligence satellite—Helios-1—in mid-1995, France

3. Priroda also sells 2-meter GSD images acquired by the KFA-3000 camera. The KFA-3000 archive is significantly smaller than the KVR-1000 archive.
4. The author's attempts to obtain KVR-1000 images of nuclear facilities near Yongbyon in North Korea, the city of Sarajevo, and the Chinese nuclear test site near Lop Nor all failed on the grounds of national secrecy. Bureaucracy also hampered the process. For an anecdotal account of the search for KVR-1000 data, see Vipin Gupta and Philip McNab, "Sleuthing From Home," *Bulletin of the Atomic Scientists*, Vol. 49, No. 10 (December 1993), pp. 44–47.
5. Ben Iannotta, "Russia Expected to Raise Ante in Satellite Image Market," *Space News*, Vol. 5, No. 16 (April 18–24, 1994), p. 18.

6. U.S. White House, "Fact Sheet on U.S. Policy on Foreign Access to Remote Sensing Space Capabilities," March 10, 1994, p. 1.

has emerged as the third influential actor in commercial high-resolution imaging. Initially the leading opponent to U.S. PD 23, the French government slowly changed its position during spring 1995 to one that was more favorable to the sale of high-resolution images. However, instead of focusing on the sale of the imagery as emphasized in the U.S. and Russian policies, France has decided to focus on the selective export of the imaging satellites themselves.[7]

While still opposed to the emplacement of high-resolution sensors on follow-on SPOT satellites or the limited commercial distribution of Helios-1 images, the French government is prepared to sell satellites like Helios-1 to friendly governments, provided France retains the option to shut down the satellite during a national emergency or international crisis.[8] Reaffirming the position that satellite images at less than 5 meter resolution are principally useful for military applications, the French government asserts that satellite sales should be confined to the defense and intelligence apparatus of a friendly state with the assurance that the collected information will be classified.

Like the U.S. policy on high-resolution imaging, the new French policy remains untested. It is not clear which states are considered by the French government to be friendly enough to be allowed to buy a fully functional satellite system.[9] It is also not certain whether France is offering interested states a regional imaging capability or a global imaging capability. French restrictions on the prospective clientele and the technical capabilities of exported satellites will ultimately determine France's ability to compete against U.S. and Russian suppliers of high-resolution images.

The Satellites

Russia's KVR-1000 system is presently the only commercial source of high-resolution satellite images (less than 5 meter GSD). Six new commercial satellites with high-resolution sensors on-board are scheduled for deployment by companies in Russia, the United States, and Israel over the next few years. This

7. Peter B. de Selding, "Spy Satellites for Sale: French Will Bar Commercial Use of Imagery," *Space News*, Vol. 6, No. 10 (March 13–19, 1995), p. 1.
8. Helios-1 has reportedly been designed to acquire images at approximately one meter GSD. The satellite usage will be shared with the two smaller partners of the Helios program, Italy and Spain. Bhupendra Jasani and Christer Larsson, "Security Implications of Remote Sensing," *Space Policy*, Vol. 4, No. 1 (February 1988), p. 48.
9. While no specific client states have been mentioned, one can reasonably deduce that France will only consider the export of a spy satellite to states that have been trusted recipients of French arms sales in the past.

section describes each satellite (see Table 1) in chronological order of the scheduled launch dates.

KVR-1000

Russia's KVR-1000 satellite dates back to 1984. Designed with the minimal technology needed to perform its imaging mission, the satellite is launched into a low orbit of 200 km so that the sensor can get as close a look at the ground as possible. Images are acquired on photographic film, which is delivered back to Earth inside the satellite reentry vehicle.[10] The mission duration is limited to a several-week period due to limits on the amount of film and of fuel for counteracting atmospheric drag effects. At the end of the operation, the satellite reenters the atmosphere and much of the hardware is recovered and reused.

As shown in Table 1, key technical capabilities of the camera system such as the total field of view and the revisit period are not publicly known, nor are significant operational characteristics such as the compilation of the priority acquisition list, the programming of the camera, the production of the final image products, and the retrieval of archived images. Consequently, KVR-1000 users cannot accurately forecast the amount of time required to fulfill an image order.[11]

Nonetheless, the images do contain more spatial detail than any other satellite image on the market today. The spatial detail within the images is good enough to describe and analyze man-made structures as well as to detect physical changes over periods of months or years. Although KVR-1000 does not have many of the technical capabilities currently under development by the foreign competition, it may serve as a useful archive of high-resolution images.[12]

EROS

EROS, the Earth Resource Observation Satellite, was a classified military reconnaissance program of the Israeli Defense Force (IDF) that has been transformed

10. There may also be a capability to scan the film product on-board the satellite and download the image to a ground station electronically. However, if such a capability exists, it is not available on a commercial basis.
11. At the present time, orders for archived images can take several weeks or months to fulfill, and images may be acquired six months to one year after the request was made.
12. By 1996, users will also have access to archives of high-resolution images acquired by retired U.S. classified remote sensing satellites. This archive will consist of images that were acquired between 1960 and 1972 by the ARGON, CORONA, and LANYARD systems. See http://edcwww.cr.usgs.gov/dclass/dclass.html.

Table 1. Technical Capabilities of Commercial High-Resolution Sensors for Existing and Planned Satellites.

High Resolution Sensors	Ground Sample Distance[a]	Spectral Range[b]	Maximum Viewing Angle[c]	Scan Line Width[d]	Max. Area Coverage over a Single Pass[e]	Photo-grammetric Accuracy[f]	Orbital Altitude[g]	Orbital Inclination[h]	Revisit Period at Equatorial Latitudes[i]	Digital Storage Capacity[j]
KVR-1000 camera	<2 m	0.49–0.59 µm	—	NA (40 x 40 km image)	—	—	200 km	60°	—	NA
EROS-1 panchromatic sensor	1.8 m	0.50–0.90 µm	30°	11 km	605 sq km	<800 m	480 km	97.4°	3 days	None
EROS-2 panchromatic sensor	1 m	0.50–0.90 µm	30°	15 km	605 sq km	<800 m	480 km	97.4°	3 days	—
EarlyBird panchromatic sensor	3 m	0.45–0.80 µm	30°	NA (four 3 x 3 km images)	1,800 sq km	40–50 m	470 km	97.3°	4.75 days	2 Gbytes
QuickBird panchromatic sensor	1 m	0.45–0.90 µm	30°	10–20 km	15,000 sq km	<20 m	470 km	97.3°	4.75 days	33 Gbytes
QuickBird multispectral sensor	4 m	Visible and near IR	30°	10–20 km	15,000 sq km	<20 m	470 km	97.3°	4.75 days	33 Gbytes
OrbView panchromatic sensor	1 m	0.50–0.90 µm	45°	4 km	8,000 sq km	10–14 m	460 km	97.3°	3 days	32 Gbytes
OrbView panchromatic sensor	2 m	0.50–0.90 µm	45°	8 km	16,000 sq km	10–14 m	460 km	97.3°	3 days	32 Gbytes
SIS panchromatic sensor	1 m	0.50–0.90 µm	30°	11 km	20,000 sq km	10–14 m	680 km	98.1°	2 days	<6 Gbytes
SIS multispectral sensor	4 m	Visible and near IR	30°	11 km	20,000 sq km	10–14 m	680 km	98.1°	2 days	<6 Gbytes

NA – Not Applicable

[a] The imaging sensor consists of a linear or 2-D array of pixels (square dots). Projected straight down, each pixel covers a square ground area. The ground sample distance (GSD) is the length of the square in meters. The size of the GSD is a key factor in the amount of spatial detail in an image.

