STRATEGY RESEARCH PROJECT

GEOSPATIAL INFORMATION IN SUPPORT OF INFORMATION SUPERIORITY

BY

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USAWC CLASS OF 2002

U.S. ARMY WAR COLLEGE, CARLISLE BARRACKS, PA 17013-5050

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ABSTRACT

AUTHOR: Ralph M. Erwin

TITLE: Geospatial Information in Support of Information Superiority

FORMAT: Strategy Research Project

DATE: 09 April 2002 PAGES: 33 CLASSIFICATION: Unclassified

Given the proliferation of commercial imaging systems and commercially available geospatial information systems, can the National Imagery and Mapping Agency (NIMA) provide U.S. forces with the data required to achieve information superiority with respect to terrain? This is possible only if NIMA can build and provide warfighters geospatial information faster, relevant, and more accurate than any adversary, therefore achieving information dominance. An adversary will also want to see the battlespace with the same fidelity. If the same information is available to all, then the U.S. will have to determine the geospatial information preparedness level required to maintain the information edge. An information superiority edge will be sustained by adherence to NIMA established standards of timeliness, relevance, and accuracy for geospatial information. Because of the availability of geospatial information from commercial sources, adversaries of the U.S. may have an archive of readiness data that is relevant and fairly accurate, yet it appears that our adversaries will lack a responsiveness capability for timely geospatial data leaving U.S. forces with an information edge.

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> The general who can assess the value of ground, maneuvers his enemy into dangerous terrain and keeps clear of it himself. He chooses the ground on which he wishes to engage, draws his enemy to it, and there gives battle.
>
> —Sun Tzu

When the Coalition forces deployed to the Persian Gulf region, the maps of Kuwait, Iraq, and Saudi Arabia were old and out-of-date. To correct this deficiency, multi-spectral imagery satellite systems were used to prepare precise maps of the Gulf area. Multi-spectral images were used to show features of the earth that exceed human visual detection. With the ability to provide seasonally adjusted battlefield maps, the multi-spectral imagery analysis identified land cover, healthy and stressed vegetation, soil boundaries, soil moisture content, fording locations, and potential landing or drop zones. These images also allowed analysts to identify shallow water areas near the coastline and earth surface areas in which spectral changes had occurred. With this information, the Army gleaned data that would help achieve military victory. Desert Shield and Desert Storm engineers had valuable data that supported plans for military airfield construction; Marines knew which areas were best for amphibious assault; land forces could monitor enemy operations; and air attackers could examine attack routes, verify target coordinates, and identify potential landing zones. At the time of Iraq's invasion of Kuwait, the Iraqi military was receiving military support from the Soviets and purchasing satellite imagery from the French. Soon after the invasion, the Soviets joined many other nations in their condemnation of the Iraqi government's behavior and the French (*Centre National d'Etudes Spatiales* or CNES) refused to sell Iraq imagery products.[1] This is an example of the capabilities of commercial industry in support of military operations. This trend to purchase geospatial information is still valid today and growing.

QUESTION AND CRITERIA

Given the proliferation of commercial imaging systems and commercially available geospatial information systems, can the National Imagery and Mapping Agency (NIMA) provide U.S. forces with the data required to achieve information superiority with respect to terrain? This is possible only if NIMA can build and provide warfighters geospatial information faster, relevant, and more accurate than any adversary, therefore achieving information dominance.

GEOSPATIAL INFORMATION

Geospatial information plays a key role in the full range of military operations from peace to war. Commanders use geospatial data to help determine friendly and enemy courses of action (COA's) and to plan for the deployment of forces and key weapons systems. When coupled with intelligence data, the disposition of friendly forces, weather, and the logistics situation, geospatial information assists the commander in visualizing and developing the battlespace in order to exploit enemy weaknesses or take advantage of friendly strengths.

Geospatial information is the precise location and attributes of natural or constructed features and boundaries, referenced to positions on the Earth. This information conveys the "what" and "where" of an object and provides a unique context for integrating different observations. NIMA specializes in providing precise worldwide positioning information, which is critical when making decisions related to the object.[2] The data, geospatial information, is the critical piece NIMA requires to provide the location, attribution, and geo-positioning for deployment of military forces. Geospatial information is the basis for all military maps.

ASSUMPTIONS

The primary assumptions for this analysis are:

- NIMA, the combat support agency, will continue to collect or acquire data and establish the standards for geospatial information to allow battlefield/battlespace visualization by the warfighter and accomplishment of information superiority.
- NIMA will implement the August 2001 Geospatial Transition Plan.
- The timeframe considered for this analysis is approximately 2010.
- Conflicts involving American military will be outside the continental United States.
- Training for exploitation of geospatial information is available worldwide in military and civilian institutions.
- Systems to exploit geospatial information are readily available from commercial vendors.
- Dissemination means are accessible by all users of geospatial information.
- NIMA will have a trusted global geospatial framework of foundation data available to warfighters for planning purposes.

INFORMATION DOMINANCE

For the U.S. military, the information dominance requirement addressed in this paper is about geospatial information. It must be timely, relevant, and accurate. An adversary will also

want to see the battlespace with the same fidelity. If the same information is available to all, then the U.S. will have to determine the geospatial information preparedness level required to maintain the information edge. If so, this research will analyze the processes required to give the U.S. the required information advantage.

To determine whether NIMA can provide data faster, more relevant and more accurate, this paper will review the need for battlefield/battlespace visualization, the definitions of geospatial information and information superiority, describe NIMA as the geospatial information provider, its global mission, the former method of map maker and its transition to information provider. This study will then review what geospatial information adversaries of the U.S. can potentially obtain and use to achieve information superiority. Finally, the study will conclude with an analysis of whether NIMA can really provide U.S. forces the information edge.

