Report of the Joint
Defense Science Board
Intelligence Science Board
Task Force on

Integrating Sensor-Collected Intelligence

November 2008

Office of the Under Secretary of Defense
for Acquisition, Technology, and Logistics
Washington, D.C. 20301-3140

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The Joint DSB/ISB Task Force on Integrating Sensor-Collected Intelligence completed its information gathering in January 2008.

This report is UNCLASSIFIED and releasable to the public.

OFFICE OF THE SECRETARY OF DEFENSE
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Washington, DC 20301-3140

DEFENSE SCIENCE BOARD

28 October 2008

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR ACQUISITION, TECHNOLOGY & LOGISTICS

SUBJECT: Final Report of the Defense Science Board (DSB) and the Intelligence Science Board (ISB) Joint Task Force on Integrating Sensor Collected Intelligence

I am pleased to forward the final report of the joint DSB/ISB Task Force on Integrating Sensor Collected Intelligence, co-chaired by Mr. Larry Meador, Mr. James Shields, and Mr. John Stenbit.

As requested in the Terms of Reference the Task Force was asked to determine what improvements are needed in tasking, collecting, processing, data storage and fusion, and the dissemination of information collected by Intelligence, Surveillance, and Reconnaissance (ISR) systems. In addition the Task Force was asked to examine the mix and balance of sensors across the entire spectrum with a view to identifying critical coverage gaps and areas of redundancy; and current and planned systems for vulnerabilities, new opportunities and potential problems associated with emerging opportunities, and consistency with the Department's net-centric strategy.

The final report addresses the tasking in the Terms of Reference and provides critical and performance improvement recommendations. The report also details the Task Force's two principal recommendations which include deploying urgent communications improvements including TSAT as soon as possible as well as metadata tagging of sensor-collected data as close to the sensor as possible.

I endorse the Task Force's findings and recommendations and encourage you to review the report.

Dr. William Schneider, Jr.
DSB Chairman

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DEFENSE SCIENCE
BOARD

October 14, 2008

MEMORANDUM FOR: CHAIRMAN, DEFENSE SCIENCE BOARD AND
CHAIRMAN, INTELLIGENCE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board and the Intelligence Science Board Joint Task Force on Integrating Sensor Collected Intelligence

Attached is the final report of the Defense Science Board and Intelligence Science Board Joint Task Force on Integrating Sensor Collected Intelligence. As directed, we reviewed the mix and balance of sensors across the spectrum with the goal of identifying gaps and shortfalls and determining the improvements needed in the full cycle from tasking to collection to posting for all and subsequent dissemination of the information gathered by intelligence, surveillance and reconnaissance (ISR) systems.

The task force noted the robust plans for acquisition and deployment of airborne ISR with particular emphasis on unmanned platforms. We also observed the more fragile state of satellite-based ISR due to the effects of well-documented execution problems with key overhead sensor acquisition programs and the changing world events that increased demands beyond the capacity of the current and planned capabilities. The report identifies the gaps that could develop as a result of this situation.

Many of the most challenging intelligence targets – including detecting WMD and its precursor agents, tracking people and characterizing deeply-buried targets – require that the relevant sensors be in close proximity to the target. The task force discussed the requirements of close-in ISR including unique platforms to deliver the sensor to the target area, specialized sensors to detect the faint signals of interest and tailored exfiltration techniques to get the data back from the sensors. The task force recommended that research and development efforts continue to address the most difficult signatures and the close-in ISR requirements.

While we reviewed the state of sensor technology, the task force concluded that more and better sensors alone are not the answer to the ISR problem. In particular, the most relevant conclusion of our study was the identification of the performance potential of integrating data from different sensors and platforms. *We determined that signal-to-noise improvements, over the performance of a single sensor, of 4 to 8 dB, factors of 10 reductions in convergence and identification times, and as much as 100 times better geolocation accuracy were achievable through multi-sensor integration.* Achieving this level of performance with improved sensor technology alone would be much more expensive if it were achievable at all.

Providing the infrastructure for the envisioned integration of sensor collected intelligence data requires that the Department and Intelligence Community extend and expand the investments they have been making in creating a network-centric enterprise. Specifically, the key elements of the recommended architecture include an assured broadband, ubiquitous communications system and implementation of the Department's net-centric data strategy that separates data, applications, and business process descriptions and meta-data tags all elements to make them visible, available and usable when and where needed. In addition to enabling the performance improvement from sensor data integration discussed above, this architecture also alleviates major bottlenecks in the existing ISR process allowing the system to better handle the rapidly increasing volumes of data being generated.

The two principal recommendations from the study are to:

- Deploy TSAT (Transformational Communications Satellite) as soon as possible to supply the assured, high-capacity communications for moving ISR data to the backbone network and to provide assured networking-on-the-move for mobile tactical users.
- Meta-data tag sensor-collected data as close to the sensor as possible using meta-data that includes, at a minimum, time, location and sensor calibration parameters.

The attached report provides the rationale for these recommendations, additional findings, and recommendations at a much higher level of implementation detail.

We speak for all members of the Joint Task Force in expressing our appreciation for the outstanding contributions made by the Department of Defense and Intelligence Community professionals who spoke, and occasionally debated with us; the government advisors and SAIC staff who supported our activities including the writing of this report; and the DSB Secretariat and its Executive Director and its military assistants. We also appreciate the support and guidance provided by the sponsors of the Joint Task Force including the Undersecretary of Defense for Acquisition, Technology and Logistics, the Undersecretary of Defense for Intelligence, the Commander, U.S. Strategic Command, and the Director for Force Structure, Resources and Assessment on the Joint Staff.

Larry Meador
Co-Chairman

James D. Shields
Co-Chairman

John Stenbit
Co-Chairman

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FOREWORD

This report summarizes the work of the Defense Science Board Task Force on Integrating Sensor-Collected Intelligence. The report consists of an Executive Summary; Introduction; chapters on the Benefits of Integrating Sensor-Collected Data, Required Communications Infrastructure, Net-Centric Data Strategy, Improving Sensor Tasking, Leveraging Processing and Exploitation, Sensors Gaps and Shortfalls; Findings and Recommendations; and unclassified and classified Appendices.

Appendix A: Terms of Reference

Appendix B: Task Force Membership

Appendix C: Briefings Received

Appendix D: Benefits of Sensor Integration - classified[1]

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Appendix F: Tasking – classified

Appendix G: Sensors Gaps and Shortfalls -- classified

Appendix H: Acronyms and Glossary of Terms

[1] For a copy of the classified appendices please contact the Defense Science Board office at 703-571-0081 or DSBOffice@osd.mil.

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EXECUTIVE SUMMARY

Sensor-collected Intelligence/Surveillance/Reconnaissance (ISR) data have proven invaluable to both national decision makers and to battlefield commanders. Despite significant increases in the number of sensors, largely on unmanned aerial vehicle (UAV) platforms at both the theater and tactical level, demands for information, particularly to support operations in Iraq and Afghanistan, continue to increase. The task force was charged to review the mix and balance of sensors across the spectrum with the goal of identifying gaps and shortfalls and to determine the improvements needed in the full cycle from tasking to collection to posting for all and subsequent dissemination of the information gathered by intelligence, surveillance and reconnaissance (ISR) systems.

More Sensors Alone Are Not the Answer

The rapid proliferation of sensors both enables and overwhelms the current ISR infrastructure. The number of images and signal intercepts are well beyond the capacity of the existing analyst community so there are huge backlogs for translators and image interpreters and much of the collected data are never reviewed.

Further, decision makers and intelligence analysts have difficulty knowing what information is available. Most collection requests, particularly for sensors beyond the commander's control, go to central tasking systems that provide little feedback on whether or when the request will be satisfied. Access to ISR information is equally problematic. Large staffs, often numbering in the thousands, are required in theater to accept and organize data that are broadcast in a bulk-distribution manner. These analysts spend much of their time inefficiently sorting through this volume of information to find the small subset that they believe is relevant to the commander's needs rather than interpreting and exploiting the data selected on current needs to create useful information.

The investment made by the Department of Defense and the Intelligence Community over the last decade in creating the infrastructure for network-centric operations provides a way to address many of the problems with ISR data collection and processing. The task force noted recent ISR processing developments, such as the Distributed Common Ground System (DCGS) and RT^{10}, where ISR sensor data are posted to a shared data store along with meta-data to describe them. The meta-data are searchable, allowing users to pull data of interest in a manner similar to Internet searches. We believe that the Defense Department and Intelligence Agencies should take all possible actions to accelerate the transition to this new paradigm leveraging the integrated sensor-collected intelligence architecture as shown in Figure 1.

The key elements of this architecture include assured broadband, ubiquitous communications system and implementation of the Department's data strategy, which calls for separation of data and applications and meta-data tagging. The communications[2] capability includes two major components – a *terrestrial-based high capacity core* built on the Defense Information System Network (DISN) investment (largely through the Global Information Grid – Bandwidth Expansion (GIG-BE) program) to provide the capability to transfer data from sensors to accessible storage and *satellite and airborne links* to download sensor data to the core and to

[2] While nomenclature is inconsistent, this entire communications system is often referred to as the Global Information Grid (GIG).

provide mobile users access to the ISR data. The meta-data tagging makes the sensor information discoverable by authorized users. The recommended architecture has not only the potential to alleviate the major bottlenecks in the existing ISR process but it also facilitates integrating data from multiple ISR sensors to provide important improvements in sensitivity and detection times, thereby increasing the performance of whatever sensor systems are acquired and deployed.

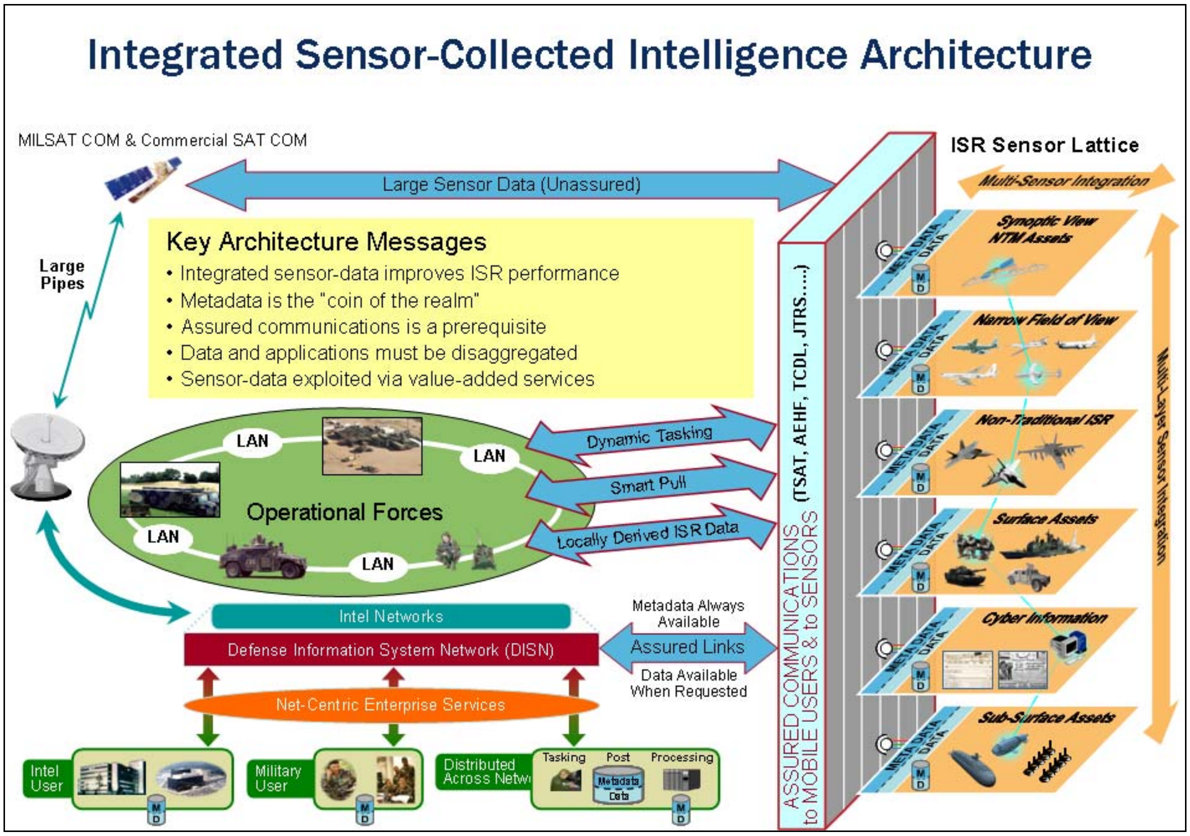

Figure 1: Integrated Sensor-Collected Intelligence Architecture

While this report will demonstrate the significant benefits of using the recommended architecture to integrate data from multiple sensors, this approach is not without vulnerabilities. Chief among them are weaknesses similar to all other aspects of network centric operations; namely, an increased reliance on the successful operation of a globally-interconnected computer and communications infrastructure. Because many others are investigating these threats, the task force did not explore them in detail other than to highlight the need to protect against physical, electronic and cyber attacks on the required computer-communications infrastructure and to prepare for the effects of such attacks by exercising regularly in degraded modes.