[b] Imaging sensors are designed to be sensitive to light at particular wavelengths. The spectral range specifies the wavelengths (in microns) that can be "seen" by the sensor.

[c] Sensors can be tilted to view areas obliquely. The viewing angle is a measure of the tilt with respect to nadir (straight down). If the sensor is pointing straight down, the viewing angle is 0°. If the sensor is pointing straight ahead (a "cockpit's view"), the viewing angle is 90°.

[d] Scan line width is a technical parameter for a pushbroom sensor. A pushbroom sensor consists of a linear array of charge-coupled devices (CCDs). The two-dimensional image is acquired through the motion of the satellite relative to the ground, in a manner that is analogous to the track of a pushbroom across a floor. The scan line width defines the ground distance (in kilometers) that falls within the sensor sweep.

[e] This parameter specifies the maximum rectangular ground area that can be imaged as the satellite passes over a specific target.

[f] This parameter specifies the error in the measurement of geographic locations from a stereo pair of images without using ground reference points as locator aids. A stereo pair consists of two images of the same scene acquired at different viewing angles. A stereo pair is used to view scenes in 3-D and measure the height of imaged features.

[g] The satellite's distance from the Earth's surface. All of the sensors listed in Table 1 will be placed in circular orbits.

[h] The angle between the equatorial plane and the orbital plane. A satellite that flies only over the equator has a 0° inclination. A satellite that flys directly over the North and South Poles has a 90° inclination. A satellite at a 97°–98° inclination is in a sun-synchronous orbit, which allows a remote sensing satellite to image areas between 82° N and 82° S and view the Earth below at the same local time of day. All of the new satellites will be in sun-synchronous orbits.

[i] The revisit period is the minimum time that must elapse before a single imaging satellite can review a specific geographic point. It decreases at higher latitudes. At the North and South Pole, the revisit period is approximately the orbit period (about 90 minutes for a satellite in low earth orbit).

[j] The amount of data in Gigabytes that can be stored on the solid-state recorders.

into a commercial venture. Built by Israel Aircraft Industries (IAI), the satellite has been pitched for environmental monitoring and land management. However, its most marketable feature remains the application it was originally designed for—intelligence gathering.

If the launch takes place as planned, EROS-1 will be the first challenger for KVR-1000. EROS-1 is scheduled for deployment in the late summer or early fall of 1995, followed by EROS-2 in early 1997. Both have been designed to operate for four years. EROS-1 will carry a 20-meter GSD panchromatic sensor and a 1.8-meter GSD panchromatic sensor. EROS-2 will carry a 1-meter GSD panchromatic sensor and possibly a 1.5-meter GSD multispectral sensor. All of the EROS sensors will function in a "pushbroom mode."

EROS operations will be divided into 7–8 distinct geographic zones all over the world. One ground receiving station will be centered in each 2,000-km radius zone. Prospective EROS customers (e.g., states, companies, individuals) will be able to purchase the right to task up to 50 percent of the satellite's imaging capacity within a zone, receive the images directly from the satellite, and use the acquired imagery confidentially. The remaining capacity of the satellite will be sold to image buyers worldwide on a first come–first served basis. Images acquired for these "walk-in" customers will be archived and made available to other customers.

If customers seek 100 percent control of EROS within a geographic region, IAI is prepared to consider the launch of additional EROS systems that would be dedicated to customers on an exclusive basis. IAI would perform the necessary housekeeping to keep the satellite functional, and the clients would confidentially uplink their image acquisition requests to the satellite as it passed overhead.

EARLYBIRD AND QUICKBIRD

The U.S. firm EarthWatch has set out to develop, deploy, and operate two types of advanced remote sensing satellites: EarlyBird and QuickBird. EarlyBird is scheduled for launch in early 1996, QuickBird in early to mid-1997.[13]

Designed to operate for five years, EarlyBird will carry a 15-meter GSD multispectral sensor and a 3-meter GSD panchromatic sensor. The high-resolution sensor will consist of a two-dimensional array of charge-coupled devices (CCDs) designed to acquire images of the ground at one instant in time, the

13. Two EarlyBirds and two QuickBirds will be constructed, one of each for backup in case of a technical mishap or increased demand.

same way an ordinary camera records an image onto film with one click. One high-resolution image will cover 36 square kilometers. Although this is a relatively small field of view, the sensor can acquire an image of up to 1,800 square kilometers by acquiring a series of connecting 36-square-kilometer images as the satellite passes overhead. The sensor can also be tilted to acquire a series of stereo pairs in one orbital pass.

QuickBird will be placed in an orbit similar to EarlyBird (see Table 1), but it will carry more advanced sensors on-board, including a 4-meter GSD multispectral sensor and a 1-meter GSD panchromatic sensor. Both sensors will operate in a pushbroom mode and be capable of acquiring images over vast areas—up to 15,000 sq. km in a single flyover. A 33-Gigabyte solid-state recorder will serve as the temporary repository of the massive image datasets.

The operation of EarlyBird and QuickBird will be centralized. EarthWatch will maintain the satellites and compile the priority acquisition list. Requests for image acquisitions will be handled on a first come–first served basis, with a rush acquisition service on offer as well as options for the imaging of specific geographic locations at regular intervals. The satellites' operations will rely heavily on on-board data storage. The data will be downloaded from the solid-state recorder when the satellite comes within line of sight of the ground station in Alaska, northern Europe, or the continental United States.[14] Customers will be able to obtain recently acquired and archived data in near real-time via the Internet. In principle, customers may be able to receive images within hours of acquisition.

ORBVIEW

The OrbView satellite design debuted in May 1995 shortly after the establishment of a new U.S. company, Orbital Imaging. Designed to operate for 3 years, OrbView is scheduled for launch in mid-1997. It will carry a 1-meter GSD panchromatic sensor, a 2-meter GSD panchromatic sensor, and an 8-meter GSD multispectral sensor. The satellite will have an oblique imaging capability to reduce the revisit period and acquire stereo images. This imaging capability can also be used to acquire images of vast areas (8,000–16,000 sq. km) by scanning the sensor back and forth during the flyover.

14. The Alaskan and European ground stations will be situated at high northern latitudes and thus will be able to communicate with EarlyBird and QuickBird on virtually every orbit (i.e., every 95 minutes). One of these ground stations will be transportable.

Orbital Imaging will maintain the satellite, program the sensors for image acquisitions, and archive digital copies of all OrbView images. Distributors—foreign firms run or regulated by governments—will receive the imagery directly from the satellite, send digital copies to Orbital Imaging, sell the data on an exclusive basis, and assemble the satellite tasking list for their region or state. The area of jurisdiction for the foreign distributors can be as large as the ground station footprint (2,130 km radius) or as small as the political boundaries of a specific state.[15] While intended to avoid many possible acquisition conflicts between different customers, the division of the globe into exclusive regional and national zones is likely to put pressure on regional adversaries and economic competitors to conclude an agreement with Orbital Imaging quickly.

For example, by locking in an exclusive regional agreement at an early date, a country could use OrbView to monitor its neighbors, while denying its neighbors the ability to use OrbView to monitor it.[16] If it failed to purchase such an agreement, one of its neighbors could do so, thereby denying the country the option of using OrbView to monitor its neighbors. Alternatively, a country could take a "defensive" approach by securing an exclusive national agreement covering its territory. It could then use OrbView to image itself and deny its neighbors access to OrbView images of it. Or each neighboring state could obtain a national agreement for its respective territory, thereby denying a country the ability to monitor its neighbors.