BATTLEFIELD/BATTLESPACE VISUALIZATION

Battlefield/battlespace visualization is the process whereby the commander develops a clear understanding of the current state with relation to the environment, envisions a desired end state that represents mission accomplishment, then subsequently visualizes the sequence of activity that moves his force from its current state to the end state.[3]

Battlefield/battlespace visualization is an essential leadership attribute of command and is critical for accomplishing missions. It is learned and attained through training, practice, experience, wisdom, and available battle-command technologies. Other resources, both human and technological, serve only to assist a commander in formulating a vision and taking action to implement it. To be successful in battle, a commander must apply experience and intuition to sort through the myriad of information available on the battlefield/battlespace.[4]

In the past, leveraging a knowledge advantage to decisively achieve a desired end state has been largely an intuitive process. Information technologies now hold a potential for making this grasp of the battlespace, and the inherent opportunities it affords, more accessible to every leader, from field army to rifle platoon. The effect of these changes will enhance battlefield/battlespace visualization by supporting leaders with a deliberate and systematic information process based upon building blocks of raw data parsed and collated by both man and machines, synthesized into a coherent whole, and focused upon drawing understanding from the chaos of battle. Additionally, by linking commanders at different echelons, this same technology will enhance situational awareness and promote synchronized operational planning and execution. Ideally, the command will see and think as one.[5] To achieve visualization of the

battlespace, geospatial information is necessary. According to Joint Publication 2-03, "Digital geospatial information forms the foundation for battlespace visualization."[6]

GEOSPATIAL INFORMATION

Geospatial information is produced by multiple sources to common interoperable data standards. It may be presented in the form of printed maps, charts, and publications; in digital simulation and modeling databases; in photographic form; or in the form of digitized maps and charts or attributed data. These data are used for the military decision-making process (MDMP), training, and operations including navigation, tactical/operational planning, mission rehearsal, modeling, simulation, and precise targeting.[7]

REMOTE SENSING

To collect geospatial information in the 21st Century, extremely sophisticated satellites and aerial photographic methods are being employed by countries and corporations. With this information, the maps of the world are made. These maps can be extremely simple with just major roads, large rivers and towns or complex and dynamically linked with the Global Positioning System and a complete vehicular mounted land navigation system. Geospatial information is the basis upon which the 'picture' that soldiers and civilians use on a daily basis is generated.

While the importance of resolution is often overstated, improved resolution clearly allows new information to be extracted from an image. As imagery resolution moves from the tens of meters to one meter and below, military applications move beyond terrain analysis, through gross targeting, to precision targeting, bomb damage assessment, order-of-battle assessment, to technical intelligence findings.[8] Resolution of spatial imagery of 10 meters means that objects of 10 meters in diameter are distinguishable to the user.

Remote sensing is a technique used to collect data about the earth without taking a physical sample of the earth's surface. NIMA gets a majority of the geospatial information it has today from a remote sensor. A sensor is used to measure the energy reflected from the earth. This information can be displayed as a digital image or as a photograph. Sensors (electro-optical, infrared, and radar) can be mounted on a satellite orbiting the earth, or on an airborne structure. A remotely sensed image is composed of rows and columns of pixels. Each pixel stores a brightness value that provides information about the earth's surface. Classification is the process of sorting these pixels into a definitive number of groups or classes of similar pixels. Pixels are sorted by their brightness values and/or other criteria prescribed by the image analyst. After like pixel values have been grouped into land cover classes they are re-coded to

a specific color representative of that class. The result is a land cover map representing forests, wetlands, developed or cultivated lands, and unconsolidated shore.[9]

As it does with some other high technology products, the U.S. government prohibits the sale of high-resolution commercial imagery to designated countries and organizations. It has also reserved the right to what is termed "shutter control" as a preventive measure to gain assurance that its adversaries do not have access to imagery (for geospatial analysis or as intelligence data), imagery intelligence and critical geospatial information. According to Defense News, "...shortly after the Afghanistan conflict began Oct. 7, 2001, the Pentagon cut a new deal with Space Imaging [Corporation], reserving exclusive right to all IKONOS imagery of Afghanistan."[10] The U.S. may still exercise its export policies to veto any purchase of U.S. built satellites or its components.

As a method to counter the power of the U.S., the Gulf Cooperation Council (GCC) thinks it needs an independent satellite-imaging capability. The mid-eastern countries of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates, commissioned a military committee to weigh options for buying satellites for communications or imagery.[11]

High-resolution geospatial information is readily available today and it is likely that the resolution will become better based on technological advances in the remote sensing industry.

INFORMATION SUPERIORITY

Information superiority is defined as that degree of dominance in the information domain, which permits the conduct of operations without effective opposition.[12] A formally used definition stated information superiority to be "the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same." Both definitions lead to a similar conclusion – gather and secure your information so that you have an information advantage that enables the commander to visualize and develop the battlespace in order to exploit enemy weaknesses or take advantage of friendly strengths.[13]

Information superiority is a key enabler of the transformation of the operational capabilities of the joint force and the evolution of joint command and control.[14] According to the NIMA Geospatial Transition Plan, "accurate enemy, friendly, terrain, and weather pictures are the primary attributes of the emerging digital command and control era. Terrain information, detail topographic data, and digital geospatial data in the form of a hard copy topographic map/image map or displayed on a computer screen are major components of this key enabler. Upon a trusted geospatial information framework, all relevant strategic, operational, and tactical situational awareness information can be rendered as knowledge for the Warfighter."[15]

GEOSPATIAL INFORMATION PROVIDER

Although the unified commands and the military services have retained a limited map-making capability for tactical purposes, NIMA provides the majority of the terrain and topographic information for soldiers and marines, aeronautical information for the pilots and nautical information for the sailors to move through and control their battle space. As with its predecessor (the Defense Mapping Agency), its best-known products among the military are the paper maps used every day during training and military operations.[16] Because of NIMA's preeminent role in geospatial information production for U.S. forces, the study will not address service topographic units.

NIMA ORGANIZATION

NIMA was established on October 1, 1996 as a Department of Defense (DoD) combat support agency. It is a member of the Intelligence Community (IC) and has been assigned, by statute, the additional mission of providing support to national-level customers and other government agencies. NIMA provides ready access to the best available imagery and geospatial information, supports national decision-making, and contributes to the operational readiness of America's military forces.

NIMA was formed through the consolidation, in their entirety, of the Defense Mapping Agency (DMA), the Central Imagery Office (CIO), the Defense Dissemination Program Office (DDPO), and the National Photographic Interpretation Center (NPIC), as well as certain imagery-related programs, elements, and personnel from the Defense Intelligence Agency (DIA), the National Reconnaissance Office (NRO), the Defense Airborne Reconnaissance Office (DARO), and the Central Intelligence Agency (CIA).[17] NIMA was created to better organize the national capabilities in imagery intelligence, mapping, charting, and geodesy into one combat support agency. This empowered the agency to balance the best support for national policy makers and military decision-makers with the best information technologically available.