Integrating Data from Multiple Sensors Will Dramatically Enhance ISR Capabilities

The ability to integrate data from sensors with different characteristics offers the potential of significant performance improvements over what could be achieved from each sensor separately. The task force investigated this topic in detail with the goal of quantifying the potential improvements. Chapter 2 and Appendix D present the results of this effort and demonstrate signal-to-noise improvements of 4 to 8 dB, factors of 10 reductions in convergence and identification times, and as much as 100 times better geolocation accuracy than a single sensor.

These improvements, which were shown with operational experiments using fielded sensors in some cases and through detailed simulation studies in others, are the result of effects achievable only by integrating data from multiple sensors, such as:

- Better detection geometries due to geographically separated platforms.
- Lower detection thresholds with false alarm control by requiring detection by more than one sensor.
- Cueing by one sensor to initiate tracking in another.
- Angle diversity for radar sensors on different platforms.

Attempting to achieve comparable levels of performance by improving only the design or deployment of single sensor systems would dramatically increase the associated cost, complexity and risk and might not be attainable. The task force recommends that the value of multi-sensor integration be factored into the future integrated sensor-collected intelligence architecture and subsequently into ISR acquisition programs (see Chapter 7 for details).

In this study, the task force took a broad view of what constituted a "sensor." We observed that there are classes of intelligence problems – such as determining the intent of nations and their leaders, detecting and tracking people, monitoring deeply buried facilities and discovering WMD and its precursor agents – that may be difficult or impossible for physical sensors due to lack of detectable signatures. In these cases, human intelligence (HUMINT), cyber ISR and other nontraditional techniques will be essential. In information poor situations, where the required sensors do not exist or where access to the target is very limited, the benefits of sensor integration will be hard to achieve. However, if there are relevant physical signals, even if they are very weak, the recommended architecture will improve performance of traditional sensors by enhancing the ability to integrate these data with HUMINT, cyber and other nontraditional information.

Widely-accessible Assured, Broadband Communications and Meta-Data Tagging Are Essential

Assured[3] Broadband Communications – The ability to transform ISR sensor data processing and exploitation from a stove-piped, analyst-controlled environment to a network-enabled, user-controlled Google-like search environment depends on assured communications. These communications must support movement of sensor data to the high bandwidth terrestrial backbone and enable authorized users to access data asynchronously and use the search and retrieval services envisioned in the integrated sensor-collected intelligence architecture.

Currently, as a result of the Department's investment in GIG-BE, a very high bandwidth (10 GB/sec), terrestrially-based fiber optic Internet Protocol (IP) network connects approximately 100 DoD sites around the world. This network provides the communications backbone capability that is the foundation for the envisioned architecture. However, today DoD relies on

[3] The Task Force used the term "assured" to include protection from a broad range of threats to communications including jamming, cyber attacks, physical attacks, etc. In effect, assured communications means freedom of action – the channel is available for use when desired and the adversary cannot deny or significantly degrade the capability.

unassured commercial and DoD communications satellites to transfer ISR data from the sensor platforms. Intra-theater communications are generally provided by terrestrial links (that are often fiber optic and a part of DISN) for large fixed installations and by radio frequency (RF) links, either terrestrial or satellite based, with protocols that may not support the IP for mobile users. Data capacity of a communications channel increases with the frequency of the carrier. The ISR information needs of most mobile users require a communications channel bandwidth which necessitates a transmission frequency so high that there must be a clear line-of-sight between the user and the transmitter. As a result, satellite or airborne-based communications relays are much more effective than horizontal communications among ground-based radios.

The task force recommends the following actions:

- Deploy TSAT[4] as soon as possible to provide the assured high-capacity communications for moving ISR data to the backbone and to provide assured networking-on-the-move for mobile tactical users.
- Integrate the core Intelligence Community transport networks (such as the National Reconnaissance Office (NRO) fiber backbone) with the DoD broadband backbone to ensure that anyone connected to any of the networks can discover and search all the meta-data using applications such as the DCGS Integration Backbone (DIB). Subsequently, selected data should be available to all authorized users.
- Ensure that intra-theater communications for ships-at-sea, small units and forces-on-the-move are compatible with the integrated sensor-collected intelligence architecture by quickly providing assured IP access to concentrators that access the DISN backbone. This initial capability will serve as a backup to TSAT after its deployment. Development of a flexible software-defined radio, such as JTRS[5], is an important capability to provide the required intra-theater connectivity.
- Require all forces to plan for and exercise in degraded communications and degraded/corrupted information access environments because the recommended ISR data access and associated reach-back processing functions are critically dependent on these capabilities.

Meta-Data Tagging – The Department's and Agencies' Data Strategy is focused on ensuring that data are visible, available and usable when and where needed. It states that data (intelligence, non-intelligence, raw and processed) will be tagged with meta-data, or data describing the data, to enable discovery. It calls for data to be posted to shared spaces to provide access to users except as limited by security, policy or regulation. Achieving the desired access to data will be greatly enhanced if all the core networks are integrated as the task force has recommended.

The Strategy also introduces the concept of managing data within Communities of Interest (COIs) rather than calling for standardization of data across the enterprise. While the Strategy is key to achieving the benefits of net-centricity, it should be noted that the Strategy was published in the spring of 2003 and that implementation has been slow. One area of concern is the progress of the COIs, with the trade between increasing the size of the COIs for optimized

[4] Transformational Communications Satellite
[5] Joint Tactical Radio System

performance and on-the-spot data sharing and smaller COIs with the attendant ease in defining the vocabularies and meta-data being a key issue. Since much sensor-collected data are geographically focused, meta-data elements that define when the data were gathered and where the sensor was directed are critical to integration. Every sensor system must have a very accurate time reference and use it to tag collected data. There has been extensive debate about the definition and format of core meta-data such as time and location (achieving agreement is referred to as "aligning" the meta-data). The task force strongly recommends that these debates not delay the collection of these meta-data for all ISR systems because it is straightforward to translate these meta-data into a common syntax to support integration and nearly impossible to find related data and do integration without them.

To push forward in achieving the benefits of ISR data integration, the task force recommends the following:

- Tag sensor-collected data with meta-data as close to the sensor as possible using meta-data that includes, at a minimum time, location and sensor calibration.
- Empower and fund Communities of Interest focused on aligned vocabularies and pilots for ISR data integration. In this effort, leverage the work of national and international standards bodies.
- Establish goals and incentives to address behavioral and social impediments to information sharing.
- Push for enterprise services and search tools. Tag both applications and value-added services with meta-data to enhance their discovery.
- Support the single DoD/DNI data strategy governance structure and enforce its execution.

Finally, the task force encourages the Department and Agencies to do everything possible to get data into the hands of the users, including:

- Adding a capability for users to tag data and for using these user-generated tags for discovery.
- Incorporating access to tagged repositories currently in use in theater into the registries and making these data stores discoverable and accessible.

Improvements in Tasking, Exploitation and Sensors Yield Multiple Benefits

Sensor Tasking Must Be More Flexible – Current ISR tasking systems generate significant frustration with users because they must balance priorities from many different stakeholders, all of whom have legitimate intelligence needs and often lack visibility into the importance of competing demands for the valuable sensor assets. This difficult situation is aggravated by the fact that there is limited transparency into the decision process and almost no feedback to users relative to the status of their requests.

As a result, there is significant demand, particularly from battlefield commanders, for more direct control of ISR collection assets. Stove-piped tasking of assets makes it difficult to optimize sensor utilization for maximum collection. The issues of trust and control must be addressed directly to make improvements in the ISR tasking process. The task force observed several promising research activities and experiments including the DARPA Heterogeneous Urban RSTA (Reconnaissance Surveillance and Target Acquisition) Team (HURT) and the

Intelligence Community's HISIT programs that are making progress in this area, and we recommend that they be continued.

The task force recommends the following additional actions:

- Post collection plans and status for all strategic and tactical ISR assets to a shared space and meta-data tag the data so that it is discoverable by all authorized users.
- Revise the approach to collection management from the current sensor modality (i.e., IMINT, SIGINT…) perspective to the intelligence need level to allow the collection system to be more dynamic and supportive of cross-platform/INT coordination.
- Develop techniques for closed loop dynamic tasking to take advantage of operational sensor integration through tipping and cueing.
- Develop value models and tools for ISR sensor tasking optimization that are informed by physics-oriented sensor, target and phenomenology characteristics.
- Conduct frequent integrated tasking exercises, such as EIX-08 and Integrated Collection Management (ICM). Design these experiments and exercises to encourage collaboration across organizations to build trust and confidence in the tasking system by all stakeholders.

Processing and Exploitation Must Leverage Appropriate Human-System Collaboration – The volume of ISR data requires computer-assisted automation if the intelligence analysts and operators are to have any hope of coping. However, research in fully automated target recognition, while promising, has failed to deliver effective solutions. One of the impediments has been the lack of realistic test/training data. Algorithms designed with simulated data have not performed as expected when confronted with real-world data. The task force believes that the goal of fully automated processing and exploitation will continue to be elusive.

The task force recommends:

- Promote a 3-layer ISR exploitation paradigm that separates data from the processing applications, meta-data tags the data to make them discoverable, and separates the presentation from the application using commercial web-based presentation tools where possible.
- Allow multiple value-added services to access and process the same data for different analytic purposes and ensure that the results of all processing are meta-data tagged and posted to a shared space.
- Provide realistic data and operationally-relevant processing and exploitation challenge problems to the community.
- Focus R&D on the computer processing--analyst exploitation boundary and exploit advances in human-systems collaboration.
- Develop model-based exploitation techniques using models that leverage those employed for physics-based tasking optimization.
- Continue to use military and intelligence exercises (e.g., Empire Challenge) to demonstrate progress.

Challenging Signals Require Balanced Sensor Systems – The task force did not conduct an extensive review of current and planned ISR sensor programs. However, we did observe that there are robust plans for acquisition and deployment of airborne ISR, with particular emphasis on unmanned platforms. Even with increased availability there is a growing demand for these airborne systems, especially those that provide full motion video in support of current operations. On the other hand, the situation relative to satellite-based ISR is much more fragile. There was a purposeful drawdown of these systems following the Cold War and modernization programs were planned to replace only a fraction of the former assets. Further, well-documented execution problems have left the U.S. behind its overhead ISR plans. Changing world events have increased demands beyond those of the planned capability. As a result, existing capability is under stress and significant gaps, as discussed in Appendix G, could develop.

Current operations in Iraq and Afghanistan are dramatically increasing the demand by operational commanders for persistent surveillance with full-motion video optical sensors. This demand places huge burdens on communications and image processing infrastructure. While full motion video is an attractive option because of its compatibility with video monitors and commanders' familiarity with viewing television, **the task force recommends that a systems perspective be adopted relative to persistent surveillance requirements.** Image resolution needs to be defined by the size of the target of interest, and sensor revisit times or frame rates need to be a function of the time-dynamics of what the target is expected to be doing. High resolution may very well be required, but there may not be many situations where high video frame rates are necessary. Designing for a balanced system based on these requirements can easily reduce communication bandwidth by an order of magnitude or more.