SPACE IMAGING SATELLITE (SIS)

Space Imaging was formed in June 1994 by the Lockheed Missile and Space Company, in partnership with other firms such as E-Systems and Mitsubishi,

15. The ground station footprint is an approximately circular ground area where the satellite is within line of sight of the ground station. The footprint size is limited by the Earth's curvature and increases at greater orbital altitudes.
16. For commercial remote sensing systems operated by U.S. companies, a state must have access to acquired images of itself under "reasonable terms and conditions" even if it does not have the contractual right to use the commercial imaging satellite. This is a condition of operation under Section 202b, clause 2 of the 1992 Land Remote Sensing Policy Act (Public Law 102–555). This condition is also consistent with Principle XII of the 1987 UN General Assembly Resolution of Principles Relating to Remote Sensing of the Earth from Space. With respect to the hypothetical example, neighbors of a given country would be entitled to OrbView images of their own territory that were requested and received by that country. If it failed to make this data available under reasonable terms and conditions, Orbital Imaging would provide the images from its central archives.

to create the Space Imaging Satellite (SIS), a high-resolution imaging satellite with a design lifetime of at least 7 years. As shown in Table 1, SIS-1 will have many technical features that will compete directly with EROS-2, QuickBird, and OrbView. SIS-1 is scheduled for deployment in mid- to late 1997 at approximately the same time as the competing systems. A second SIS will be constructed as a spare in case SIS-1 breaks down prematurely or in case an additional system is needed to meet market demand.

The operation of SIS will be delegated to regional affiliates run by foreign firms or government agencies. These affiliates will control sensor tasking, data reception, distribution, and archiving. In contrast with the planned operation of the competing satellites, they will also have the capability to upload the acquisition schedule directly to the satellite.[17] As a result, the area of jurisdiction for each affiliate is likely to cover the entire ground station footprint. The SIS system architecture offers greater autonomy to its regional affiliates. By eliminating the middleman to program the satellite, they will have more control over the efficiency of the tasking process and greater authority to handle image acquisition conflicts between customers within the region.

The Buyers

Since the 1980s, U.S. and foreign governments have routinely used commercial satellite images for defense planning and intelligence gathering.[18] The future availability of high-resolution images from the next generation of commercial satellites will open up a myriad of intelligence applications that could not be fulfilled by existing satellites such as SPOT and Landsat.

From the buyer's perspective, certain technical and operational capabilities are needed for defense planning and intelligence gathering. The technical requirements match the capabilities that will be available in the near future: high spatial resolution, oblique imaging in any direction, and multiple image acquisitions during a single orbital pass. The operational needs—control of the

17. Space Imaging will perform all necessary housekeeping tasks and will be able to supersede all commands from the affiliates.
18. See Jeffrey T. Richelson, "Implications for Nations Without Space-Based Intelligence-Collection Capabilities," in Michael Krepon, Peter Zimmerman, Leonard Spector, and Mary Umberger, eds., *Commercial Observation Satellites and International Security* (New York: St. Martin's, 1990), pp. 55–73; Peter Zimmerman, "The Uses of SPOT for Intelligence Collection: A Quantitative Assessment," in ibid., pp. 74–77.

satellite, real-time data transmission, and large geographic jurisdictions—are likely to be fulfilled in part for those buyers who are able to enter exclusive arrangements with suppliers.

TECHNICAL DEMANDS

Although high-resolution imaging is, in itself, insufficient for making a remote sensing satellite usable for intelligence purposes, it is required for the detection, identification, and description of various objects and activities. Table 2 gives a conservative estimate of the ground resolution thresholds for interpreting various targets.[19] The GSD of the proposed new systems (see Table 1) can be compared with these values to obtain a rough estimate of the utility of these sensors. Prospective buyers are likely to be most attracted to the 1-meter GSD sensors, as these systems have the potential to detect, identify, and occasionally describe in detail objects of intelligence value.[20]

In addition to images with high spatial detail, intelligence applications require sensors that can image sites at various viewing angles. Imaging to the left and right of the satellite significantly decreases the satellite's revisit period. Such oblique imaging can also be used to acquire stereo pairs. It is preferable to acquire a stereo pair in a single orbital pass through fore and aft viewing. This way, the time gap between the two image acquisitions is minimized to a few tens of seconds, increasing the likelihood that the objects of interest will be captured in both images.[21]

Any mismatches within the stereo pair due to the rapid movement of viewed objects could be used by analysts to make deductions about the level and significance of the observed activity. Detection of rapid motion could be carried one step further through the acquisition of multiple images of the same site in one orbital pass and then the creation of time-lapse movies. All of the new satellites could be used to acquire such image sequences.

19. Whether an object within an image can be seen and analyzed depends on not only the sensor capabilities, but also the scene characteristics (e.g., visibility conditions, ground contrast, object shape and orientation). If the scene characteristics are favorable to overhead observation, objects can be detected and identified at coarser resolutions than those listed in Table 2. See Peter Zimmerman, "Introduction to Section on the Photo-Interpretation of Commercial Observation-Satellite Imagery," in ibid., p. 204.
20. In addition, the multispectral capability can be used to discriminate man-made objects from natural ones by adding color to the image.
21. If the stereo pair is obtained through starboard and port viewing, the time gap between the two image acquisitions would be at least a few days. For areas obscured by clouds over most of the year, the time gap could be several months, during which the scene is likely to change dramatically.

Table 2. Approximate Ground Resolution in Meters at Which Target Can Be Detected, Identified, Described, or Analyzed.

Target	Detection[a]	General ID[b]	Precise ID[c]	Description[d]	Technical Analysis[e]
Bridges	6	4.5	1.5	1	.3
Communications					
Radar	3	1	.3	.15	.015
Radio	3	1.5	.3	.15	.015
Supply Dumps	1.5–3	.6	.3	.03	.03
Troop Units (in bivouac or on road)	6	2	1.2	.3	.15
Airfield Facilities	6	4.5	3	.3	.15
Rockets and Artillery	1	.6	.15	.05	.045
Aircraft	4.5	1.5	1	.15	.045
Command and Control Headquarters	3	1.5	1	.15	.09
Missile Sites (SSM/SAM)	3	1.5	.6	.3	.045
Surface Ships	7.5–15	4.5	.6	.3	.045
Nuclear Weapons Components	2.5	1.5	.3	.03	.015
Vehicles	1.5	.6	.3	.06	.045
Minefields	3–9	6	1	.03	—
Ports and Harbors	30	15	6	3	.3
Coasts, Landing Beaches	15–30	4.5	3	1.5	.15
Railroad Yards & Shops	15–30	15	6	1.5	.4
Roads	6–9	6	1.8	.6	.4
Urban Areas	60	30	3	3	.75
Terrain	—	90	4.5	1.5	.75
Surface Submarines	7.5–30	4.5–6	1.5	1	.03

SOURCE: Senate Committee on Commerce, Science, and Transportation, NASA Authorization for fiscal year 1978, pp. 1642–1643; and *Reconnaissance Hand Book* (McDonnell-Douglas Corporation, 1982), p. 125. Table from Ann M. Florini, "The Opening Skies: Third Party Imaging Satellites and U.S. Security," *International Security*, Vol. 13, No. 2 (Fall 1988), pp. 91–123.
[a] Location of a class of units, objects, or activity of military interest.
[b] Determination of general target type.
[c] Discrimination within target type.
[d] Size/dimension, configuration/layout, components construction, equipment count, etc.
[e] Detailed analysis of specific equipment.