NIMA MISSION

A guiding concept for this paper is based on NIMA's mission..."to provide timely, relevant and accurate geospatial information for information superiority..."[18] *NIMA support must be faster, more relevant, and more accurate than geospatial information available to our potential adversaries.* With the concept clearly articulated in order to maintain and dominate information superiority and sustain geospatial information supremacy, mechanisms must be planned, programmed, and budgeted in the near term to satisfy Joint Vision 2010 requirements and meet the tenets of Joint Vision 2020. As the first step, NIMA has developed a readiness and

responsiveness strategy which satisfies the need to remain engaged at the global level while ensuring the ability to rapidly respond to a local or regional level conflict. The cornerstone of this strategy is the concept of foundation-based operations.

NIMA SCOPE

The scope of NIMA's mission is global. As recent as May 1999, NIMA was stretched to its limits trying to support the possibility of two simultaneous major theaters of war. LTG King, the Director of NIMA at that time, stated that NIMA required a $5 to $8 billion investment to meet a rapid customized mission-planning library.[19] With the evolution of digital technologies, a strategy developed by NIMA and the services and the recent successful topography mission flown by the National Aeronautics and Space Administration, there is a lot of optimism that NIMA can meet its requirements for one major theater of war and several other types of operations deemed important by the Department of Defense.

Conversely, most known or potential adversaries of the United States do not have a global concern. They can focus their resources on getting information for only a small portion of the earth thus reducing the scope of their geospatial information requirements. Thus, from an area perspective, potential adversaries have a significant advantage over NIMA in defining geospatial information needs.

LEGACY NIMA DATA

For a majority of the 20th Century, the Army has depended on the NIMA produced Topographic Line Map (TLM) at a 1:50,000-scale to visualize the terrain. Its effectiveness has diminished with the coming of the digitization of the Army (and the other services) and technological advances. The TLM was based on a definitive set of terrain features and geographic symbols. During planning and execution phases, the warfighter had no options on the information available or what could be displayed. As hard as NIMA (and its predecessor, DMA) worked, it could not provide worldwide coverage of the earth's surface. During crises NIMA found that even in an optimal environment they could not produce complete products that were timely, relevant, and accurate. In addition, updating, warehousing, and cataloging the TLM was a costly and time-consuming process, which was not responsive to the needs of the military.

To support decision-making, many users still rely on hardcopy maps and charts and employ manual overlays to integrate and analyze information from other domains. Some users have state-of-the-art automated information tools, but lack the types of data and area coverages needed to support their missions. Within DoD, today's warriors must deal with long lead times

for the production and delivery of standard map and chart products and they must also deal with the inability to effectively integrate digital data from stovepiped information flows.[20]

NIMA has not been able to provide worldwide coverage at a 1:100,000 or 1:50,000 scale based on the missions given to U.S. forces for deliberate planning. Crises require immediate response and legacy data has not always met the requirements of timeliness, relevance, and accuracy.

Several current and projected weapons systems require digital geospatial information for precision targeting. The requirements of precision-guided munitions indicate that timely, relevant, and accurate geospatial information is paramount to success.

NIMA's legacy data will not serve the needs of the U.S. forces because the military is digitizing its mission planning and rehearsal systems and advanced wargaming scenarios, which require timely, relevant and accurate coverage for planning and situational awareness. Quality visualization of the battlefield/battlespace is not possible with the paper-based TLM's.

Accuracy of legacy paper products

The accuracy measures provided with geospatial paper products and digital data define the envelope of reliable use. Geospatial data cannot be more accurate than its original source, and sources vary in accuracy. In addition, each step in the production process can introduce errors due to limitations of the production hardware and software, human factors, and the inherent characteristics of the product itself (i. e., size and scale of the chart or the specification accuracy for digital data). These typically manifest themselves as errors in position or elevation.[21] In the past, during deliberate or crisis action planning, the military was faced with the following:

- Regardless of what the warfighter wants or needs, he gets a standard NIMA product.
- Standard NIMA products are not changed during operations.
- Little or no automated decision analysis is possible.
- Standard products are static representations of the earth. There are no mechanisms to get higher resolution information from an authoritative source (NIMA).

NEW NIMA DATA

Based on strong recommendations by the Defense and Army Science Boards that convened in 1995, NIMA and its stakeholders developed the Geospatial Information Infrastructure Master Plan in 1997. This plan laid the groundwork for foundation-based operations, which will benefit every warfighter. Subsequently, the Geospatial Transition Plan

with an Implementation Plan was developed in 2001 in order to fulfill the information superiority tenets of Joint Vision 2010 and set the stage for compliance with Joint Vision 2020. These plans defined information superiority with respect to geospatial information as essential for mission success.

NIMA is transitioning to foundation-based operations as rapidly as resources allow, with current targets of initial operational capability in Fiscal Year 03 and full operational capability in Fiscal Year 05. The respective aspects of foundation-based operations are focused on readiness and responsiveness.

Readiness

A readiness and responsiveness strategy satisfies the need to remain engaged at the global level while ensuring the ability to rapidly respond at a local or regional level and information superiority. Foundation-based operations are the basis of this strategy, which is designed to make the best use of available resources.[22]

Foundation data, the readiness portion of the strategy results in a near-global framework of trusted geospatial content at the accuracy and resolution typically needed for strategic assessment, operational planning, safety of navigation, and targeting. This readiness data set called foundation data and includes: elevation data; cultural and physical features; controlled imagery; precise positioning data; and safety of navigation information. In addition, high-resolution digital stereo classified image data set called Digital Point Positioning Data Base (DPPDB) is used for precision targeting. Regardless of location or mission, the foundation data will be available and maintained to provide a consistent, worldwide level of preparedness or readiness. From foundation data, one can:

- Safely navigate the air and seas,
- Generate two-dimensional views of the data in the form of screen displays or hardcopy maps and charts,
- Generate three- and four-dimensional (the time factors) visual representations of the earth's surface for situational awareness,
- Conduct initial terrain analyses, and
- Produce precise locations for targeting.[23]

Responsiveness

The second step in foundation-based operations is to enhance the foundation data to produce mission-specific data sets to satisfy specific mission information needs. Mission-

specific data sets (MSDS) are more detailed than foundation data and contain more time-sensitive geospatial content to meet intended uses as defined by the customer. MSDS is a data set that is developed by the further densification of foundation data. As part of the readiness strategy, mission-specific data sets can be generated in advance where military operations are imminent and anticipated lead times are short.[24]

CHARACTERISTICS OF THE DATA

Feature

To fully support an automated decision-making and analysis process, geographic feature information is necessary. Features include: transportation, vegetation, boundaries, surface drainage, populated areas, and/or elevation data. This set of features would satisfy the requirements for populating the Foundation Feature Data (FFD) set of the readiness portion of the overall foundation-based operations. The features would have metadata (also known as data about data, data about the features). This metadata is commonly referred to as attribution. Examples of attribution are characteristics such as road width, road/runway surface types, tree types, tree stem diameter and bridge load classification available to the operators of digital display devices. This feature and attribution data will allow automated decision making functions, such as automated route selection and cross-country mobility analysis to take place. Based on this attributed feature data set, NIMA and services can prepare vital terrain analysis data in support of the military decision-making process and Intelligence Preparation of the Battlefield. Greater details of features and attribution are considered part of a mission-specific data set.