The task force recommends that future sensor-platform system development programs leverage the benefits of multi-sensor integration identified in this study. Specifically, we **recommend that future acquisition programs disaggregate sensors from platforms with the goal of acquiring more platforms with potentially less capable, and therefore less costly, sensors and plan to achieve increased performance by integrating data from multiple sensors/platforms.** There are two important prerequisites for this acquisition strategy, which should be adopted for as many programs as possible (this should include adding these requirements to existing systems). The first is to buy sensor calibration data from the development contractor (much of this is already generated for development testing). The second is to add meta-data tags to the sensor data as close as possible to the point and time of collection and to ensure that the meta-data includes the sensor calibration data.

Many of the most challenging intelligence targets – including detecting WMD and its precursor agents, tracking people and characterizing deeply-buried facilities – require the sensor be in close proximity to the target. Close-in ISR requires unique platforms to deliver the sensor to the target area, specialized sensors to detect the faint signals of interest, and tailored exfiltration techniques to get the data back from the sensor. To date, most of these missions have been planned on an ad hoc basis and have been matched to a specific scenario. With the increased frequency of these collection needs, **the task force recommends that a broader systems view be developed for addressing close-in ISR requirements.**

Finally, the task force reviewed the status of research on sensors for detecting WMD, characterizing deeply-buried facilities, seeing into dense foliage and complex urban environments. Chapter 7 summarizes this status and recommends specific promising technologies for continued development.

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CHAPTER 1: INTRODUCTION

1.1 Background

In February 2007, the Under Secretary of Defense for Acquisition, Technology and Logistics USD(AT&L) commissioned a Defense Science Board (DSB) Task Force on Integrating Sensor-Collected Intelligence. The objectives of the study were to assess the adequacy of current and planned ISR; determine what improvements are needed in collection, processing, data storage and fusion, exploitation, and dissemination of information collected by ISR systems; examine the mix and balance of sensors across the entire spectrum with a view to identifying critical coverage gaps and areas of redundancy; and review current and planned systems for vulnerabilities, new opportunities and potential problems associated with emerging opportunities, and consistency with the Department's net-centric strategy. The chairs of the DSB and the Intelligence Science Board (ISB) concluded that there was a large intersection set of combined interests and objectives in this area between the two Boards. A decision was made to pursue these issues in a Joint Task Force with leadership and members from both Boards actively contributing. The results of this work are presented herein.

1.2 Challenge and Opportunity

The evolving international security landscape has become much more complicated, diverse, distributed and challenging with much shorter time constants than those that existed in the days of the Soviet Union. The dimensions in Figure 2 abstract many of the critical differences between the security challenges of the past, and what the U.S. currently faces and will probably face well into the future.

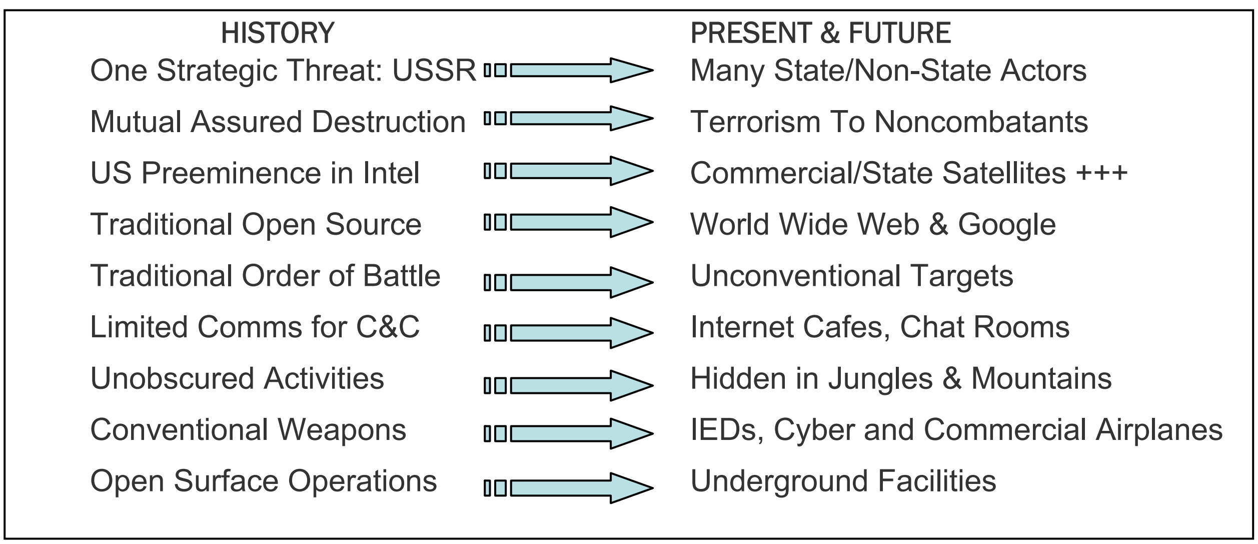


Figure 2: The Evolving International Security Landscape[6]

During the Cold War the U.S. had one key strategic threat – the USSR. Now the U.S. faces threats from many state/non-state actors; the traditional order of battle has shifted to unconventional targets; and activities that were once unobscured are now hidden in jungles,

[6] Adapted from NIMA 02-090

mountains, underground facilities and urban environments. This evolving landscape presents many challenging ISR problems. The problems range from reducing the time to provide meaningful results, to processing the huge volumes of data from currently deployed ISR sensors, to monitoring activity in deeply-buried facilities and exploiting new phenomenologies. These challenges require solutions that improve ISR performance. The task force discovered that performance cannot be improved without a transformation to new a new ISR strategy. This new strategy would transform from the current relatively linear task, process, exploit and disseminate (TPED) to a more dynamic ISR value chain where data is posted at the earliest usable stage, and would be accelerated using current systems. In addition, a longer term ISR strategy transformation with new programs and services will deliver significantly better results.

The onset of new and varying threats has resulted in an increase demand for intelligence information from all legitimate user communities. ISR data have provided high quality, near-real time information to warfighters, fueling the demand for more ISR particularly by forward-deployed forces. As a result national intelligence and battlefield situational awareness have competed for priority. In addition, the Quadrennial Defense Review identified persistent surveillance as a key to conducting effective joint operations, possibly contributing to the influx of demand.

New intelligence challenges – detecting and tracking people and weapons and agents of mass destruction – require more sensitive sensors and faster processing. The demand for intelligence to combat these new targets has resulted in the rapid proliferation of sensors which has both enabled and overwhelmed the current ISR infrastructure. The number of images and intercepts collected exceeds the capacity of the existing analyst community, thus creating a backlog for translators and image interpreters and resulting in massive amounts of collected data that are never reviewed.

Sensor-collected Intelligence/Surveillance/Reconnaissance (ISR) data are invaluable to both national decision makers and to battlefield commanders. Despite significant increases in the number of sensors, largely on unmanned aerial vehicle (UAV) platforms at both the theater and tactical level, demands for information, particularly to support operations in Iraq and Afghanistan, continue to increase. To investigate this trend, the USD(AT&L) directed the DSB to create a task force with the principal goal of determining what improvements are needed in collection, processing, data storage and fusion, exploitation, and dissemination of information collected by ISR systems. The joint DSB/ISB task force divided into six groups to examine:

- Benefits of sensor integration
- Enhancing ISR communications
- Meta-data tagging
- Improving sensor tasking
- Leveraging processing and exploitation
- Sensor gaps and shortfalls

From March 2007 – April 2008, the task force conducted 13 meetings, heard 75 briefings, reviewed numerous studies, and held several discussions. During the course of its study the task force made the following observations:

- Integrating data from multiple sensors can improve performance.

- Widely-accessible assured, broadband communications and meta-data tagging are essential.
- Improvements in tasking, exploitation and sensors yield multiple benefits.

1.3 Report Organization

This report reflects the deliberations of the entire task force as well as the integrated assessment of the findings and recommendations of the six groups. The report is divided into six chapters each supporting the task force's overall finding that sensor integration is the key to improved ISR performance. Each chapter provides specifics and examines the requirements, technologies and policies necessary to achieve sensor integration. The organization of the report is as follows.

Chapter 2 and Appendix D address the benefits and value of integrating sensor-collected data. The task force investigated the ability to integrate data from sensors with different characteristics to achieve significant performance improvements over what could be achieved from each sensor separately. The task force investigated this topic in detail with the goal of quantifying the potential improvements. Chapter 2 and Appendix D present the results of this effort which demonstrate signal-to-noise improvements of 4 to 8 dB, factors of 10 reductions in convergence and identification times, and as much as 100 times better geolocation accuracy than a single sensor. Attempting to achieve comparable levels of performance by improving only the design or deployment of single sensor systems would dramatically increase the associated cost, complexity and risk and might not be attainable.

Chapter 3 and Appendix E demonstrate the need for assured broadband communications. The ability to transform ISR sensor data processing and exploitation from a stove-piped, analyst/collector-controlled environment to a network-enabled, user-controlled Google-like search environment depends on assured communications. These communications must support movement of sensor data to the high bandwidth terrestrial backbone and enable authorized users to access data asynchronously and use the search and retrieval services envisioned in the integrated sensor-collected intelligence architecture.

Chapter 4 identifies the need for a net-centric data strategy with meta-data tagging as a key enabler. This chapter explores the current data strategy which is focused on ensuring that data are visible, available and usable when and where needed. It states that data (intelligence, non-intelligence, raw and processed) will be tagged with meta-data, or data describing the data, to enable discovery. It calls for data to be posted to shared spaces to provide access to users except as limited by security, policy or regulation. This chapter shows how achieving the desired access to data will be greatly enhanced if all the core networks are integrated as recommended by the task force.

Chapters 5, 6, and 7 explore additional improvements that will build on the recommended ISR architecture foundation. These chapters provide the improvements required in tasking, exploitation and sensors to yield multiple benefits.

Chapter 5 and Appendix F describe ways to make sensor tasking more flexible. The chapter shows the current situation, and describes promising technologies and activities. Current ISR tasking systems create significant frustration for users because they must balance priorities from many different stakeholders, all of whom have legitimate intelligence needs and often lack visibility into the importance of competing demands for the valuable sensor assets. This situation is aggravated by the fact that there is limited transparency into the decision process and almost no feedback to users relative to the status of their requests.

Chapter 6 presents processing and exploitation enablers for integrating sensor-collected information/intelligence. The volume of ISR data requires computer assisted automation if the intelligence analysts and operators are to have any hope of coping. However, research in fully automated target recognition, while promising, has failed to deliver effective solutions. One of the impediments has been the lack of realistic test/training data. Algorithms designed with simulated data have not performed as expected when confronted with real-world data.

Chapter 7 and Appendix G show the current sensor gaps and shortfalls and describe how they should be addressed. This chapter explores the current sensor issues facing the Department and the IC and provides examples of advanced platform/sensor combinations that need to be researched and/or developed to address hard problems.

Many of the most challenging intelligence targets – including detecting WMD and its precursor agents, tracking people and characterizing deeply-buried facilities – require the sensor to be in close proximity to the target. Close-in ISR requires unique platforms to deliver the sensor to the target area, specialized sensors to detect the faint signals of interest, and tailored exfiltration techniques to get the data back from the sensor. To date, most of these missions have been planned on an ad hoc basis and have been matched to a specific scenario.

Finally, the task force reviewed the status of research on sensors for detecting WMD, characterizing deeply-buried facilities, penetrating into dense foliage and complex urban environments. Chapter 7 also summarizes this status and recommends specific promising technologies for continued development.

Chapter 8 offers the task force's overall findings and recommendations.

CHAPTER 2: BENEFITS OF INTEGRATING SENSOR-COLLECTED DATA

The task force heard from various experts working in the ISR community concerning current sensor integration strategies and their benefits and complexities. This chapter addresses the benefits expected out of the integration of sensor-collected intelligence, based on representative examples. This discussion is followed by a description of the architecture required to achieve these benefits and an explanation of the existing shortfalls and complexities of an integrated architecture.