OPERATIONAL DEMANDS

For intelligence applications, customer demands revolve around control: the authority to task the satellite privately, receive the images confidentially in real-time, and use the data exclusively. Like any other hardware of military significance, buyers seek virtual possession of imaging satellites. However, considering how the supply side of the market has evolved, buyers will not be allowed to operate remote sensing satellites directly, as with terrestrial military systems—at least not initially. The first wave of commercial high-resolution imaging satellites will all be subject to monitoring and intervention by the supplying company as well as its national government. Both the company and the government will be able to monitor the satellite tasking schedule, delay data reception from the satellite, and even revoke use of the system.

Buyers are likely to have a strong security incentive to purchase whatever remote sensing services become available. Even though buyers could be subject to deliberate disruptions beyond their control, the satellites and ground receiving stations would provide them with a greater capability than they have ever had. Furthermore, they will have an interest in denying their adversaries the option of purchasing remote sensing capabilities from the same supplier.

As the high-resolution image market develops, buyers could generate demand for the export of remote sensing satellites that would operate under their complete control. Such satellites could operate behind the same veil of secrecy that covers classified reconnaissance systems. While the export could still be subject to conditions of usage (e.g., only for defensive purposes), the conditions would not be readily enforceable. The prospects for the sale of the satellites will ultimately depend on whether national governments see such a development as an economic opportunity as well as a useful foreign policy instrument.

The Opportunities

There have been numerous articles on how commercial remote sensing satellites can be used as a tool to implement arms control, manage crises, and complicate adventurist military plans.[22] These articles evaluate the utility of existing commercial satellites such as SPOT and Landsat, and abstractly consider the value of more advanced systems. With the known technical capabilities of the commercial remote sensing satellites under development, the application of this technology to security issues can be addressed in greater

22. Susan B. Chodakewitz and Louis J. Levy, "Implications for Cross-Border Conflict," in Krepon, Zimmerman, Spector, and Umberger, *Commercial Observation Satellites and International Security*, pp. 90–103; Hugh De Santis, "Commercial Observation Satellites, Alliance Relations, and the Developing World," in ibid., pp. 78–79; Ann M. Florini, "The Opening Skies: Third Party Imaging Satellites and U.S. Security," *International Security*, Vol. 13, No. 2 (Fall 1988), pp. 91–123; Vipin Gupta, "Sensing the Threat—Remote Monitoring Technologies," in Stephen P. Cohen, ed., *Nuclear Proliferation in South Asia: The Prospects for Arms Control* (Boulder: Westview, 1991), pp. 225–264; Bhupendra Jasani and Christer Larsson, "Remote Sensing, Arms Control, and Crisis Observation," *International Journal of Imaging, Remote Sensing, and Integrated Geographical Systems*, Vol. 1, No. 1 (1987), pp. 31–41; Michael Krepon, "The New Hierarchy in Space," in Krepon, Zimmerman, Spector, and Umberger, *Commercial Observation Satellites and International Security*, pp. 16–32; Leonard Spector, "Monitoring Nuclear Proliferation," in ibid., pp. 125–141.

detail. High-resolution satellite imagery can be used for three general applications: verification, threat assessment, and peacekeeping.[23]

VERIFICATION

Since the late 1980s, two trends have developed in the arena of arms control and confidence building. First, the global powers—particularly the United States—have encouraged regional security initiatives in areas such as the Middle East and South Asia, while states such as Argentina, Brazil, and South Africa have undertaken their own security initiatives. Second, multilateral forums have concluded two major agreements in the past few years—the Conventional Forces in Europe (CFE) Treaty and the Chemical Weapons Convention—and negotiations are under way on a comprehensive nuclear weapons test ban.

These trends have involved a greater number of states in the verification of treaty compliance and are likely to generate greater demand for verification from national governments. Many of these states lack advanced national technical means (NTM), yet they are likely to have verification requirements that are as technically demanding as any ever accepted by the United States and the former Soviet Union in their arms control accords.

Satellite imaging has a long tradition in verification, and the new commercial satellites present states with the opportunity to incorporate this technology into their NTM. The new satellites offer states a unique verification capability: the ability to search an adversary's territory regularly and discreetly without consent. States can use the space-based sensors to detect, identify, and generally describe treaty-limited items (see Table 2) and thus become more self-reliant in their ability to verify an adversary's compliance with an agreement. Even without a formal or informal accord, commercial remote sensing satellites could provide valuable, independent data on force structures, thereby aiding the negotiation of arms control accords as well as the respective verification provisions.

A balance in remote sensing capability could become as important a factor as a balance of power to make a bilateral accord workable. In the near term, this will require both states to gain access to comparable commercial remote sensing systems, or one state to secure a commercial arrangement that matches an adversary's indigenous remote sensing capability. With access to compara-

23. The use of high-resolution imaging in the visible and infrared for these applications depends on a lack of significant cloud coverage and the absence of thick foliage.

ble satellites (for example, SIS and QuickBird), an equitable monitoring arrangement can emerge between two states regardless of the original motivation for purchasing the remote sensing services.

For regional agreements, commercial imaging satellites allow several states to verify treaty compliance. Satellites that carry on-board recorders and ground stations that are capable of line-of-sight reception over 2,000–3,000 km can provide coverage of the same geographic area to different regional clients.[24] Verification tasks could be coordinated within a bloc of states, or individual states could act alone. Either approach would add more participants to the regional verification regime, and monitoring could be done according to a diverse array of national and subregional interests.

Coordination of remote sensing could extend to the international sphere. The increased number of remote sensing actors involved in the verification of International agreements could augment U.S. and Russian efforts in this area. New remote sensing participants could enhance the effectiveness of verification by tasking commercial satellites according to their own collateral information.[25] Through the coordination of verification efforts, specific participants could search neglected areas or focus on regions that require more intensive examination. All of this could be done within existing national institutions or regional alliances, without new international bureaucracies.

In instances of treaty non-compliance, commercial imagery could be used as public evidence. Since the technical capabilities of commercial satellites are essentially public knowledge, commercial high-resolution imagery would be inherently more suitable for wider dissemination than classified data.[26] The images could be shared with friends and foes alike to substantiate a claim of noncompliance or compliance. The evidence could also be presented to the state in question, to justify a response to a violation. Thus, the introduction of commercial high-resolution imagery could facilitate a greater degree of due process in cases where treaty compliance was called into question.

24. OrbView-1 could be a notable exception if states within the region obtain exclusive rights to OrbView images of their own territory.
25. The trick is to get a satellite to view the right place at the right time. Timing is probably the most important factor in overhead observation. It can make the difference between valuable and useless knowledge. For example, an image that captured a parked fighter-bomber at 2 meter GSD could be much more useful than an image of its shelter at .2 meter GSD.
26. Although there would generally be less concern about the disclosure of sources and methods, the release of commercial images could still put other information sources at risk of exposure, particularly if collateral information was used to assist in the interpretation of images.

THREAT ASSESSMENT

Although instruments of war have changed radically over the past 100 years, the basic military components have remained constant. Military forces still need soldiers, weapons, ammunition, energy, transportation, communications, intelligence, and logistical support to fight effectively. By gathering information on these components as well as data on the readiness, distribution, and overall effectiveness of military forces, a state can make long-term and short-term assessments of security threats.

High-resolution imaging satellites offer states a relatively safe vantage point for monitoring an adversary's territory, as well as the necessary spatial detail for locating the basic components of a military force. Satellites can acquire images of sites that would otherwise have required risky forays into an adversary's airspace or territory. States whose adversaries are geographically large are likely to be most attracted to the deep territorial reach of remote sensing satellites. The ability to view beyond international borders could be particularly important in the search for troop assembly points and long-range missile sites.