Elevation

Elevations are normally represented as points or spots, such as at mountain peaks, lake surface elevations, confluences of streams, and cultural landmarks (e.g. airports, cities, geodetic control marker locations). Cadastral survey, Global Positioning Survey, photo interpretation, or other techniques may determine elevations. The portion of the foundation-based operations readiness strategy is Digital Terrain Elevation Data (DTED) level 2. The representation of this data set is a 30-meter separation, which is approximately equivalent to the contour (line) interval on the 1:50,000 TLM discussed earlier. This medium resolution elevation data set provides warfighters the ability to locate intervisibility lines in their areas of operations using readily available line of sight algorithms and the ability to construct realistic three-dimensional views and fly throughs. Higher resolution elevation data is expected to satisfy the

MSDS requirements of warfighters. In February 2000, using a synthetic aperture radar, the Shuttle Radar Topography Mission (SRTM), imaged in 11 days what has taken NIMA more than 20 years to collect.[25] This elevation data set is expected to be available to the military on a critical needs basis (such as the ongoing Operations Enduring Freedom and Noble Eagle) to the DoD and the balance of the military, civil, and scientific users by early 2002.[26]

Imagery

The pending expansion in commercial imaging sensors and sources of geospatial information provides an unprecedented opportunity to address existing shortfalls in coverage, currency, and accuracy. Although in their infancy, multi-spectral and hyper-spectral imagery, in conjunction with advanced technologies, offer promise for automated feature extraction and automated change detection. Radar imagery is demonstrating its ability to provide day or night coverage and overcome perpetual cloud cover problems. Automated technologies for developing three-dimensional situational models are also offering potential solutions to the rapidly expanding requirements for military operations in urbanized terrain.[27] NIMA uses this quality imagery from commercial and national technical means to generate Controlled Image Base (CIB) initially in support of the readiness data set of the foundation-based operations. A higher resolution data set is projected as part of the responsive data set.

FOUNDATION-BASED OPERATIONS - TIMELY, RELEVANT, AND ACCURATE DATA

Foundation-based operations will allow the commander to request tailored sets of geospatial information by a given time, focused specifically on his mission. NIMA is setting in place the capability and mechanisms to meet the needs of the commander and his warfighters. NIMA has clearly articulated the key performance parameters (KPP) (detailed in capstone and operational requirements documents (CRD/ORD)) to be responsive to the commander's data needs for timely, relevant, and accurate geospatial information for the warfighters.

Timeliness

With foundation data, warfighters have a good start, no more Kuwait's or Grenada's where tourist and image maps had to be used. It all comes down to NIMA's ability to build on foundation data to give the warfighter what he needs when he needs it. As was stated above, the KPP has been established and when NIMA meets this benchmark, the warfighters will get what they need to be successful.

The Army has established and NIMA has accepted the timeliness and area needs of its leaders and warfighters. Those requirements for high-resolution data sets are: 20 kilometers by

20 kilometers delivered within 18 hours; 90 kilometers by 90 kilometers delivered within 72 hours and; 300 kilometers by 300 kilometers within 12 days. This is an MSDS requirement and is considered a key performance parameter by NIMA.

In addition, by 2010, NIMA will have set up portal operations from which a readiness data set will be readily available directly from a secure Internet connection. Sensors (national technical means and commercial), which can be tasked or contracted by NIMA will be available that can respond to the commander's regional requirements.

Two primary reasons for providing timely data to the warfighters are for Air Force engagement of time-critical targets and to determine the effects of seasonal changes on cover and concealment. NIMA must provide this data to meet the needs of the warfighter and it must be available before operational decisions are made.

Relevance

Although NIMA may have huge holdings of raw or processed source geospatial information, if it is not relevant to the mission of the warfighter, it will not help U.S. forces achieve information superiority. Primarily through the ability to provide responsive MSDS to a warfighter, NIMA will be able to provide geospatial information that is relevant for operations.

Relevance is a function of what the warfighter needs. Prior to the implementation of foundation-based operations, warfighters had no choice on the content of the mapping products. By making only what is needed, time and personnel assets are saved. NIMA has to resource the production mechanisms to meet the focused needs submitted by U.S. forces and provide the relevant data sets.

It is essential that the processes set in place reduce the volumes of data, pinpoint the level of detail required and enhance the relevance to a situation and add value to the decision makers. The Geospatial Transition Plan identifies the necessity for the Warfighter to have a system that enables the user to specifically identify what data are needed. The system under development by NIMA is called the Order, Entry and Tracking (OET) system. With the establishment of an OET system, this relevant and timely responsive MSDS can be available via NIMA 's secure portal operations element.

Accuracy

The primary consideration, which is independent of mission, is that geospatial information for the warfighter must be relatively stable, accurate, and tied to a common 3-D geometry. One example is the World Geodetic System 1984 (WGS 84) ellipsoid or datum. The aforementioned

imagery, elevation data, and features data sets will all be registered to this common reference system for accurate targeting and planning.

While the data from foundation-based operations is more accurate than the legacy products, its absolute accuracy will result from a user evaluating errors found while defining the position of a single feature or point in a geodetic datum or system.[28] The overall accuracy is greatly improved by proper analysis techniques.

The primary payoff of improvements in precision targeting will be the ability to use smaller munitions to create the same effect. This translates into more weapons per launch platform; more targets at risk per sortie, therefore fewer sorties, and ultimately into reduced risk to launch platforms and crews as well as lower cost. Precision targeting will also yield more controlled weapons effects, resulting in some reduction in collateral damage. While the absolute accuracy of the data is classified by NIMA, the data will meet the needs of commanders for precision targeting.