2.1. Benefits of Sensor Integration

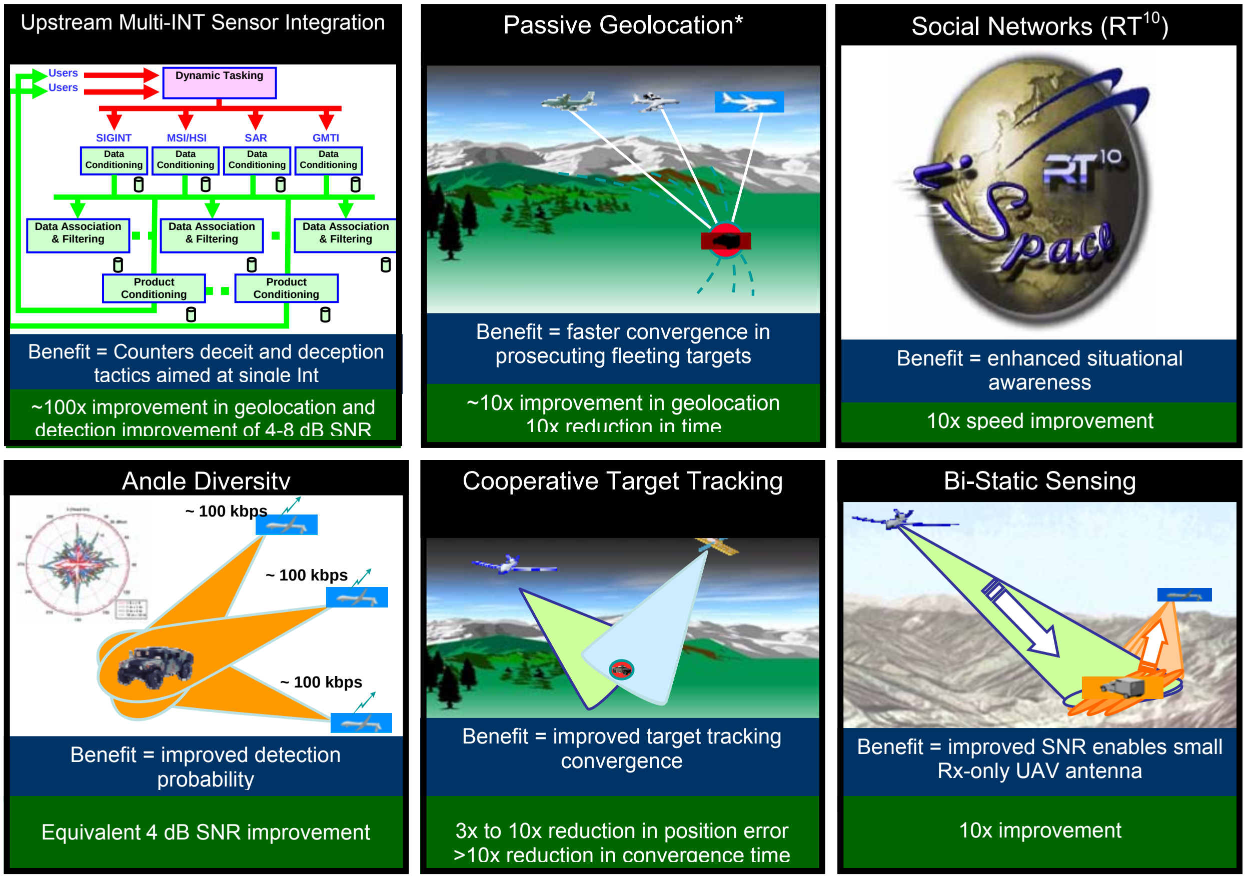
The ability to integrate data from sensors with different characteristics offers the potential of significant performance improvements over what could be achieved from each sensor separately. The task force investigated this topic in detail with the goal of quantifying the potential improvements. Figure 3 summarizes the results of this effort and demonstrates signal-to-noise improvements of 4 to 8 dB and sometimes more, factors of 10 reductions in convergence and identification times, and as much as 100 times better geolocation accuracy than from a single sensor.

These improvements are the result of effects achievable only by integrating data from multiple sensors, such as:

- Better detection geometries due to geographically separated platforms.
- Lower detection thresholds with false alarm control by requiring detection by more than one sensor.
- Cueing by one sensor to initiate tracking in another.
- Angle diversity for radar sensors on different platforms.

Attempting to achieve comparable levels of performance by improving only the design or deployment of single sensor systems would dramatically increase the associated cost, complexity and risk and might not be attainable.

The first example in Figure 3 shows the benefits accrued from performing upstream processing to counter denial and deception as tactics potentially used against a single INT. In this experiment the John Hopkins Applied Physics Lab demonstrated the ability to improve detection by 4 to 8 dB from multi-INT integration relative to a single sensor. Other examples shown in Figure 3 come from actual experiments, such as the reduction in geolocation error and convergence in time to localize a target with improvements approximating an order of magnitude (e.g., the Net-Centric Collaborative Targeting demonstration). Appendix D provides the classified details on the results.



* On-going programs briefed to DSB ISR panel = NCCT and AOIO

Figure 3: Example Benefits of Sensor Integration

2.2 Integrated Sensor-Collected Intelligence Architecture

The integration of sensor information across multiple sensors is enabled by the net-centric infrastructure of broadband, assured communications. As discussed in the last section, this integration can provide benefits of a significant magnitude to U.S. military forces and the Intelligence Community. However a new architecture must be created before these benefits can be fully realized. Figure 4, Integrated Sensor-Collected Intelligence Architecture, illustrates the required integrated sensor-collected intelligence initiative.

Capabilities enabled by this architecture include leveraging angle diversity, simultaneous looks from different sensors, exploitation of multi-INTs phenomenology, use of machine-to-machine data transfer to decrease cycle times, data driven tasking, and upstream processing of multi-INTs. This architecture will also allow significant improvements in the optimum use of human capital.

Useful integration cannot be achieved by increasing the number of sensors alone. The following elements must be incorporated into the architecture:

- Meta-data. Meta-data is critically important to effect the capabilities desired.

- Assured Communications. Results from an integrated architecture must be supported by assured and a low probability of interception communications.
- Disaggregate. The disaggregating of data from the applications enables significant improvements to apply innovative techniques and to extract more valuable information from sensors.
- Net-Centric Services Strategy. Complying with net-centric enterprise services facilitates the inclusion of value-added services.

The inclusion of these elements into the architecture is necessary for improved sensor integration. However, since the DoD is pursuing many of these attributes to support net-centric warfare, performance improvements should be available at little or no increase in infrastructure costs.

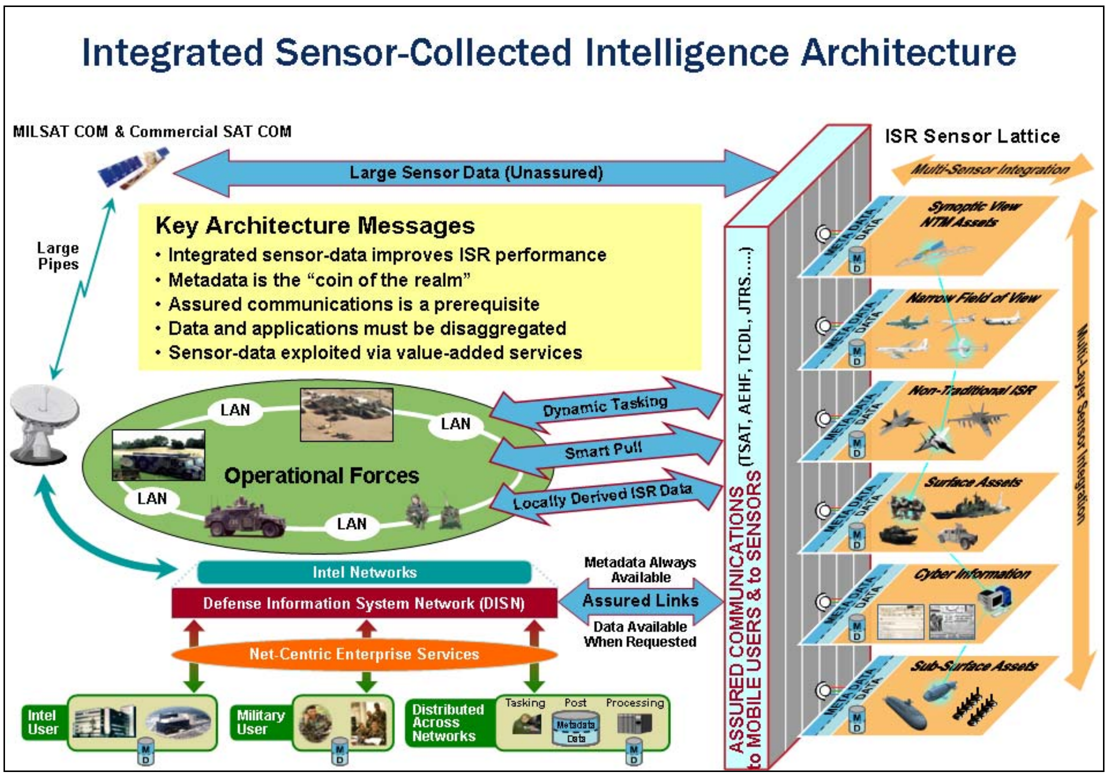


Figure 4: Integrated Sensor-Collected Intelligence Architecture

2.3 Spectrum of Sensor Integration Complexity

The expected benefits of sensor integration span a range of levels of complexity from an architecture perspective. Downstream processing, as performed in some of the SIGINT experiments, requires a loose level of coordination among the assets. Meta-data are crucially important in all cases as shown in Figure 5. Communications bandwidth requirements increase as one moves from downstream processing to the other end of the spectrum where one would perform coherent sensor processing. The latter will also demand a much higher degree of integrated sensor coordination.

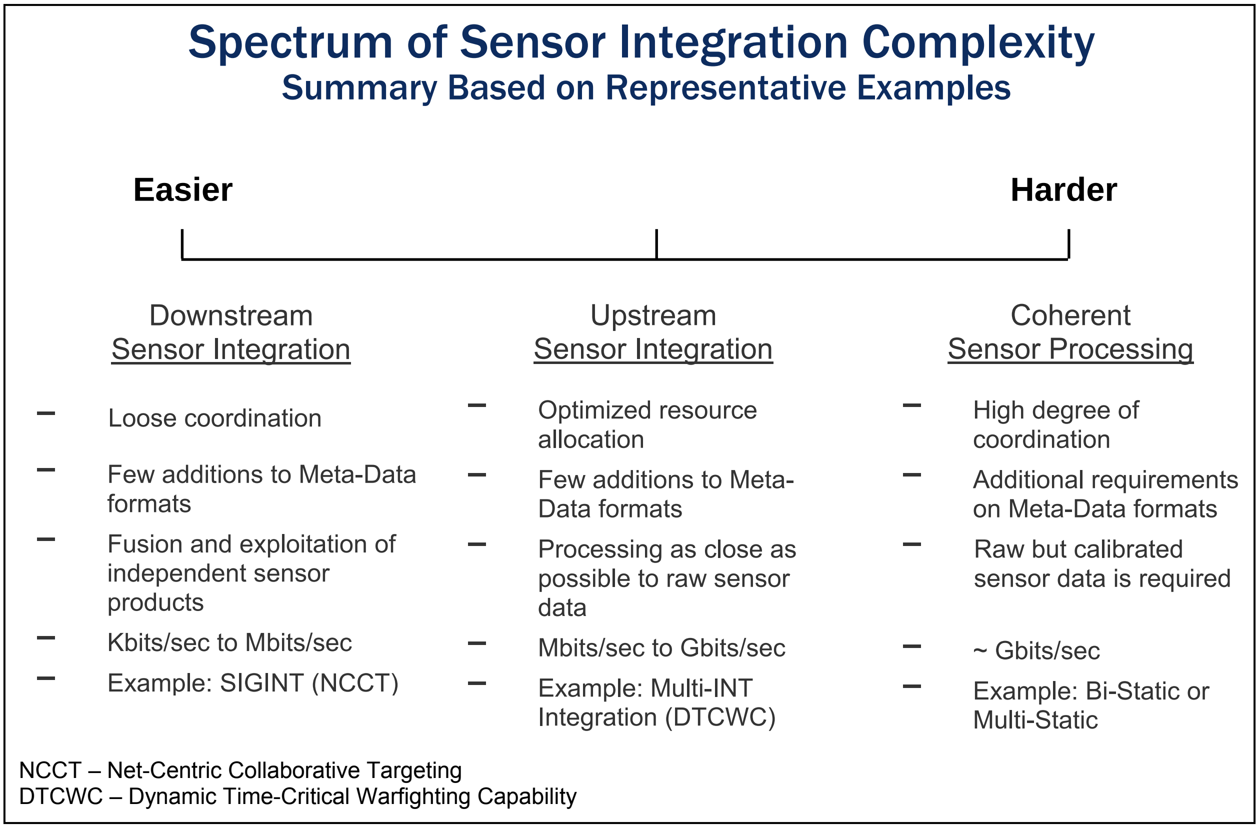


Figure 5: Spectrum of Sensor Integration Complexity

The classified Appendix D provides further details on the benefits of integrating sensor-collected intelligence. A discussion of existing shortfalls and a set of recommendations, to include backup data of supporting quantitative benefits, are included as well.