High-resolution imaging satellites also offer states the capability of collecting images at regular intervals for updating assessments of an adversary's military force. Remote sensing satellites could be programmed to conduct routine broad-area surveys, and image databases could be constructed to assist the tracking of observed structures and objects over time. States could vary the frequency of surveys and the quantity of image acquisitions, depending on the magnitude and immediacy of an identified threat.[27] Such routine monitoring could hinder and deter the execution of conventional first strikes by exposing the gradual buildup and disposition of forces.

Active methods for countering satellite observation would run the risk of prematurely triggering armed conflict. If an attacking force decided to disrupt, disable, or destroy the critical components of a commercial remote sensing system, it would run the risk of losing the element of surprise and initiative. If the satellite were attacked, the offensive force would risk an armed response from not only the state that bought the remote sensing service, but also the state whose flag was flown on the commercial satellite. If an attacking force

27. In peacetime or in a protracted crisis, images could be incorporated into intelligence analyses in a timely manner. However, if the tempo of events in a crisis or armed conflict outpace the image acquisition and interpretation rates, the timeliness (and thus utility) of the data would rapidly diminish.

chose passive methods to counter overhead observation, such as concealment and deception, extensive preparations would be required to hide troop positions, deploy decoys, and cover tracks from satellite view. Even if passive measures were used, the attacking force could not be certain that the tactics would successfully counter satellite observation. And if acquired images revealed the attacking force's efforts at concealment and deception, the defending force could be alerted to the imminence of an attack and prepare accordingly.

Besides being used to collect information without an adversary's cooperation, high-resolution imaging satellites can also be used as a means of signaling. With knowledge of who operates a particular commercial satellite and when it passes overhead, an adversary can deliberately deploy its forces to convey a specific threat (e.g., invasion, resistance to occupation) or assurance (e.g., withdrawal, disarmament). For example, adversaries with a mutual desire to avoid armed conflict could convey their unilateral restraint by openly displaying a stand-down of their forces as the high-resolution imaging satellite passed overhead.[28] The use of satellite imagery for signaling would be particularly suitable in situations where adversaries could not or would not communicate with each other directly.

PEACEKEEPING

Since the end of the Cold War, there has been an exponential increase in the number and size of UN peacekeeping operations. The mission objectives have widened to include crisis prevention (Macedonia); the protection of humanitarian programs (Bosnia, Somalia); the implementation of internal peace agreements (Cambodia, El Salvador); and the enforcement of UN Security Council ultimatums (Bosnia, Iraq-Kuwait, Somalia).[29] High-resolution imagery can support such operations.

Commercial satellites can be used to assess threats against UN forces. Commanders could also use satellite images to gather timely intelligence on the mass movement of refugees, on road closures, and on battles. This data would be especially valuable for those UN missions where airborne support was not provided due to hazardous flight conditions or the lack of funding.

28. The conclusion of the Cuban Missile Crisis is a good historical example: Soviet ships deliberately placed their cargo in open view so that U.S. airborne reconnaissance could easily observe the removal of nuclear missiles from Cuba.
29. See John Roper, Masashi Nishihara, Olara A. Otunnu, Enid C.B. Schoettle, *Keeping the Peace in the Post–Cold War Era: Strengthening Multilateral Peacekeeping* (New York: The Trilateral Commission, 1993), pp. 1–101.

In addition, the imagery could be used to filter fact from fiction in some types of eyewitness and government reports. With an independent source of information, UN missions could exercise a greater degree of informational autonomy from the host population and governing authority. Satellite imagery could suggest to UN commanders the right questions to ask local authorities, in order to determine whether UN objectives and government promises were being fulfilled.

The Risks

While the sale of high-resolution satellite images will open up many opportunities, it will also create a variety of risks. The risks depend on how the new remote sensing services will be distributed throughout the political landscape, how belligerent states will use high-resolution images, and how observed states will respond to routine overhead imaging by their neighbors.

THE POLITICS OF SATELLITE REMOTE SENSING

The opportunities for using high-resolution imaging to enhance security depend on how this technology will affect conflicts and alliances.[30] Since remote sensing services will be distributed according to free-market principles, high-resolution imaging could upset delicate balances of power or aggravate existing asymmetries in military capability. The absence of regional or international guidelines could undercut national policies, such as PD 23, that attempt to allay such security concerns.

A free-market environment encourages economic and military powers to gobble up the premier remote sensing services for themselves. Since the services of satellites such as OrbView and SIS will be offered on an exclusive basis, a powerful state could establish itself as the exclusive regional client of multiple suppliers and thus deny its neighbors a comparable remote sensing capability for years to come. A state with exclusive access to OrbView and SIS could become the dominant collector of 1-meter GSD images of a region.[31] In the short term, less powerful states could be compelled to settle for technologically inferior or operationally inadequate remote sensing systems. They might, as a

30. See Chodakewitz and Levy, "Implications for Cross-Border Conflict," pp. 90–103; De Santis, "Commercial Observation Satellites, Alliance Relations, and the Developing World," pp. 78–89.
31. Remote sensing superiority could be achieved by accident rather than by design, if a catastrophic malfunction disabled an imaging satellite or if financial hardship put a supplier out of business.

result, raise objections to specific political formulas for dealing with security issues in a regional or international setting. Peace treaties, arms control accords, and confidence-building measures could be hampered by an imbalance in remote sensing capability. Remote sensing asymmetries could also complicate regional security calculations through the addition of new states into the equation. Since the geographic coverage of a ground station could extend into adjacent conflict zones, a state with access to superior remote sensing capabilities could use the image information to influence events in those zones.[32]

The proliferation of high-resolution imaging could strain alliances. For example, a state might permit the sale of a high-resolution imaging service to a friendly client or ally, to the detriment of the security interests of other allies.[33] In addition, the diffusion of remote sensing capabilities could change the decision-making dynamics within an alliance.[34] Rather than rely on the leading member states or the collective institutions of an alliance, member states could take a more independent role by using their own NTM, including commercial satellite imaging.

The spread of high-resolution imaging could make regional and international crises more difficult to manage.[35] With a remote sensing capability to observe flashpoints, a larger and more diverse set of political actors could participate in a crisis and attempt to influence the sequence of events. Peripheral participants could maneuver themselves onto the center stage of a crisis by providing the main actors with badly needed information, or by acting diplomatically or militarily on the image information themselves. The main actors in a crisis could find themselves deluged with true and false information, bogged down in dealings with additional information gatherers, and left without time to consider their next move carefully before the release of a new revelation. Disengagement options for defusing the crisis discreetly, such as the voluntary display of concealed forces and the disassembly of fortifications, might be dissuaded by their visibility to numerous satellite observers.

32. For example, the footprint of a ground station in Riyadh, Saudi Arabia, could cover not only the Persian Gulf conflict zone, but also the Indo-Pakistani conflict zone to the east and the Arab-Israeli conflict zone to the west.

33. The United States has routinely faced this dilemma in the supply of arms to Saudi Arabia and Israel.

34. For an analysis on the impact of commercial imaging satellites on NATO, see De Santis, "Commercial Observation Satellites, Alliance Relations, and the Developing World," pp. 78–89.

35. See Michael Nacht, "Implications for Crisis Decision-Making," in Krepon, Zimmerman, Spector, and Umberger, *Commercial Observation Satellites and International Security*, pp. 185–197.