Based on the implementation of the foundation-based operations, the services (and other customers of NIMA) are anticipating a marked increase in the timeliness, relevance, and accuracy of geospatial information. The timeliness will be enhanced because of the readiness database for planning purposes and the responsiveness based on the requested mission-specific data set for tactical operations and mission execution. Data relevance should be evident based on the focused area and content in which data is required. NIMA only has to produce what the warfighter needs. A major component of this is the mission-specific data request and ability for NIMA to access or collect the right data set for the warfighter. Because of the recent acquisition of high-resolution geospatial information collected by commercial organizations, it is anticipated that NIMA will assure its customers that data sets will be extremely accurate for precise targeting and pinpoint navigation.

ADVERSARIES

The U.S. Government operates very high-resolution space-based reconnaissance systems for intelligence and military purposes. These systems are among the most valuable U.S. national security assets because of their high quality data collection, timeliness, coverage, and the capability they provide to monitor events around the world on a near real-time basis. More nations have discovered the value of these satellites and are developing their own indigenous capabilities, or are seeking the purchase of data or systems.[29]

Very little information is available in unclassified articles describing what geospatial information capabilities specific adversaries have as compared to what the U.S. military

possesses. Therefore this analysis is based on research and expectations of what is possible in 2010.

For digital geospatial information, as stated earlier, NIMA has a worldwide mission to provide data to U.S. forces and that most adversaries have the ability to focus on a single region of concern. Because data can be purchased, the emphasis of the U.S. and its partners must be to rapidly collect, process, and exploit digital geospatial information for dissemination to the warfighters.

ACCESS TO COMMERCIAL DATA

Adversaries can readily obtain digital geospatial information from commercial sources as well as open source declassified data repositories. The most accurate form this digital geospatial information comes in is imagery. Because of its availability on the open market, it can be focused on specific regions of interest to the customers.

Remote sensing is the preferred method that quality digital geospatial information is gathered. Several companies have remote sensing systems in space. These firms sell geo-referenced high-resolution imagery and multi-spectral imagery from which elevation and feature data can be extracted.

One example of a commercial firm, which is remotely sensing imagery that is used to derive geospatial information, is Space Imaging Corporation. Since its founding in late 1994, the Denver, Colorado-based Space Imaging has quickly become a world leader in digital earth information to better map, measure, monitor, and manage the world we live in - from national assets to global crop production. Space Imaging's already diverse collection of resources grew with the launch of IKONOS, the world's first one-meter resolution, commercial imaging satellite, on September 24, 1999.[30]

Another likely source for data by 'any citizen of the world' is ImageSat, International. The company is registered in the Netherland Antilles, and is headquartered in Cyprus although a source called it an Israeli corporation (ImageSat operates under a commercial remote sensing license issued by the Government of Israel). ImageSat (formally West Indian Space) successfully launched the EROS A1 (earth remote observation system) a lightweight commercial high-resolution imaging satellite on December 5, 2000.[31]

According to the Deputy Chief of Staff for Intelligence at the Army Training and Doctrine Command, in the near future, potential adversaries are investing in active and passive sensors.[32] The limitation to that investment is that sensor "satellite production will drop sharply in 2003 and continue to slide through the remainder of the decade" according to Forecast

International.[33] Based on these examples of commercial sources of remotely sensed geospatial information, it is paramount that the U.S. continually monitors the production of sensors, availability of data, and archives of data for use by adversaries.

Readiness

As previously mentioned, the importance of a readiness archive of geospatial information is easily obtained from archives or commercially by any military power or nation. From recently declassified Russian and American archives, almost any person can collect a set of elevation and feature information from which to make maps and do rudimentary terrain analysis. The data is available for purchase from multiple sources. We can assume that any potential adversary will have a set of paper maps or readiness data set of digital geospatial information necessary for battlefield/battlespace visualization.

Responsiveness

The availability of high-resolution feature, elevation and imagery data to adversaries of the U.S., from remote sensing devices in the near future (by 2010) will be limited by the ability to purchase commercial data sets. The canonical "rogue state" threats – the Iran's and Iraq's of the world – currently lack space capabilities and are unlikely to develop worthwhile space systems for many years to come. "Even Communist China, which has recently enjoyed something of a renaissance on the threat board, has declined to deploy military space systems in any appreciable quantity. Moreover, Russia is too recently departed from the enemies list to return as the baseline planning threat."[34]

WHAT ADVANTAGES DO ADVERSARIES HAVE?

The primary advantage of adversaries is not necessarily recently collected geospatial information; it is more likely the knowledge of their particular region, the scope of their concern, and the fact that they may have grown up in that area. This is the opposite of the majority of places where the U.S. military protects or defends the U.S. national interests. Therefore, the U.S. has placed a great deal of emphasis on the collection of reliable and apropos feature, elevation, and spatial imagery. Most adversaries have not placed any importance on 'non-region' high-resolution geospatial information collection.

While talking specifically about information technology, the Center for Strategic and International Studies, stated "No other nation has the range of sensor capabilities, for example, that the U.S. possesses, and therefore no other nation will gain as much from integrating sensor

data into military networks."[35] From this deduction, the U.S. must continue to apply resources toward sustaining that edge.

The investment by manufacturers in post launch remote sensing operations has become a growing trend. Alliances and partnerships involving manufacturers, operators, value-added and software companies, distributors and resellers is now commonplace within the civil and commercial remote sensing industry.

ADVERSARIES AND TIMELY, RELEVANT, AND ACCURATE DATA

From the perspective of the adversary of the U.S., geospatial information collection and exploitation will be limited by what they can buy (commercial firms) or produce with their organic national assets to accomplish battlefield/battlespace visualization. Therefore, we can assume that a reasonable set of geospatial information is available to any potential adversary. The following discussion is focused on a potential MSDS capability.

Geospatial information is used to derive additional knowledge or used directly. It is a fact that users range as wide as the geospatial information itself. Many adversaries of the U.S. may only care about finished products, not focus on the specific spatial relationships for detailed visualization of the terrain for strategic or tactical military situations. Because of this, the importance of timely, relevant, and accurate geospatial information may not be as vital to the military decision-making and battlefield/battlespace visualization processes of our adversaries as it is to us.