CHAPTER 3: ENHANCING ISR COMMUNICATIONS

3.1 Introduction

Assured communications are essential to ISR support and a prerequisite to any initiatives to better integrate sensor-collected intelligence. A secure, ubiquitous communications architecture is particularly critical to meeting the needs of mobile tactical users and ships at sea.

In formulating its findings, the task force received briefings from officials in the Office of the Secretary of Defense, the Military Services, Defense agencies, agencies of the Intelligence Community, and industry. Further, the panel drew from the expertise of its members as well as seeking additional information during discussions with government officials outside the formal meetings format.

3.1.1 Key Findings

The findings below are those the task force believes merit priority attention and are the subject of the recommendations at the end of the chapter.

- Assured, high capacity communications are essential to making ISR information available to military forces and national security agencies as needed, when needed.
- Mobile land forces and ships at sea now lack adequate ISR support communications capabilities.
- DoD is progressing towards its net-centric communications goal, but realization is impeded by an enormous legacy inventory and a slow pace of implementation.
- More quickly integrating ISR data collected from multiple sensors offers significant benefits, but will require a substantial increase in DoD's satellite communications capacity.
- Rapidly growing airborne ISR collection capabilities are outstripping the supporting communications infrastructure, with satellite communications and local distribution of data the limiting factors.
- Existing development and acquisition programs, particularly the Transformational Satellite System (TSAT) and the Joint Tactical Radio System (JTRS), will provide critical ISR support capabilities and can narrow the communications capacity gap, but are at risk due to cost and schedule challenges as well as competition for funding with other Defense needs.

3.1.2 Background

DoD and intelligence agency communications systems have evolved over the years from single purpose, narrow band, point-to-point circuits to high capacity circuits and broadcasts as well as local area digital networks. In Iraq today, large fixed headquarters citadels are well served by fiber trunks and/or large SATCOM terminals and the hundreds of operators busy fusing data. From these bases dispersed operations are conducted by mobile (on the move) company and smaller size units, with limited or no high-capacity communications support. Further, a number of effective, special ISR capabilities have been developed and employed in Iraq and Afghanistan, but often with point-to-point (stovepipe) communications connectivity which limits overall utility and impedes integration and fusion with other ISR data.

ISR information needs vary by theater, nature of threats, kind of operations or warfare, and by joint command, military service and intelligence agency, thus requiring flexible, scalable communications solutions. In a conventional war, military units and intelligence agency operators may lack the fixed citadels forward, as in Iraq, that have the hundreds of operators and analysts needed to process broadcast data and high capacity communications capability. Additionally, strong enemy opposition may be encountered, at least in early days of a war, which would preclude setting up such protected enclaves. This highlights the need for robust on-the-move ISR communications for land forces at all echelons to support the high capacity demands of joint force commanders, their mobile subordinate component commanders, and those units down the command chain. Further, because of the critical impact of assured communications capability on the provision of ISR capability, protection against the full range of vulnerabilities including physical attack on key nodes, electronic attack (e.g., jamming and spoofing) and cyber attack must be provided.

Theater commanders have strongly expressed the need for increased communications capacity. This need is occasioned by:

- The need for smaller units to have access to information previously available only at higher echelons;
- The near-insatiable demand for real-time ISR imagery and data noted since 2001;
- Special needs of mobile land forces and ships at sea which are seriously communications capacity-deprived, limiting access to ISR data; and
- Marked growth in the quantity of imagery and other ISR sensor data being collected.

The net result has been overwhelmed theater communications and calls by operational commanders for vastly increased capacity.

Figure 6 shows the key communications challenges facing military forces in five selected situations which span the range of operations. Indicated also is the study task force's assessment of the capability of the DoD, the intelligence agencies, and deployed military forces to provide communications support adequate to meet these challenges. The column titled "Comms Capability" refers to the ability of our communications infrastructure and systems to provide assured[7] access to ISR data by operating units as needed, when needed. Where the capability is shown as less than adequate, the lack of both assured, high capacity satellite communications and Internet Protocol (IP) networking capability to facilitate "reach-back" are the principal limiting factors, particularly for land forces on the move and Navy ships at sea.

[7] The term "assured" includes protection from a broad range of threats to communications – jamming, cyber attacks, physical attacks, etc. In effect, assured communications means the channel is available for use when desired and the adversary cannot deny or significantly degrade the capability. The word "protected" is often used to more narrowly indicate that a system has anti-jamming capabilities.

ISR Support Communications Posture Today

Situation	Characterized By	Examples	Communication Challenges	Communications Capability
Routine peacetime ops in today's GWOT environment	Recce and surveillance ops, routine forward deployments, joint/unit training, cyber intrusions	NTC training, U-2 & EP-3 recce, satellite ops, fleet exercises	Maintaining & improving comms readiness, availability & integrity without wartime stimulus. Countering cyber intrusions	
War or counter-insurgency conflict in mixed military-civil environment	Land forces operating from fixed bases. Small units on the move. Little threat to space and airborne ISR systems. Cyber attacks probable.	Iraq and Afghanistan today	Establishing/maintaining assured connectivity with, and providing ISR data to, battalions/ companies/ platoons on the move, countering jamming	
Missile and air strikes, SOF raids by US forces	Significant air and SAM opposition to ISR systems. Cyber attacks. Possible attacks and countermeasures against US satellites. US land forces not involved.	Iran, Taiwan Straits (China), North Korea	Maintaining connectivity and providing high capacity comm links with air defense/ attack aircraft and airborne ISR elements plus ships. Countering jamming and cyber attacks	
Traditional invasion of enemy country	All military services involved. Army and Marine units, large and small, on the move. Significant air and SAM threats to airborne ISR units, but likely eliminated in a few days. Cyber attacks and comm jamming likely. In future, attacks against comsats unlikely unless enemy is major power	Iraq 1991 & 2003	Maintaining connectivity and providing high capacity comm links with Army and Marines on the move. Also with airborne ISR units early on, and with Navy ships throughout campaign. Countering jamming and cyber attacks	
Special/Covert Operations	Highly mobile small unit operations, undetectable insertions into mixed civil-military environments.	Initial OEF operations in 2001 and others unknown	Providing highly reliable, secure (LPI, minimal power) comms any time/place with lightweight equipment. Countering jamming	

Figure 6: ISR Support Communications Posture Today

While the requirement for enhanced communications support for both ISR and command and control has been elevated to a very high level in recent years due to wartime operations in Iraq and Afghanistan, the movement towards net-centric operations and enhanced support communications dates back to 1991 and Operation Desert Storm. Following the first Gulf War, the DoD instituted a number of measures to improve its communications posture. Over time, these have evolved into what is now called the Transformational Communications Architecture (TCA).

3.2 The Transformational Communications Architecture

The DoD is implementing a net-centric architecture to facilitate collaboration and enable enterprise-wide discovery and access to data by authorized users. Essential to this architecture is the Global Information Grid (GIG), which includes a very high capacity communications network comprised of a terrestrial fiber backbone, communications satellites, and broadband ground and air radio networks as well as associated IT equipments, applications and services. This Transformational Communications Architecture is comprised of three key components: terrestrial fiber, secure satellite communications, and software programmable radios with networking capability. In this architecture users access ISR information by an IP-based request to the network vice traditional broadcast or dedicated circuit “push.” This strategy is along the lines of DSB study recommendations dating back to 1994, most recently to that of the 2006 Summer Study.[8]

There have been objections to this move to IP-based communications for several reasons. First and foremost, all communications should not be moved to the IP environment. Command and Control systems for nuclear weapons is an obvious example, where the difficulty of getting any signals through sophisticated jamming and/or nuclear effects is extreme, in which the overhead required for IP systems to operate is too large a burden. Perhaps more importantly, the very attributes of IP-based net-centric systems which make them extremely attractive for modern warfare offer similar advantages to opponents who might wish to disrupt our systems, namely, one can access any part of the network from anywhere at the time of his choosing. These attributes are wonderful for both deployed forces and attackers of the network. The solution to this conundrum is central to the DoD standards used for the GIG, namely the use of a dedicated, encrypted core communications network which connects all major ISR sources to all major command centers, with possible extension to mobile forces using satellite links. This architecture requires attacks on the network to be from inside the network and precludes them from becoming rampant, as long as proper safeguards are used. Careful attention to the potential vulnerabilities of such a network can protect the significant advantages of that same network for our forces and users.

The Transformational Communications Architecture is not yet complete and progress to date has been uneven. The status of implementing DoD's net-centric communications concept is as follows:

- The terrestrial fiber component of the GIG is essentially built out and provides assured, high capacity communications linking major military commands and agencies at fixed land sites.
- The terrestrial backbone is supplemented by government and commercial communications satellites, with higher capacity satellites under development. Current systems can easily be jammed except for very low-data rate C2 circuits.
- Agency networks (NRO, NSA, other IC, NASA) are not fully integrated with the GIG.
- Overall pace of implementation has been uneven, with principal shortcomings being insufficient satellite communications (SATCOM) capacity, lack of networking-capable, software-defined radios, and poor compliance with systems interface standards.
- Acquisition and R&D programs exist that, if successful, will provide badly needed increases in assured SATCOM capacity and improve networking capabilities, but these developments have been impeded by shifting of funds to legacy systems to support current wartime operations.

It is important to note that the old architecture will never be able to support a move from a producer-focused environment where data are pushed to consumers to an operator/consumer-focused environment, with data being delivered on demand when and where needed. Assured communications and the ability to network on the move, exemplified by TSAT, are essential components of this new architecture which will enhance communications and ISR support,

[8] A list of DSB studies can be found at <http://www.acq.osd.mil/dsb/reports.htm>.

particularly for mobile forces out near the "tactical edge" as well as facilitate rapid integration of data collected from multiple sensors.

Several systems and developments are essential for realizing the net-centric architecture: Defense Information Systems Network (DISN), Transformational Satellite System (TSAT), Joint Tactical Radio System (JTRS), Net-Centric Enterprise Services (NCES) and High Assurance Internet Protocol Encryption (HAIPE).

The DISN is the GIG's communications backbone, recently expanded by the now completed Global Information Grid–Bandwidth Expansion (GIG-BE) program. It provides a very high speed, robust, fiber-based, terrestrial IP network linking major fixed installations worldwide.

TSAT is a program to deliver very high capacity assured satellite communications. It will extend access to the fiber backbone directly to mobile and fixed theater terminals. It will enable airborne ISR data transfer and, in some cases, assured communications with on-the-move platforms. Progress in developing TSAT has slowed because of budget pressures.

The JTRS program is a family of networking-capable radios based on software waveforms provided to tactical users — mobile platforms and individual combatants. It can be used to connect mobile users to TSAT and other satellite communications terminals. This program has also slowed because of technical challenges and diversion of funds to procure legacy equipment to meet immediate wartime needs.

NCES is the program intended to create an "internet-like" environment for the DoD through the delivery of enterprise software services. These services will allow users to collaborate, post, process, use, store, manage and protect information across the enterprise. Five of the nine planned services are currently available, although in their prototype form.