OFFENSIVE MILITARY APPLICATION OF HIGH-RESOLUTION IMAGING

High-resolution imaging can provide an attacker with the reconnaissance element of air superiority before the initiation of an offensive. The same set of images required for threat assessment or verification can be used to search for weaknesses in an adversary's defenses, identify targets for destruction, and plan the composition of forces for the occupation of conquered territory.

For air strikes, high-resolution imaging is likely to be most useful for supporting an initial onslaught through the identification and location of targets such as air defenses, troop concentrations, chokepoints, and command centers. For ground or naval forces, high-resolution imaging is likely to be most useful for the selection of invasion routes through land and sea, as well as the targeting of rear areas using long-range weapons. For all branches of the military, commercial high-resolution images can be used to generate realistic digital simulations of targets for the specialized training of tank crews, pilots, and special forces. Using virtual-reality techniques, critical aspects of the attack can be practiced to prepare personnel for operations in unfamiliar terrain, to anticipate problems that could arise during the attack sequence, and to reveal tactical flaws in the plans for an offensive.

Commercial high-resolution imaging could drive improvements in offensive weapons capability. It could act as a gun-sight for ballistic and cruise missiles, providing the visual data for detecting and identifying targets as well as the geographic coordinates of the located targets.[36] The new commercial satellites will provide images with absolute location errors of less than 100 meters without using the geographic position of nearby points as absolute references. If the absolute location of nearby reference points can be established from other sources (such as the Global Positioning System [GPS], ground surveys, and maps), the photogrammetric accuracy could be reduced to the order of a few meters. If states with long-range weapons can compile image maps of an adversary's territory to such high photogrammetric accuracies, they will be encouraged to develop or import new guidance systems capable of directing weapons to the designated point at a comparably high accuracy.

States will also have the option of exporting image maps and target databases to other states and military groups. Because digital imagery and the

36. The utility of advanced guidance systems would be appreciably enhanced by the availability of accurate geographic coordinates from high-resolution imagery. The imagery would tell the weapon where to go and the guidance system would make sure the weapon got there.

derived information are fluid commodities, a state's entire target list could be stolen and conveyed via phone lines, radio transmissions, or storage media in diplomatic pouches.

RESPONSES TO OVERHEAD OBSERVATION

Although remote sensing companies hope to gain widespread approval for their commercial venture into high-resolution imaging, some states could respond with countermeasures. Indeed, the sale of high-resolution images could create new markets for products and techniques, both active and passive, designed to thwart overhead viewing.

States are likely to increase their reliance on passive measures because such measures are immediately available and are not inherently provocative.[37] They could intensify the application of camouflage, concealment, and deception to obstruct the overhead viewing of their military forces and other strategic assets. Garages, warehouses, tunnels, foliage, and natural cloud cover could be used to hide supplies and hardware. Deception tactics could be devised to cover up the true purpose of strategic facilities. Decoys could lure observers away from key sites and satiate their appetite for information. If certain activity could not be concealed or masked (e.g., military redeployments, ship loading, etc.), it could be scheduled to take place at times when commercial satellites were not within view.[38]

For wartime contingencies where the scale and uncertainty associated with passive measures may be too great, states could pursue more direct means of disabling or destroying a remote sensing system. In the near term, the communication links and ground stations will probably be the most vulnerable components. Jamming could be used against the ground station to disrupt the download of images or against the satellite to prevent the reception of uplinked

37. Iraq has already demonstrated the effectiveness of passive measures such as camouflage and dispersal against high-resolution imaging from airborne and space platforms. William Burrows, "Give Space Reconnaissance Systems a B+," *Space News*, Vol. 2, No. 27 (August 5–18, 1991), p. 21.
38. In theory, small-scale activities could avoid an oblique imaging sensor in sun-synchronous orbit with relative ease because the overpass times would always be confined to a small portion of the day (for example, late morning). Avoidance of satellites in asynchronous orbits (e.g., KVR-1000) could be more cumbersome because the local overpass time would vary. Scheduling around numerous remote sensing satellites—whether in sun-synchronous orbit or not—could be even more difficult because the observed state would be subject to multiple dates and times where outdoor activity could be detected.

commands.[39] A military assault on the ground receiving station could disable the remote sensing system.

As the survivability of the ground components improves over time through defenses, mobility, and redundancy, active countermeasures could be directed upwards at the satellite itself. An adversary's access to high-resolution imaging could provide a state with the motive for developing or purchasing ASAT (anti-satellite) weaponry and a satellite tracking capability. Long-term programs could be initiated to derive ASAT interceptors from ballistic missile programs and to develop more exotic weapons for destroying remote sensing satellites.

ASAT weapons could present new security problems within the next ten years. ASATs acquired to target imaging satellites cannot be technically or operationally confined to such targets. They can be used against whatever trackable low earth orbit (LEO) target comes into range, including not only commercial imaging satellites that serve multiple users worldwide, but also any other satellite that periodically passes over the same region: U.S. and Russian intelligence satellites, non-imaging satellites, and manned orbiters.[40]

Future Trends

More states are likely to become future commercial suppliers of high-resolution images. Japan has already made preliminary plans to deploy a 2.5-meter GSD panchromatic sensor in the year 2001 on the Advanced Land Observation Satellite (ALOS). India plans to launch a 10-meter GSD panchromatic sensor in mid-1995 on its IRS-1C satellite, opening the possibility of developing higher resolution sensors for follow-on IRS systems. Brazil, China, and Germany have the technical capability to develop their own commercial systems within the next 5–10 years. Future suppliers, such as China, might choose to cater to clients such as Iran and Libya that have political difficulties making deals with Western suppliers. Eventually, there could be enough image merchants to

39. SIS could be particularly susceptible to uplink jamming because the satellite has been designed to receive commands from regional ground stations. The other new satellites will receive uplink commands from central stations located far from most regional threats.
40. Whether a satellite would ever be attacked principally depends on the extent to which states perceive its continued operation as threatening, or on how much strategic value the satellite has. See Ashton B. Carter, "Satellites and Anti-Satellites: The Limits of the Possible," *International Security*, Vol. 10, No. 4 (Spring 1986), pp. 46–98.

accommodate any customer—a state, institution, or individual—with sufficient funds.

The spread of commercial high-resolution imaging is likely to complicate future U.S. military operations and introduce additional U.S. security commitments in space. The U.S. military could face opponents with timely high-resolution images of U.S. forces.[41] The opponents could use this information to strengthen their defenses or to launch preemptive attacks as the United States attempts to build up forces in a region. If the images come from satellites owned by unfriendly states, or if the images are acquired before the outbreak of armed conflict, nonmilitary options could prove inadequate at precluding access to the sensitive data.

If the sale of high-resolution imagery eventually results in the proliferation of LEO ASATs, the U.S. military will also have to consider the vulnerability of its own intelligence satellites during wartime. ASAT countermeasures may be needed to protect the multibillion dollar investment in U.S. space systems and preserve U.S. global coverage during and after an armed conflict.[42] In addition, the U.S. military might face future demands to defend commercial orbiting platforms. Just as the U.S. military has a history of protecting U.S. ships on the high seas, it may have to take on new defense commitments to counter future threats against U.S. property in space.[43]

The spread of high-resolution imaging will give the UN Security Council the opportunity to assume greater authority over access to such data. With the contractual distinction between satellite owners and satellite users, the international commerce of high-resolution images will be subject to interdiction authorized by the UN Security Council. Such sanctions could be imposed to compel a state to comply with specific UN Security Council resolutions.[44] This option is likely to be a politically attractive one, as it could directly affect a state's leadership and military.[45]

41. General Charles A. Horner, Senate Committee on Armed Services, *Department of Defense Authorization for Appropriations for Fiscal Year 1994 and the Future Years Defense Program*, 103rd Cong., 1st sess., 1993, S. Hrg. 103–303, pp. 427–428.
42. Allen Thomson, "Satellite Vulnerability: A Post-Cold War Issue?" *Space Policy*, Vol. 11, No. 1 (February 1995), pp. 19–30.
43. Such defense commitments would also protect foreign clients who pay to use U.S. space systems.
44. Threats of such sanctions could help deter the violation of UN Security Council resolutions.
45. Image sanctions could affect states in one of two distinct ways. Sanctions against states that are image consumers would have direct impact on their intelligence-gathering capability. Sanctions against states that are image suppliers would result in loss of revenue.