Timely

Initially, we assumed that foundation data is readily available for the U.S. as well as its adversaries. It is not likely that an adversary of the U.S. can redirect sensors to 'hot spots' and receive tailored MSDS unless the 'state' has immediate access to divert a commercial or national asset. At this time, the U.S. has the most capable national systems available to gather geospatial information. This information can be retrieved at the most opportune times, which are necessary for the warfighter. A telephone interview conducted with Space Imaging revealed that once a request was submitted, one-meter imagery could be delivered within 60 days for approximately $6,850, under normal conditions.[36] The image area size would be approximately 110 kilometers by 110 kilometers. This digital imagery would provide elevation and basic features information. There is no 'citizenship check' for the customer – this data is available to the world with a major credit card and a U.S. address. In another telephone inquiry to ImageSat, it offered imagery support to customers based on a standing subscription price of $1 to $5 million and a per image ("Priority Acquisition Service") cost of approximately $1,500.[37]

The company has recently released EROS A1 information about potential Iranian military activities, which strongly indicates that its mission is both military and civilian.[38] In addition, the company cannot sell imagery of less than 2-meter resolution of Israel to any customer. Earlier this year, the Israeli Ministry of Defense bought the exclusive rights to all photographs of Israeli territory and any area within a 2,000-kilometer (1,240-mile) radius taken by ImageSat International's EROS A1 civilian satellite. Eros-1 can obtain 1.8-meter resolution images.[39] An adversary is going to have a difficult time getting timely geospatial information for any military purpose.

Relevant

An adversary can get germane geospatial information to see his battlespace and that of his enemy from whatever commercial resources are at his disposal. Whether he can get the recent pertinent geospatial information from national resources or commercial resources may be possible in the next eight years if organizations such as the GCC are able to launch and put into operation regional remote sensing assets. Without an organic asset available, geospatial information can be purchased from numerous commercial firms as outlined earlier. MSDS is very relevant in urban and rugged terrain and it is unlikely that adversaries of the U.S. would be able to task assets to gain an information edge with some exceptions. The foes of the U.S. may, within the next eight years, be able to purchase an MSDS-like data set and produce the end product similar to the U.S.'s MSDS for precision munitions and responsive to particular missions. Although, adversaries believe that, by denying or threatening forward operating bases, they may delay, if not preclude, U.S. military operations. Therefore as the U.S. military transforms, it must remain cognizant of its footprint requirements when deploying ground forces.[40] Therefore, adversaries may focus on an anti-access strategy by obtaining militarily significant geospatial information on harbor facilities and airfields.

Accurate

Very few if any potential adversaries (within this decade) have established accuracy or precision standards similar to the U.S. (NIMA). This provides numerous advantages to the U.S. The primary advantage is in targeting the right location the first time (precision targeting). U.S. adversaries will generally have access to older data sources; the data may be mixed on one map sheet even if obtained from the same source. If an adversary does not employ precision weapons, it may not be important that the data available meets the rigorous accuracy standards of NIMA data. If area weapons are employed then commercial data may be accurate enough. Precision needed to avoid friendly fire and civilian casualties may not be as important to some

rogue military forces as they would be to civilized societies, therefore, true accuracy standards may not apply.

CAPABILITIES OF ADVERSARIES

As described above, adversaries of the U.S., will have difficulty obtaining timely geospatial information, may be on an equal footing in acquiring relevant data, and the accuracy may not matter based on the weapons employed. Based on this analysis, it appears clear that an adversary can obtain (procure, remotely sense, covertly acquire, etc.) geospatial information in an attempt to meet their required timelines, relevance, and accuracy standards. Thus, in order to affect U.S. view of battlespace, a strategy of denial of remote sensing capability may be appropriate. This however seems to be a remote possibility at this time and in the next several years. Foes will look for exposed seams in U.S. and adversarial commercial systems, from space to ground, and aim to destroy or damage the discrete capabilities that will cause the greatest degradation to the overall force.[41]

CONCLUSION

An information superiority edge will be sustained by adherence to NIMA established standards of timeliness, relevance, and accuracy for geospatial information. Because of the availability of geospatial information from commercial sources, adversaries of the U.S. may have an archive of readiness data that is relevant and fairly accurate, yet lack a responsiveness capability for timely high-resolution data. This lack of high-resolution geospatial information may prohibit them from rapidly and effectively reacting to dynamic military situations.

It is imperative that U.S. forces sustain the requirement for precise and absolutely dependable geospatial information for deliberate and crisis planning to maintain information dominance. NIMA will continue to implement the foundation-based operations for the U.S. forces to meet this requirement. The central focus will be on geospatial information for the warfighter to achieve battlefield/battlespace visualization. NIMA and the U.S. government will continue to take steps to establish partnerships with remote sensing and information exploitation corporations to maintain this information superiority. NIMA must build alliances with commercial firms and nations with organic remote sensing capabilities. It is also important that the U.S. enhances its education programs at universities and government institutions to maintain an upper hand in training. U.S. military leaders must understand, endorse, and fund the implementation of foundation-based operations for the U.S. to maintain that information edge.

WORD COUNT = 6,891

ENDNOTES

[1] Cynthia A. S. McKinley, "When the Enemy Has Our Eyes," 1996; available from <http://www.fas.org/spp/eprint/mckinley.htm>; Internet; accessed 27 November 2001.

[2] National Imagery and Mapping Agency, "Frequently Ask Questions," available from <http://www.nima.mil/general/faq.html#anchor833136>; Internet; accessed 19 January 2002.

[3] Department of the Army, Topographic Operations, Field Manual 3-34.230, 3 August 2000; available from <http://www.adtdl.army.mil/cgi-bin/atdl.dll/fm/3-34.230/ch1.htm>; Internet; accessed 19 January 2002.

[4] Ibid.

[5] Department of the Army, Information Operations, Field Manual 100-6 (Washington, D.C.: U.S. Department of the Army, 27 August 1996), Chapter 1.

[6] Department of Defense, Joint Tactics, Techniques, and Procedures for Geospatial Information and Services Support to Joint Operations, Joint Publication 2-03 (Washington, D.C.: U.S. Department of Defense, 31 March 1999), I-1.

[7] Department of the Army, "Concept for Army Imagery and Geospatial Information and Services, Version 3.0 Draft" (Fort Leonard Wood, MO: U.S. Department of the Army, October 2001), 4.

[8] National Imagery and Mapping Agency, "NIMA Commission Report;" August 2000; available from <http://www.nimacommission.com/article05.htm#3.3>; Internet; accessed 19 January 2002.

[9] National Oceanography and Atmospheric Administration, "About Land Cover and Change Analysis Data," available from <http://www.csc.noaa.gov/products/sccoasts/html/ccapdat.htm>; Internet; accessed 19 December 2001.