HAIPE will deliver the high assurance, IP encryption devices to secure the communications backbone.

Appendix E provides a description of, and information on, the status of key elements of the TCA: (1) GIG communications; (2) satellite communications, the space element of the GIG; and (3) coverage of combat theater communications that directly support the warfighter.

3.3 Future Capabilities and Capacity of the TCA

The Transformational Communications Architecture, indeed any future communications architecture, will need far greater capacity than is currently available to handle the ever growing demands for ISR support. Because communications have always been critical to successful operations, and our adversaries are becoming smarter and more capable of interrupting them, future architectures must be protected against jamming at all levels of command, including those serving units out at the "tactical edge." Because our forces are increasingly mobile, to include land forces as well as ships and aircraft, future architectures must provide for increased levels of ISR support to those forces as well as assured connectivity. Lastly, because of the ever increasing joint and international nature of operations, and the growing dependence on reach-back, future architectures must demand strict adherence to interoperability standards and IP constructs.

Figure 7 summarizes the anticipated future demands on the TCA and current concerns about its capability to meet them. And it also highlights the importance of both TSAT and JTRS. While both these developments are essential and complementary, TSAT will still be of great benefit without JTRS, providing assured communications and links between airborne ISR sensors, senior command levels, and tactical terminals which the small unit user will need to connect to in order to get on the net. Without TSAT, on the other hand JTRS radios will still offer much needed networking and flexibility, but they will not provide the assured data communications capacity necessary for ISR support.

TCA's Capabilities and Capacity – The Future

Meeting the Demand ?

- Four principal demands must be met by the TCA in the future:
  - More capacity – vastly greater communications throughput
  - Protection from jamming, across the force at all command levels
  - Improved ISR support and assured C2 connectivity for mobile forces and ships
  - Improving interoperability through standards discipline and reliance on IP-based networks
- TSAT and JTRS play major roles in satisfying these demands
  - The two systems are complementary and both are needed
  - TSAT provides very high capacity, assured communications, while JTRS extends IP networking to the tactical edge
  - Without JTRS, TSAT will still link airborne ISR collectors with senior level commands, but cannot provide assured voice and data communications to lower command levels
  - Without TSAT, JTRS still provides voice and low bandwidth ISR data to the tactical edge
- The pacing TCA element is satellite communications, both capacity and coverage
  - Demand for Satcom continues to outstrip capacity
  - Gap is predicted to continue even after TSAT is fielded, but would widen dramatically if TSAT is cancelled
- Mismatch between growing communications needs generated by unmanned air systems and capacity of the TCA, even with TSAT, raises questions that merit answers:
  - Are we buying more airborne ISR systems than we can accommodate?
  - Can commercial comsats fill the capacity gap and meet other needs as well?
  - Should we slow ISR UAS fielding, diverting funds to enhance communications?
  - Or alternatively, should we move to dramatically increase MILSATCOM assets?
- Seeking answers to these questions should be the subject of a thorough review by OSD and Joint Staff

Figure 7: TCA's Capabilities and Capacity - The Future

Figure 8 illustrates the challenges to SATCOM capacity today and in the future, and conveys two key messages. First, it recognizes the large and rapidly growing trend toward ubiquity of unmanned aerial vehicles and the demand they place on the communications infrastructure. As noted, around 2015 the growth rate is expected to increase rapidly – at about the time TSAT was originally expected to be deployed. Second, there is a large mismatch between the expectations of operational users and the funded programs to support these expectations now and in the future, with the gap continuing to grow. From the demand generated by sensors and the expressed needs of users, one must apply the limitations imposed by ground terminal availability as well as military SATCOM capacity and area coverage.

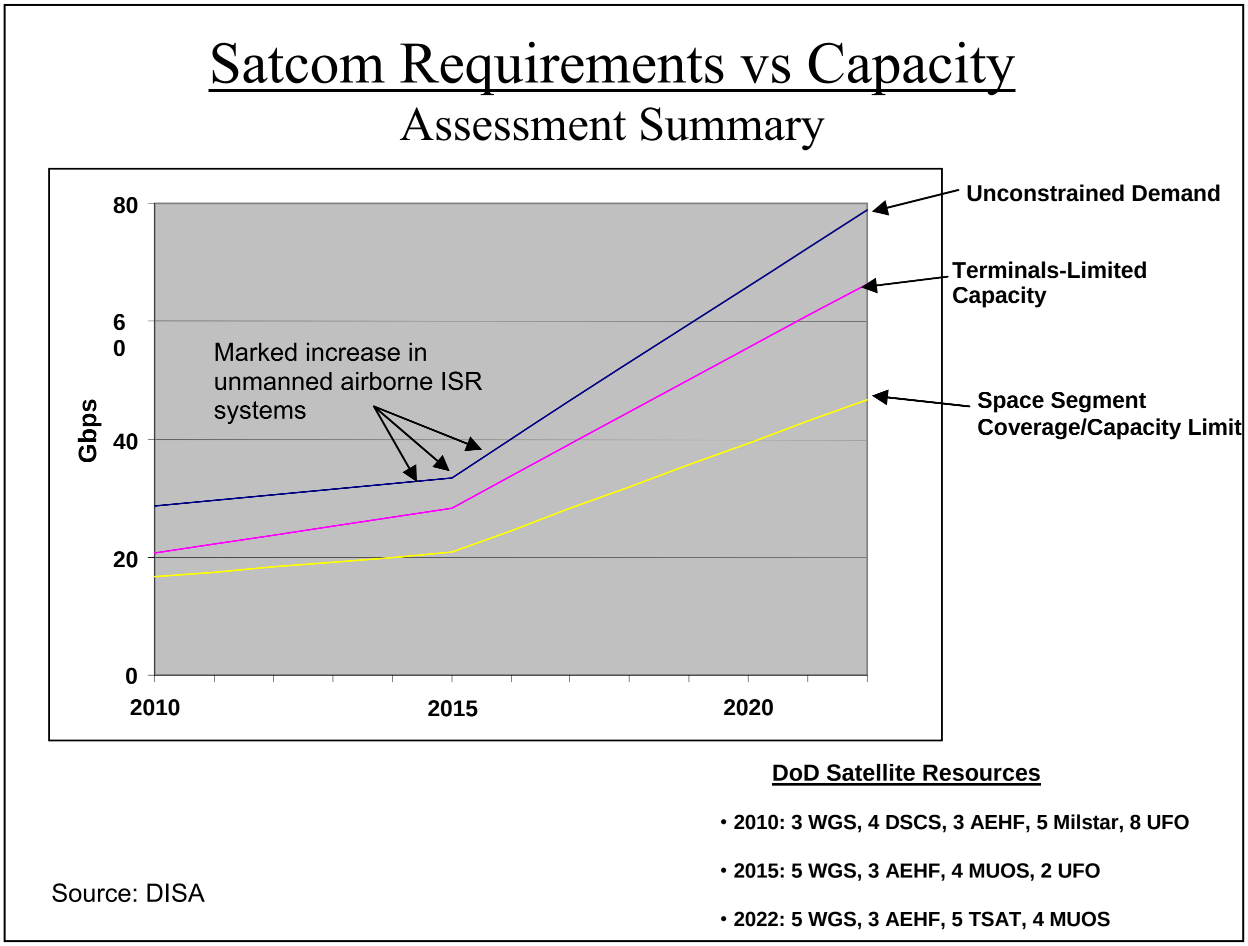


Figure 8: SATCOM Requirements vs. Capacity

The summary point of Figure 8 is that more satellite resources will be needed, more ground terminal investments are required, or there must be a more realistic and better adjudicated set of demands developed by the military and intelligence communities. Such large demand growth, especially in support for UAVs, cannot be sustained without deployment of additional communications satellite resources.

Finally, the pacing element in the DoD's move to a transformational communications architecture is satellite communications, and in particular, TSAT. Even with TSAT, the gap between demand and capacity will grow in view of the rapid increase in deployed ISR sensors and unmanned platforms. If TSAT is cancelled or further delayed, the situation becomes even more dire. It follows that the DoD must begin to ask if it is adequately questioning the validity of the rapid increase in sensors given the inability of the communications system to support them. Should more funds than are currently programmed for satellite communications be allocated or should the procurement of additional ISR sensor systems be reduced? Are there commercial or other workarounds to mitigate the shortfalls? These are critical questions which need to be thoroughly analyzed and appraised by the DoD and the intelligence community.

3.4 Conclusions and Recommendations

3.4.1 Conclusions

DoD has made progress towards realizing its net-centric communications goal, but more needs to be done to remedy shortcomings:

- Implementation of the TCA is not well coordinated and capacity lags demand, indicating a definite need to pick up the pace.
- Our rapidly growing airborne ISR collection capabilities are not in balance with supporting communications.
- A clear need exists for more assured communications capacity as well as networking capability for units at the tactical edge, with focus on SATCOM (TSAT) and network-capable software-defined radios (JTRS).

The task force believes very strongly that continuing to expend funds on the current architecture and its legacy systems will not and can not deliver the required improvements. The core of the net-centric architecture is the high capacity, IP-capable assured communications backbone, including TSAT, as well as networking capability for tactical forces through JTRS. Without this core communications capability, net-centric operations are not possible.

The provision of sufficient, assured satellite capacity and flexibility in user ground equipment, both fixed and mobile, is critical to ISR support for mobile and globally deployed theater commanders and tactical users. And because of the variety of ISR collectors available, the architecture must make it possible for these sources to be accessed easily, and seamlessly integrated.

The task force concluded that TSAT and corresponding JTRS radios are critical to:

- Providing ships and mobile land forces with needed access to time-sensitive ISR data.
- Ensuring that communications are protected from enemy jamming.
- Maximizing utility of ISR data by facilitating integration and use of data collected from multiple and diverse sensors.
- Handling the rapidly increasing quantity of ISR data generated by the growing fleet of unmanned air systems.

We also believe that a comprehensive review is needed of the sufficiency of capacity of the planned TSAT and JTRS-enabled communications infrastructure.

While the transformation in military operations and the Global War On Terror have necessitated radically new modes of operation requiring enormous bandwidth and flexibility in communications, the Secretary of Defense and the Director of National Intelligence, along with senior military commanders, must recognize the finite capability limits of even the best technology and take care that ISR and communications requirements are justified by true operational need and coordinated to prevent duplication and over-demand.

Here, the ever increasing demands of operational users for ISR support and the accompanying required communications, must be accorded more scrutiny and justified in light of limits on capability and capacity of the GIG's space segment, even with TSAT deployed. For this reason, a comprehensive review of the planned satellite communications capacity posture and future ISR data transport needs is indicated.

The task force is concerned that there is **no hedge against possible TSAT delays or cancellation** which provides assured wide-bandwidth communications. SATCOM alternatives that are contemplated must recognize the requirement to assure ISR relay and connectivity to mobile forces. While communications systems interoperability has improved, the task force concluded that inadequate interface and data standards and weak enforcement continues to degrade effectiveness.

Enforcing "test-to" standards at the enterprise level will be required to make the core communications capability a reality. This will be a significant challenge for the DoD since the move to NCO will touch virtually everyone and every process. Highly competent engineering oversight and enforcement of standards will be essential, and here the study task force endorses the use of fiscal leverage to enforce standards across the TCA.

Military units in combat theaters require assured communications and the ability to operate in degraded environments, particularly as they increasingly depend on "reach-back" for ISR support. "Reaching back" for ISR information, rather than relying on pre-selected information which is periodically broadcast into theater, will make military units more agile and lethal. During combat, however, communications assets can suffer interruptions and losses from time to time. For this reason, a resilient communications infrastructure must be provided the warfighter and protected from threats, both cyber and physical, and capable of continuing operations in degraded environments. Redundant facilities and alternate communications routing must be part of protection plans, and facilities guarded against physical attacks. Further, military units should exercise routinely in degraded communications environments, particularly if dependent solely on SATCOM.