Conclusions

To facilitate the peaceful application of high-resolution satellite imaging and hinder the use of orbiting systems for aggressive purposes, states and remote sensing companies should implement measures that capitalize on the opportunities while minimizing the risks. These measures will have to be applied at the corporate, national, and multilateral level in order to enhance regional and international security.

At the corporate level, remote sensing firms should make imaging deals with clients that do not undermine the use of commercial high-resolution imaging satellites for politically sensitive applications such as verification, threat assessment, and peacekeeping. This requires the preservation of satellite imaging's fundamental advantage—the ability to fly over national airspace and acquire images without the consent of the observed state.

Exclusive national deals, such as that proposed by Orbital Imaging, undercut this capability to transcend international borders and consequently stunt the growth of commercial intelligence gathering from space. By purchasing exclusive rights to high-resolution images of its own territory, a state could prevent others from using certain satellites to monitor activities on its territory. As a result, it could introduce bilateral or regional imbalances in remote sensing capability.[46] It could also preclude the minimum transparency that is needed between adversaries to make arms control and confidence building technically feasible.

The remote sensing industry itself or national governments should prohibit exclusive national agreements to task imaging satellites and distribute the images. The free market would act as the enforcement mechanism by making illicit national agreements unattractive in two ways. First, it would make such agreements more expensive, given the supplier's risk of being shut down or blacklisted if caught. And second, it would be extremely difficult to implement secretly. The imaging satellite would be in orbit and a multitude of states would know it. If nobody could buy images of a specific state's territory, it would quickly become apparent that an exclusion arrangement was in place.

Remote sensing firms should either sell images to anyone on a first come–first served basis, or sell regional agreements that give client states the exclusive use of the satellite within a geographic region (e.g., the ground station foot-

46. Such imbalances would have the most significant effect in the short term. Market forces could correct these imbalances in the long term.

print). Both of these arrangements would enable image buyers to use high-resolution imaging satellites for monitoring neighboring territory and international waters.[47]

At the national level, governments should allow image buyers the confidential use of commercial high-resolution imaging satellites to facilitate the development of the market for treaty verification and threat assessment. That way, intelligence agencies from a variety of states could use commercial high-resolution imagery without revealing their monitoring tactics to the states they are observing.

The United States presently has a legal provision in the 1992 U.S. Land Remote Sensing Policy Act that prevents such discreet use of U.S. commercial high-resolution imaging satellites. Under Section 202b, clause 2 of this Act, each observed state will be able to obtain "under reasonable terms and conditions" all high-resolution images of its territory acquired by EarlyBird, QuickBird, OrbView, and SIS, even if another state used these satellites on a regionally exclusive basis to view the observed state. These images would be made available to the imaged state despite the value of the data for intelligence purposes.

However, allowing imaged states access to high-resolution data acquired by others for intelligence purposes could compromise the utility of the imagery for arms control verification and remote threat assessment. Imaged states could track how their adversaries monitored them and select infrequently imaged areas for clandestine activities. By obtaining and analyzing commercial images of their own territory, imaged states could determine what their adversaries did and did not know about them. Weaknesses and gaps in their opponents' imaging operations could be identified and exploited while the strengths could be countered using passive measures. The analysis of archived images could also provide imaged states with invaluable feedback on the effectiveness of its passive countermeasures since the imaged state would know exactly where specific items were hidden.

Given the special utility of high-resolution satellite images to intelligence applications, the 1992 U.S. Land Remote Sensing Policy Act should be amended to exempt commercial high-resolution images, just as images from U.S. classified systems are exempted. Like their foreign competitors, U.S. remote sensing firms should have the discretion to determine whether or not their

47. Both arrangements would also permit the use of high-resolution images for civil applications on one's own territory, such as national mapping, urban planning, and agricultural monitoring.

high-resolution images will be made available to the imaged state. Leaving the decision in the hands of image suppliers allows market forces to determine the number of high-resolution imaging firms that are needed to cater to the confidentiality needs of intelligence-gathering clientele.

At the multilateral level, the supplier states—presently the United States, Russia, France, and Israel—must be made politically accountable for the security consequences of their image exports. This is possible provided the supplier states retain ultimate control over the flow of images to the buyers. Thus, supplier states should prohibit sales or leases that give buyers full control of high-resolution imaging satellites.[48]

If suppliers relinquish control of the on-off switch, sensor system, and altitude control, client states could undertake belligerent actions without the fear of having their remote sensing capability revoked. The purchased satellites could be relied on for use in wartime as well as peacetime. The suppliers would lose access to the users' tasking schedule and thus would no longer be able to obtain advance indications on the users' motivations.

In the long term, the retention of supplier control over remote sensing satellites could discourage the unwelcome spread of ASATs. It could reassure imaged states that their adversary's access to high-resolution images depended on its conduct. It could also complicate the usability of ASATs. If ASATs could not be used without drawing satellite suppliers into the conflict, it could dissuade states from using their finite resources for the development or import of ASAT weapons.

In addition to retaining control over the satellites, the supplier states should adopt common criteria for a cut-off or time delay in the supply of high-resolution images of a particular geographic area. Since crisis or wartime situations could arise where supplier states would not want commercial high-resolution imaging used against them, the supplier states should devise agreeable contingency rules that would protect them from the threatening use of each other's commercial remote sensing systems.[49]

The supplier states should also try to prevent image sales to states that are likely to use the information for an attack on another. They should identify

48. Fortunately, this is technically feasible. Unlike terrestrial military systems, high-resolution imaging from space is a highly controllable arms sale. Sellers can build, deploy, and operate satellites without releasing physical control of the systems to the buyer.
49. Specifically, the United States, France, and Israel should devise such a contingency agreement given their substantially overlapping security interests in Europe, North Africa, and the Middle East.

states with a history of belligerency and deny them the capability to task imaging satellites, receive images directly from satellites, and access images from data archives.[50] In addition, they may need to link image deals with certain states to the verifiable absence of long-range weapons.

The supplier states need to make their foreign distributors accountable for the security consequences of their image sales as well.[51] This can be accomplished in part by confining distributors' image acquisitions and sales to their own geographic region—an area inside the 2,000–3,000 km radius of their central location.[52] This way, foreign distributors would be forced to give the security implications of their image sales greater consideration, since images of neighboring areas could directly affect the regional security interests of the host state. Unable to sell high-resolution images of targets located on the opposite side of the world, they could not rely on large geographic distances to insulate themselves from the risks associated with image sales to parties at war with each other, or to states with weapons of mass destruction.

While there are a few key security measures that should be taken at the multilateral level, there is one that should not—the creation of an International Satellite Monitoring Agency (ISMA). Originally proposed by France in 1978, ISMA was conceived as a remote sensing institution that would promote the international use of high-resolution imagery for "benign" security applications such as verification and early warning, with safeguards to minimize access to the data for "malign" security applications such as warfighting. With ISMA's capability to collect and analyze high-resolution imagery, states would turn to ISMA to perform their monitoring tasks rather than develop or purchase their own remote sensing capability.