[10] Warren Ferster and Gopal Ratnam, "GCC Mulls Spy Satellite," Defense News, 10 December 2001, 1.

[11] Ibid.

[12] Department of Defense, Department of Defense Dictionary of Military and Associated Terms, Joint Publication 1-02 (Washington, D.C.: U.S. Department of Defense, 12 April 2001 (as amended through 15 October 2001), 216.

[13] Department of Defense, Joint Tactics, Techniques, and Procedures for Geospatial Information and Services Support to Joint Operations, I-9.

[14] Department of Defense, Joint Vision 2020 (Washington, D.C., U.S. Government Printing Office, 2000), 3. Note that information superiority is also a key enabler of the transformation of the 'strategic' capabilities of the joint force and the evolution of joint command and control.

[15] National Imagery and Mapping Agency, Geospatial Transition Plan (Bethesda, MD: National Imagery and Mapping Agency, August 2001), GTP1.

[16] Rudi Williams, "NIMA: The Eyes of America," Space Daily, 19 February 2001, available from <http://www.spacer.com/news/milspace-01f.html>; Internet; accessed 10 November 2001.

[17] Director of Central Intelligence/Central Intelligence Agency, "National Imagery and Mapping Agency," available from <http://www.odci.gov/ic/nima.html> Internet; accessed 29 November 2001.

[18] National Imagery and Mapping Agency, "Frequently Ask Questions," available from <http://www.nima.mil>; Internet; accessed 19 December 2001.

[19] Hunter Keeter, "NIMA Lacks Resources to Support Multiple Conflicts," Defense Daily, May 10, 1999; Library resource <http://proquest.umi.com>; Internet; accessed 18 December 2001.

[20] National Imagery and Mapping Agency, "Geospatial Information Infrastructure Master Plan, Volume 1, October 1997," available from <http://www.fas.org/irp/agency/nima/masterplan/vol1/vol1body.htm#I2>; Internet; accessed 22 January 2002.

[21] Department of the Air Force, "USAF Intelligence Targeting Guide," available from <http://www.fas.org/irp/doddir/usaf/afpam14-210/part13.htm>; Internet; accessed 19 January 2002.

[22] National Imagery and Mapping Agency, Geospatial Transition Plan, GTP2.

[23] Ibid., GTP2.

[24] Ibid., GTP3.

[25] Robert K. Ackerman, "Balkans serve as providing ground for operational imagery support," Signal, October 1999, 17-20.

[26]Ackerman, 17-20.

[27] National Imagery and Mapping Agency, Geospatial Transition Plan, GTP5.

[28] Academic Press Dictionary of Science and Technology, available from <http://www.harcourt.com/dictionary/def/3/2/6/0/32600.html>; Internet; accessed 11 February 2002.

[29] Federation of American Scientists, "Fact Sheet, Foreign Access to Remote Sensing Space Capabilities," available from <http://www.fas.org/irp/offdocs/pdd23-2.htm>; Internet; accessed 19 January 2002.

[30] Space Imaging, LLC, available from <http://www.spaceimaging.com/aboutus/overview1.htm>, Internet; accessed 19 December 2001.

[31] ImageSat, International, available from <http://www.imagesatintl.com/800/news/press.html>; Internet; accessed 17 January 2002.

[32] U.S. Army Training and Doctrine Command, Deputy Chief of Staff for Intelligence, "The Future Operational Environment and Threat: A View of the World in 2015," (Fort Monroe, VA, U.S. Department of the Army, Draft, Not for Distribution, 4 October 2001), 4.

[33] Amy-Jane Wade, "Remote Sensing Satellite Production Headed for Slump," Forecast International, Inc., 18 April 2001, available from <www.forecast1.com/press/press27.htm>, Internet; accessed 23 January 2002.

[34] Federation of American Scientists, "American Control of Outer Space in the Third Millennium," available from <www.fas.org/spp/eprint/space9811.htm>, Internet; accessed 14 January 2002.

[35] Center for Strategic and International Studies, "Computer Exports and National Security, A Report of the Center for Strategic and International Studies Commission on Technology Security in the Twenty-First Century, Multilateral Cooperation on Export Controls," (Washington, D.C., Center for Strategic and International Studies, June 2001, 28.

[36] Sales Associate, Space Imaging Corporation, telephone interview by author, 17 January 2002. Specific information gathered was that a customer could request an orthorectified image of a 'geo-product' (one meter black and white image) costing $18 per km2 over North America, $25 per km2 over most other international areas, and $35 per km2 over what are considered to be sensitive areas. Sensitive areas are determined by U.S. government officials and corporate leadership.

[37] Sales Associate, Image Sat, International, telephone interview by author, 17 January. Specific information gathered was that a customer could request an orthorectified image of a product (one meter black and white image) costing $10 per km2 to $25 per km2 over most international areas. A per image cost if one had a standing subscription could vary. Sensitive areas are determined by corporate leadership.

[38] Doug Richardson, Jane's Missiles and Rockets, "Strategic and Sub-Strategic," 1 September 2001, available from <http://www.imagesatintl.com/800/dloads/Janes_article_shahab.pdf>; Internet; accessed 17 January 2002.

[39] Maryann Lawlor, "Satellite Images Capture Picture Perfect Future," Signal, 1 March 2001, available from <http://www.us.net/signal/Archive/Mar01/satellite-march.html>; Internet; accessed 21 January 2002.

[40] U.S. Army Training and Doctrine Command, Deputy Chief of Staff for Intelligence, "The Future Operational Environment and Threat, 4.

[41] Ibid., 6.

BIBLIOGRAPHY

Academic Press Dictionary of Science and Technology. Available from <http://www.harcourt.com/dictionary/def/3/2/6/0/32600.html>. Internet. Accessed 11 February 2002.

Ackerman, Robert K. "Balkans serve as providing ground for operational imagery support." Signal. Fort Gordon, GA: U.S. Department of the Army. October 1999.

Center for Strategic and International Studies. "Computer Exports and National Security, A Report of the Center for Strategic and International Studies Commission on Technology Security in the Twenty-First Century, Multilateral Cooperation on Export Controls." Washington, D.C.: Center for Strategic and International Studies. June 2001

Clinton, William J. A National Security Strategy for a Global Age, Washington, D.C.: U.S. Government Printing Office, 2000.

Federation of American Scientists. "American Control of Outer Space in the Third Millennium." Available from <www.fas.org/spp/eprint/space9811.htm>. Internet. Accessed 14 January 2002.