3.4.2 Recommendations

The task force recommends that:

1. The Secretary of Defense direct more rapid implementation of the Transformational Communications Architecture, DoD's net-centric broadband communications strategy.
2. The Secretary of Defense direct the Air Force to pick up the pace of the TSAT program, continuing technology development and risk reduction, and fully funding it.
3. USD(I) and ASD(NII) jointly undertake assessments to determine:
   - Sufficiency of the ISR communications component of DoD's TCA by reviewing assumptions about usage and capacity; and
   - Alternatives for improving ISR communications support for ships and mobile land forces if TSAT and/or JTRS are delayed or cancelled. Rigorous risk/rewards tradeoffs must be part of the analyses of potential alternatives.
4. As the DoD's CIO, ASD (NII) formulate clearer, more precise interface and data standards for communications equipments and software, and USD(AT&L) ensure compliance through acquisition program funding withholds as necessary.

5. ASD (NII), DISA, the Military Services, and COCOMS ensure critical communications and infrastructure are safeguarded, and provisions made for restoration of service, if lost.

More rapid implementation of the TCA is essential since it is key to achieving the Department's net-centric operations goal and promises to significantly enhance the combat effectiveness of U.S. forces. Specific recommendations include:

- Integrating and encrypting the DoD and IC backbone networks, and implementing effective, federated network operations (NetOps).
- Fielding TSAT, the key satellite communications element, along with JTRS, which is essential for tactical radio networks.
- Completing development and fielding of WGS, AEHF, and MUOS as lower priorities.
- Users accessing ISR information by IP-based request to the network vice "push" by broadcast or dedicated circuit.
- Commanders retaining capability to "push" critical intelligence to subordinate units when necessary.
- Having available backup provisions for communications outages, particularly for military forces normally dependent on SATCOM.

The Secretary of Defense should direct full funding for the key programs, TSAT and JTRS in particular, and push for their earliest possible deployments. This should be done concurrent with critical reviews of continuing legacy systems procurements since these may not be able to provide the required net-centric capabilities.

Both GAO and independent assessments have determined that the technologies necessary for TSAT development are mature. History tells us that funding inadequacy and uncertainty inevitably lead to cost and schedule increases, and that operational users are reluctant to transition away from a legacy system to one whose future is uncertain. Fully funding and aggressively executing the TSAT program is therefore essential. Accordingly, the USAF should be directed to establish a firm cost, schedule, and performance baseline and aggressively execute it, and should adequately and fully fund full scale development of the TSAT system.

The task force recommends a comprehensive review of operational demands for ISR data and supporting communications in order to determine sufficiency of current and planned communications support and to ensure proper coordination and sharing where appropriate. Further, because of TSAT's inconsistent funding record to date, the task force believes it would be prudent for the Secretary of Defense, with concurrence of the Director of National Intelligence, to direct the Defense Information Systems Agency (DISA) and operational commanders to draft contingency plans for employing current and program-of-record systems as hedges against TSAT delays, and also direct acquisition and support agencies and offices to present alternatives for more efficient use of such systems.

Strong engineering leadership will be required to drive the implementation of communications standards at the "test-to" level across the entire enterprise. It is recommended that ASD(NII), as the Department's CIO, undertake this role and formulate the requisite standards, with USD(AT&L) enforcing compliance with them by leveraging fiscal controls.

ASD(NII), DISA and the COCOMS must give priority attention to minimizing vulnerabilities, with special focus on guarding against cyber attack, maintaining integrity of the satellite communications infrastructure, and making provisions to cope with, and exercising in, degraded communications environments. Specific actions include:

- Maintaining strong defenses against cyber attacks.
- Assessing physical security of commercial satellite communications facilities under contract to DoD with a view to minimizing risk of loss of service.
- Providing backup communications for military units dependent on satellite communications.
- Planning for and exercising in degraded communications environments.

The physical security of commercial satellite communications facilities must be assessed on a regular basis. And to the extent a commercial provider does not provide robust physical protection against threats beyond typically those found in the commercial world, the provider should be required to upgrade the level of protection to the DoD standard.

To reduce the risk of deployed military units losing communications services at critical times, the Military Services and COCOMS should be directed to aggressively explore, develop and field alternative communications links that will ensure connectivity in the event normal SATCOM services are interrupted by enemy action, equipment failures or other causes. Candidates for employment as backup command and control and ISR data relay means include UAVs, manned aircraft, aerostats, local area line of sight VHF/UHF networks, and HF radio.

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CHAPTER 4: NET-CENTRIC DATA STRATEGY

Over the course of the study, the task force determined that DoD and the Intelligence Community (IC) need to push the implementation of their net-centric data strategy. The task force agreed that this strategy should separate data from applications and the value-added services that control both; and ensure the data are made visible, accessible, understandable and secure by authorized users anytime and anywhere. The DoD/IC net-centric data strategy calls for access to the data would be controlled via a technology-enabled policy and all unprocessed data would be posted promptly to shared spaces. In this way, interoperability is enabled through "many-to-many" exchanges rather than point-to-point exchanges. The task force found that DoD standards for tagging are available, but are not widely used. They also noted that necessary governance processes that include the IC are in development. The task force determined that the primary element of this strategy is meta-data. The task force found that integration of sensor data cannot be done without comprehensive meta-data. Tagging sensor data with meta-data enables information discovery by users and machines. In addition, tagging should be done at the sensor, or as close to it as possible.

4.1 Introduction

Historically, data structures were created by and for specific applications, which then "owned" the resulting data. The data were "locked up" in the applications and it was difficult–often impossible practically–to reuse the data in other applications. Modern design recognizes that digital value is more often in the data than in the applications, and thus requires that the data be separated from the applications from the start. Further, applications themselves must be designed in a way that allows them to be discovered and coupled together through services. For example, Amazon.com reuses customer sales data in a variety of ways (product recommendations, inventory management, etc.) which evolve over time.

Data can only be reused if they are discoverable and consumable. This is accomplished by describing the data through other data (meta-data). The meta-data are usually produced at the time data is created and, for example, allows different computers to determine the instant in time the data were created, or if a particular 10 digit number represents a social security number or a vehicle license number, and so forth. This meta-data can often be larger in quantity than the data itself, but its existence and availability is essential to the use of the data by different systems/services. The existence of meta-data does not imply that the underlying data will necessarily be shared. Rather, sharing is a policy question. But the data must be produced in a sharable form so that sharing can occur as policy permits.

Recognizing that different systems/services will have different purposes for data and derive different business value from it, modern design allows for on-going association of new meta-data with data. This "tagging" process expands the usability of data. For example, a camera used for portraiture may create meta-data for a photograph such as date, time, and lens settings. The photographer may add further meta-data such as the names of the subjects.

Data should be made available as soon as it can be consumed. It is not necessary to wait until the producing application has completed its processing, as other applications (perhaps lower fidelity processing algorithms) can derive value immediately.

Finally, data should be made available through general purpose interfaces. Specialized system-to-system interfaces make it difficult to reuse data, as the specialized interface itself must be replicated. Modern design achieves large scaling advantages through generalizing the interfaces to data rather than particularizing them.

4.2 Need for Meta-Data

Data from multiple sensors can enhance speed and targeting only if they can be correlated in some way – same place, same time, same intelligence target, with calibration data for collections sensors. Information collected from separate sensors cannot be combined in a meaningful way unless some element of common data can be related in this fashion. Simply correlating data from separate sensors based on the content of the data itself (an image, a signal, some text, etc.) is very hard and slow. For example, determining that two images are looking at the same place by having a computer analyze the images is unreasonably complicated. The task force found that the only way to hope to correlate unstructured sensor data from separate sensors is to get data "about" the data, in other words meta-data. For sensor data this means the location, time, resolution, and source. A critical enabling requirement for the Integrated Sensor-Collected Intelligence Architecture, as shown in Figure 4: Integrated Sensor-Collected Intelligence Architecture, is meta-data, where it is considered the "coin of the realm" of the architecture.

Data from multiple sensors can be integrated only if a basis for integration is known. Often, time and space are useful bases for integration. Other data may be useful in specific scenarios. For example, relationships related to telephones, telephone owners and telephone calls can be correlated using telephone numbers or other signaling information from the communications network. For some sensors, having calibration data available is essential to optimum signal integration. In all cases, however, some common element must be known in order to allow integration of data collected by separate sensors.

The essential meta-data elements are often known at the time the sensor collects the data, but are not always published with the data itself. The sensor designer may assume that all possible uses of the sensor data are known to the sensor designer, and therefore that publication of meta-data is not necessary. However, it is this lack of meta-data that prevents re-use of the sensor data and integration, perhaps in new and novel ways, with other data sources of which the original designer may not have been aware or anticipated. There is no alternative to having the meta-data generated at the time of data collection. In general, it is not possible to produce meta-data from the data itself. If we have data about our data holdings, we can manage our data holdings and derive more value from them. Absent this data, our ability to integrate data is minimal.

4.3 Meta-Data Alignment

Meta-data are descriptive data "about" other data. For sensor data, this means such data as location, time and resolution. Integrating data from different sensors requires alignment of the meta-data. That is, the values of the meta-data must relate to each of the sensors. We might have two photographs, one using a sensor responsive to visible light and one responsible to infrared radiation. We can derive value from the integration of these photographs if the meta-data is "aligned" – that is, it allows us to know that space photographed is the same (through common use of measurement units, reference points, and so forth).

Aligning meta-data can be accomplished by aligning the standards with which the meta-data are created at the point of collection or it can be "translated" later to allow data from two sensors with misaligned meta-data to be "mapped" onto one another downstream in the process.

The complexity of correlating sensor data is based on the diversity of the sensors and how closely the meta-data is aligned. In general, the techniques for correlating data from multiple instances of the same sensor are well understood. As the characteristics of the sensors deviate from one another, correlating may become more difficult. However, the value derived from the ability to sense in different domains (e.g., the RF spectrum and imagery) can be significant.

Our understanding of a domain of interest is improved by sensing that domain in different ways, using meta-data to ensure the data correlations are done in sensible ways. The task force found that it was better to have diverse sensors with aligned meta-data than similar sensors with misaligned meta-data.

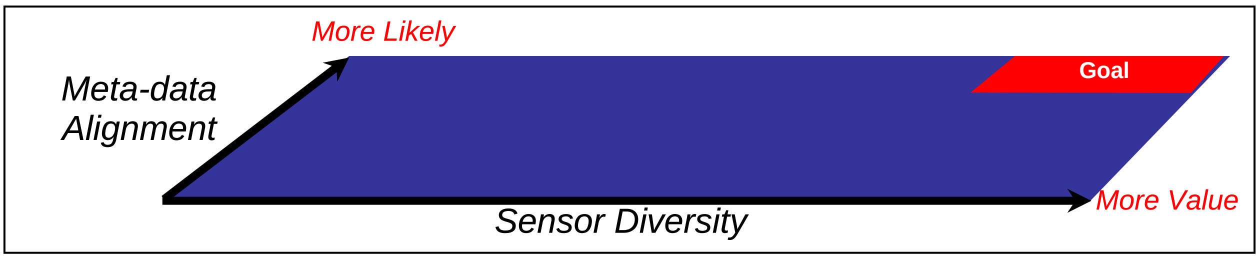

Figure 9: Sensor Diversity

4.4 Net-Centric Data Strategy Findings

The task force found that, in certain specific areas, excellent progress has already been made in aligning meta-data from various sources across the Department of Defense and the Intelligence Community.

The task force found that meta-data standards and processes are evolving, noting the expected publication of Universal Core 2.0. These standards efforts have focused on defining a minimal set of meta-data (such as data regarding time and place) which will be included in all collections. Progress has also been made in defining standards for meta-data which will facilitate information search and discovery. However adoption of these standards in sensor systems has been slow.

In an effort to ensure that information assets are visible, available, trusted and usable, the DoD's Data Strategy[9] calls for data to be posted to shared spaces that provide access to users except as limited by security, policy, or regulation. Achieving the desired access to information will be greatly enhanced if all of the core networks are integrated as the task force has recommended.