The fundamental problem with the ISMA concept is that satellite remote sensing is unsuitable for international management. The operational beauty of satellite imaging is that it does not require cooperation with anyone, neither friend nor foe. Creation of a central institution that would require multilateral consensus to function would destroy this important aspect of satellite imaging. The commercial proliferation of high-resolution imaging avoids the drawbacks of relying on an ISMA. By obtaining remote sensing capabilities from the international market, states can conduct their monitoring tasks according to their own security agendas rather than according to the negotiated terms of an international body. They can rely on their own intelligence apparatus to interpret the imagery, and they can avoid the political paralysis that frequently plagues international organizations.

The proliferation of high-resolution satellite imaging is as much a national, regional, and international security issue as the proliferation of weaponry. Yet, the United States, Russia, France, and Israel have allowed their commercial remote sensing firms to forge ahead—with other states at their heels—without any agreed guidelines on the security aspects of the competition. Fortunately, there is still time to devise national policies and multilateral accords that address the security implications of image sales before the planned deployment of new high-resolution imaging satellites over the next few years. These unilateral and multilateral policies can engender greater political support for commercial high-resolution imaging by facilitating regional arms control, strengthening international verification, enhancing non-intrusive threat assessments, and supporting peacekeeping. If high-resolution imaging is used by states to adopt less threatening security postures, the remote sensing endeavor could pay off economically as well as strategically.

50. Besides forgoing image contracts with belligerent states, remote sensing suppliers need to monitor the organizations and individuals who make image orders, and determine the targets the customers are observing. If a belligerent state tries to use a commercial imaging satellite systematically (through a front company, for example), experienced intelligence analysts could discover the illicit attempt by looking for tasking patterns that would fulfill the intelligence requirements of the state in question.

51. Firms that centralize their operations, such as EarthWatch, Priroda, and Sovinformsputnik, do not rely on a network of regional ground receiving stations and may not rely on foreign distributors. The respective national government has to monitor and regulate their global operations.

52. The radius of 2,000–3,000 km represents the coverage of the ground receiving station that many of these distributors will use.

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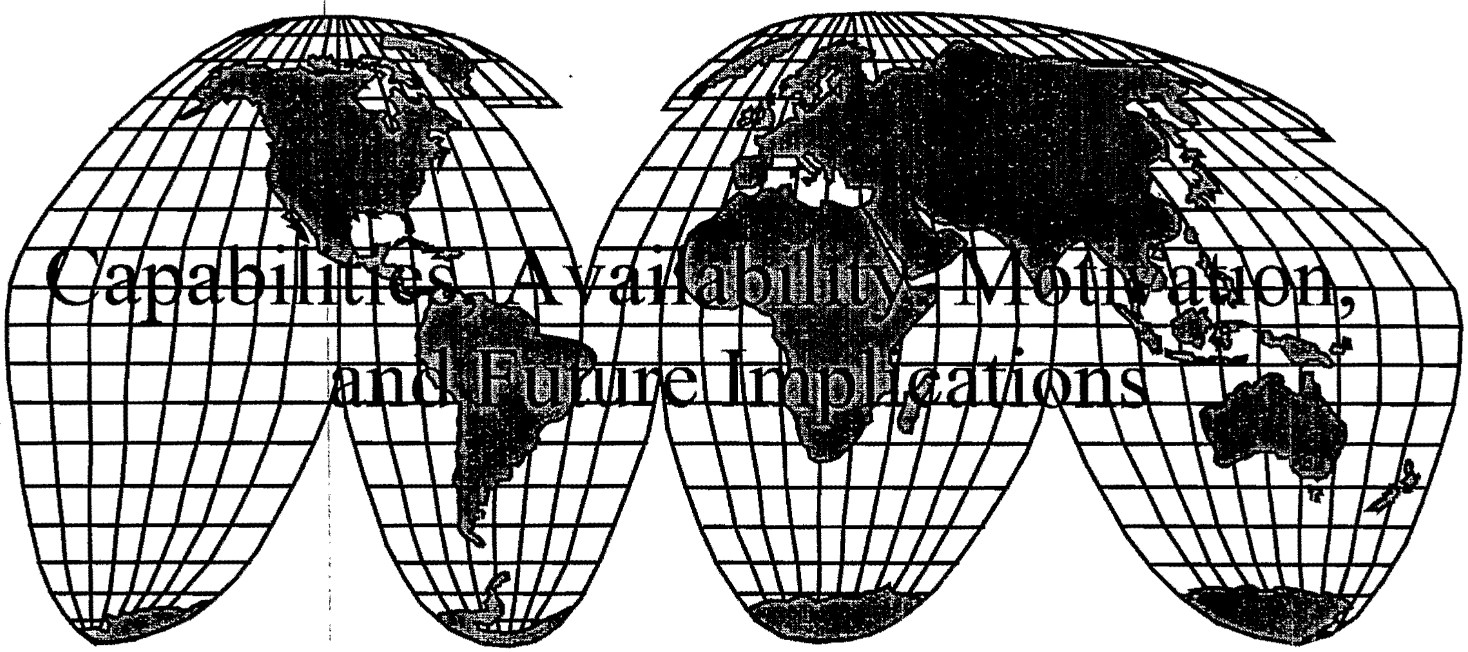
Space-Based Sensors



Capabilities, Availability, Motivation, and Future Implications

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Outline

- Foreign Motivations
- Present and Future Programs
- Availability of Technologies and Services
- Challenges
- Future Implications

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Summary

- Foreign nations are seeking independent space-based sensor capability
- Few countries presently have advanced systems
- Technology and data available on open market
- Implications for United States

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Foreign Motivations

- Keen awareness of US and Russian use of satellite reconnaissance
- Desert Shield/Desert Storm demonstration of benefits
- Critical intelligence information
- Break the monopoly

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Who's Doing What

- Russia and China
  - ◆ Multiple, advanced capabilities
- France
  - ◆ SPOT, Helios
  - ◆ Italy and Spain
- Israel
  - ◆ Offeq 3
- Japan
  - ◆ MOS, JERS, AEOS

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Who's Doing What (cont'd)

- India
  - IRS series

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Land Data Satellites Planned for Next Decade

Country	Program	Type	Resol/P	Resol/M	Resol/R	# Bands
France	Spot 5B	P&M	5	10		4
France	Spot 5A	P&M	5	10		4
India	IRS1-D	P&M	10	20		4
Korea	KOMSAT	P&M	10	10		3
ESA	ENVISAT	R			30	
France	Spot 4	P&M	10	20		4
Russia	Almaz 2	R			5	
Japan	ADEOS	P&M	8	16		4
China-Brazil	CBERS	P&M	20	20		7
Canada	RADARSAT	R			9	
India	IRS1-C	P&M	10	20		4
Russia	Resours2	M		27		3

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Open Market Availability--A Complicating Factor

- Countries are selling or want to sell product, platforms, and support services
    - US, Russia, France, Europe
- Is there a market for everything?

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Challenges--More Than Meets the Eye

- Technology and Infrastructure
  - Communications, Expertise, Signal Transmission/Processing
  - Real time or not?
- Financial
  - Reduced defense R&D and procurement funding
- Data Access Control?

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Implications

- The "club" grows larger
  - ◆ Information openly available
- Availability of military intelligence
  - ◆ Knowledge = improved planning, targeting, guidance
  - ◆ Balancing military concerns and commercial interests
- New Space Race?
- More difficult for US to hide?