Federation of American Scientists. "Fact Sheet, Foreign Access to Remote Sensing Space Capabilities." Available from <http://www.fas.org/irp/offdocs/pdd23-2.htm>. Internet. Accessed 19 January 2002.

Ferster, Warren and Gopal Ratnam. "GCC Mulls Spy Satellite." Defense News. 10 December 2001.

Flournoy, Michele A., QDR 2001: Strategy-driven choices for America's Security. Washington, D.C.: National Defense University Press, 2001.

Griffith, Samuel B. Sun Tzu, The Art of War. New York: Oxford University Press, 1963.

Imagery and Geospatial Information Integrated Concept Team. Concept for Army Imagery and Geospatial Information and Services, Version 3.0 Draft. Fort Leonard Wood, MO: U.S. Army Engineer School, October 2001.

ImageSat, International. Available from <http://www.imagesatintl.com/800/news/press.html>. Internet. Accessed 17 January 2002.

Keeter, Hunter. "NIMA Lacks Resources to Support Multiple Conflicts." Defense Daily. May 10, 1999. Available from <http://proquest.umi.com>. Internet. Accessed 18 December 2001.

Lawlor, Maryann. "Satellite Images Capture Picture Perfect Future." Signal. 1 March 2001. Available from <http://www.us.net/signal/Archive/Mar01/satellite-march.html>. Internet. Accessed 21 January 2002.

Lewis, James A. Computer Exports and National Security, New Tools for a New Century, A Report of the CSIS Commission on Technology Security in the Twenty-First Century. Washington, D.C.: Center for Strategic and International Studies Press, 2001.

Lykke, Jr., Arthur F. "Toward An Understanding of Military Strategy." In U.S. Army War College Guide to Strategy, edited by Joseph R. Cerami and James F. Holcomb. Carlisle Barracks, PA: U.S. Army War College Strategic Studies Institute, 2001.

McKinley, Cynthia A. S. "When the Enemy Has Our Eyes." 1996. Available from <http://www.fas.org/spp/eprint/mckinley.htm>. Internet. Accessed 27 November 2001.

National Imagery and Mapping Agency. "Geospatial Information Infrastructure Master Plan, Volume 1, October 1997." Available from <http://www.fas.org/irp/agency/nima/masterplan/vol1/vol1body.htm#I2>. Internet. Accessed 22 January 2002.

National Imagery and Mapping Agency. Available from <http://www.nima.mil>. Internet. Accessed 15 September 2001.

National Imagery and Mapping Agency. "Report of the Independent Commission on the National Imagery and Mapping Agency." August 2000. Available from <http://www.nimacommission.com/index.htm>. Internet. Accessed 16 September 2001.

National Imagery and Mapping Agency. Geospatial Transition Plan. Bethesda, MD: National Imagery and Mapping Agency, August 2001.

Richardson, Doug. "Jane's Missiles and Rockets." Strategic and Sub-Strategic. 1 September 2001. Available from <http://www.imagesatintl.com/800/dloads/Janes_article_shahab.pdf>. Internet. Accessed 17 January 2002.

Space Imaging, Limited Liability Company. Available from <http://www.spaceimaging.com/aboutus/overview1.htm>. Internet. Accessed 19 December 2001.

U.S. Army Training and Doctrine Command, Deputy Chief of Staff for Intelligence. "The Future Operational Environment and Threat: A View of the World in 2015, Draft, Not for Distribution." Fort Monroe, VA: U.S. Department of the Army. 4 October 2001

U.S. Department of Defense. Department of Defense Dictionary of Military and Associated Terms. Joint Publication 1-02. Washington, D.C.: U.S. Department of Defense. 12 April 2001, as amended through 15 October 2001.

U.S. Department of Defense. Doctrine for Command, Control, Communications, and Computers (C4) Systems Support to Joint Operations. Joint Publication 6-0. Washington, D.C.: U.S. Department of Defense, 1995.

U.S. Department of Defense. Doctrine for Intelligence Support for Joint Operations. Joint Publication 2-0. Washington, D.C.: U.S. Department of Defense, 2000.

U.S. Department of Defense. Doctrine for Joint Operations. Joint Publication 3-0. Washington, D.C.: U.S. Department of Defense, 1995.

U.S. Department of Defense. Joint Doctrine for Employment of Operational/Tactical Command, Control, Communications, and Computer, Systems. Joint Publication 6-02. Washington, D.C.: U.S. Department of Defense, 1996.

U.S. Department of Defense. Joint Tactics, Techniques and Procedures for Joint Intelligence Preparation of the Battlespace. Joint Publication 2-01.3. Washington, D.C.: U.S. Department of Defense, 2000.

U.S. Department of Defense. Joint Tactics, Techniques and Procedures for Geospatial Information and Services Support to Joint Operations. Joint Publication 2-03. Washington, D.C.: U.S. Department of Defense. 1999.

U.S. Department of Defense. Joint Vision 2020. Washington, D.C.: U.S. Department of Defense, 2000.

U.S. Department of the Air Force. "USAF Intelligence Targeting Guide." Available from <http://www.fas.org/irp/doddir/usaf/afpam14-210/part13.htm>. Internet. Accessed 19 January 2002.

U.S. Department of the Army. Information Operations. Field Manual 100-6. Washington, D.C.: U.S. Department of the Army, 27 August 1996.

U.S. Department of the Army. Topographic Operations. Field Manual 3-34.230. 3 August 2000. Available from <http://www.adtdl.army.mil/cgi-bin/atdl.dll/fm/3-34.230/ch1.htm>. Internet. Accessed 19 January 2002.

U.S. Director of Central Intelligence/Central Intelligence Agency. "National Imagery and Mapping Agency." Available from <http://www.odci.gov/ic/nima.html>. Internet. Accessed 29 November 2001.

U.S. National Oceanography and Atmospheric Administration. "About Land Cover and Change Analysis Data." Available from <http://www.csc.noaa.gov/products/sccoasts/html/ccapdat.htm>. Internet. Accessed 19 December 2001.

Wade, Amy-Jane. "Remote Sensing Satellite Production Headed for Slump." Forecast International, Inc. 18 April 2001. Available from <www.forecast1.com/press/press27.htm>. Internet. Accessed 23 January 2002.

Williams, Rudi. "NIMA: The Eyes of America." Space Daily. 19 February 2001. Available from <http://www.spacer.com/news/milspace-01f.html>. Internet. Accessed 10 November 2001.