The Strategy also introduces the concept of managing data within communities of interest (COIs) rather than calling for standardization of data across the defense and intelligence enterprise. While the Strategy is key to achieving the benefits of net-centricity, it should be noted that it was published in the spring of 2003 and that implementation has been slow. One area of concern is the progress of the COIs, with the trade-off between increasing the size of the COIs for optimized performance and on-the-spot data sharing and smaller COIs to simplify defining the vocabularies and meta-data. Since sensor-collected data are geographically focused, meta-data

[9] DoD Net-Centric Data Strategy, May 2003

elements that define when and where the data were collected are critical to integration. Every sensor system must have a very accurate time reference and use it to tag collected data. There has been extensive debate about the definition and format of core meta-data such as time and location. **The task force strongly recommends that these debates not delay the collection of these meta-data for all ISR systems because it is straightforward to translate these into a common syntax to support integration and nearly impossible to find related data and do integration without them.**

These Communities of Interest (COIs) are the focal point for defining the vocabulary and use of meta-data among participant programs and for registering the artifacts and data in the Meta-Data Environment (MDE) so that it is visible and accessible by unanticipated users. Progress should be accelerated through the establishment of ISR-relevant COIs involving operational users, and by leveraging momentum from actions and successes in theater.

To make this happen, the task force recommends the Battlespace Awareness Capability Portfolio Manager (BA CPM), as formalized in DoDD 7045.20 in September, 2008, take a strong role in assessing progress and advocating for funding for ISR COIs. As the advocate for the ISR COIs, the BA CPM should: 1) assess the visibility, accessibility and availability of ISR data across the portfolio and by users of the portfolio, and 2) advocate for funding for COIs where there are gaps. Although the new Directive does not define management roles for the CPMs, the task force believes that there are two management functions that should, at a minimum, be reviewed by the CPM. These are: 1) to review and advocate for cross-CPM COI activities (for example between Battlespace Awareness and ISR users in the C2 CPM), and 2) to ensure proper lifecycle management of COI artifacts after the COI has completed its work (for example, making sure that the entries in the MDE are maintained to support users over time). Additionally, as the advocate for ISR activities, the BA CPM should review the data artifacts (architecture and plan) provided by programs of record within the BA portfolio to make sure that they meet the needs of the ISR community and their users. Specifically, the BA CPM should review the data products defined in the Acquisition Guidebook as being required prior to both Acquisition Milestone (MS) A and B. This includes: 1) a Net-Centric Data Sharing Plan that outlines how a programs' data and processes will be made visible, accessible and understandable is called for prior to MS A; and 2) a data plan that prioritizes data assets and identifies required COIs, is called for prior to MS B.

The task force determined a main issue to overcome is the social and cultural impediments to sharing information. The integration of sensor data is extremely valuable, as shown in the Chapter 2 and throughout this report; however, it will take strong leadership to enforce the data sharing required to achieve these goals.

In summary, future success depends on meta-data tagging at the sensor (rather than through downstream translation); establishing clear DoD/DNI standards, policies, and governance; and establishing incentives for those who exploit the meta-data standards.

4.5 Net-Centric Data Recommendations

The DoD needs to proceed in implementing its Net-Centric Data Strategy, published in May 2003. This strategy should:

- Tag sensor-collected data with meta-data as close to the sensor as possible using meta-data that includes, at a minimum, time, location, classification, and sensor calibration.

- Engage the Battlespace Awareness Capability Portfolio Manager in empowering and funding Communities of Interest focused on aligned vocabularies and pilots for ISR data integration. In this effort, leverage the work of national and international standards bodies.
- Establish goals and incentives to address behavioral and social impediments to information sharing.
- Ensure continued support for Net-Centric Enterprise Services (NCES).
- Support the single DoD/DNI data strategy governance structure and enforce its execution.

In addition to implementing the required meta-data alignment process and data standards, DoD should take the required actions to enable short-term information integration by:

- Including sensor calibration in the meta-data for ISR sensor data.
- Identifying and sharing obvious, common "identifiers" (phone number, name, VIN, etc.) to allow bridging of different communities of interest and pragmatic discovery of "unknown unknowns."

To speed progress, the task force recommends that the DoD and DNI CIOs introduce a mechanism for users to tag data themselves and accept/use (for discovery purposes) the tags in use in theater today.

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CHAPTER 5: IMPROVING SENSOR TASKING

5.1 Tasking Requirements for Integration

To get the most of integration, the intel system needs to be able to task based on full awareness of prior collects, current sensor status, in-place tasking orders, real time detection alerts, and high level intelligence objectives. In addition, some value must be assigned to collections both in terms of net contribution to the information need for which the collection is intended, the relative value of the information need, and the cost and impact of using a particular asset at a particular time for the collect. With knowledge of sensor status and plans, an analyst or operator can know if a multi-sensor collection is feasible. With the additional knowledge of cost and priority, trades can be made across collections for tasking assignments. In order to make value trades, additional information is needed on target spectral and geometric characteristics, environmental response, and sensor performance details.

There is no technology limitation on making these data available. Signature models exist such as the National Exploitation Factors (NEF) data base. Automation tools for optimizing collection value across diverse INTs against most of these constraints have been demonstrated in programs such as NGA's ARTT. Data-driven tasking processes have been shown in the NRO HISIT project. These capabilities could be implemented in operation.

National and theater operators need to develop the confidence that their intelligence needs will be satisfied better if they have broader access to the larger collection of sensors than through stovepipe control and guarded access of their own assets. This requires a cultural change which will likely only happen through demonstrating that the rewards for access far outweigh the risks for relinquishing control of assets. Problems implementing the IC MAP program demonstrate the difficulty of trying to implement tasking architecture changes without convincing sensor control communities of these rewards, and demonstrating the ability to retain control only when it is absolutely necessary.

5.2 Current Situation

The current Intelligence tasking, processing, exploitation and dissemination (TPED) cycle process is largely linear, with many informal routes providing feedback on collections, and feed forward on ad-hoc collection needs.

Tasking requests are typically expressed in terms of the desired sensor modality (INT) to collect rather than the actual information required. This approach deprives taskers of the flexibility to assign better assets that can get the needed information, to trade off the relative cost and benefit of using a particular sensor platform, and the ability to seek alternative means to get the info if priorities overtake a planned collection. This process also contributes to all-or-nothing situations since alternatives cannot be easily judged without understanding the ultimate need. Geo-political and military hotspots tend to be redundantly tasked since high priority skews multiple sensors to collect at the hotspot, but lack of visibility across tasking systems prevents the common need from being satisfied by fewer collections.

Once tasked and collected the analysis and reporting process is also stovepiped until final production of intelligence, at which point upstream, real-time tipping and cuing is no longer possible.

Tactical ISR resources are allocated by STRATCOM JFCC ISR to Combatant Commands. These resources are allocated to theater commanders and service commanders based on priorities, and tasked for specific missions. Some, but not all of the assets plans and status are exposed across the commands by virtue of collocated operators at integration centers. The tools for coordinated/integrated tasking are not automated, and require informal networks. Visibility for assets outside theater is limited. DCGS allows exploitation across collected intel, but because of the lack of automated tools and decision aids, dynamic real-time tasking and opportunistic collection are only possible at great effort and require coincidental discovery of mission synergy. Feedback on success or lack thereof is often not documented due to the fast pace of operations. Asset visibility is limited across Services and across command echelons. Synchronization of assets for concentration on particular collection problems is difficult because of the visibility and tasking process limitations, and also because the system favors equitable distribution over prioritized, synchronized collection. The asset visibility and predictive collection planning tools required to task effectively across assets are lacking and as a result it is difficult to provide meaningful persistence. Since collection systems were not designed to easily synchronize (separate control systems, often at different locations, and separate data paths and repositories), synchronization and real time tipping/cueing is further hampered. Because of these factors, clustering of capabilities on specific time critical problems is difficult.

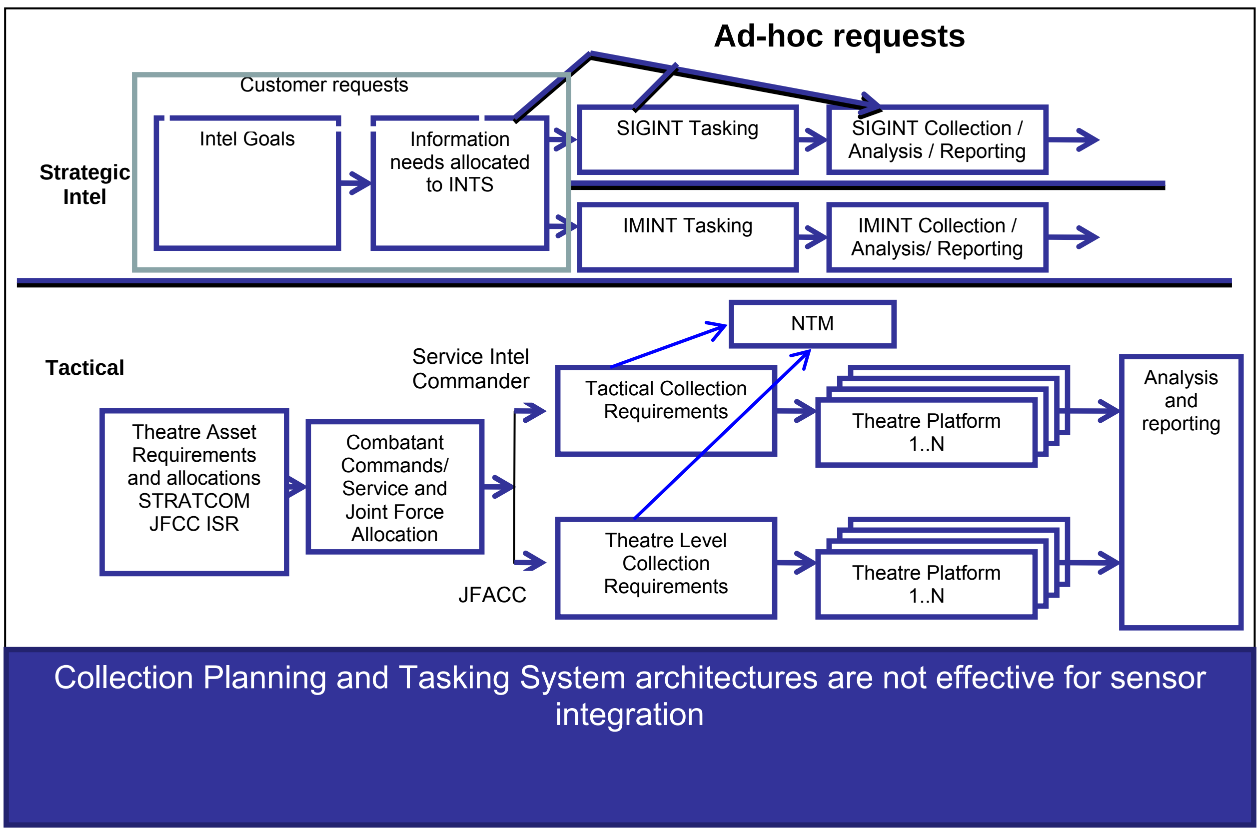

Figure 10: Current Collection Planning and Tasking Situation

There are informal feedback paths in the current tasking systems allowing ad-hoc tasking. The efficiency of these paths is inherently low since information relating the impact of triage on original information needs is not maintained in the tasking system, and because models to assess the relative value of the ad-hoc request are not implemented.

Although the current situation is not optimal for achieving the potential benefits of integration, it is still possible to plan for diverse collections. The ability to do this in a manner in which sensor tasking is informed by target characteristics, priority, and collection plans is not available at present.

5.3 Promising Technologies and Activities

The DARPA Heterogeneous Urban RSTA Team (HURT) program is working to demonstrate and validate that real-time Reconnaissance, Surveillance and Target Acquisition (RSTA) services can be provided to warfighters in complex, multi-sensor environments using autonomous tasking and flight planning technologies. The infrastructure (algorithms, networks, user interfaces and server architecture) to support the demonstration and validation activities was put in place under the prior phase of the program. The current phase, still in process, will develop metrics and experiments to quantify performance gains. Initial demonstrations of the technology performed under the prior phase showed that squad leaders could task the overall system with high level requests for area surveillance, route recon, monitoring, and tracking, while providing constraints such as no fly zones. Although on a smaller scale, this multi-sensor environment is analogous to the global Intel system. The current phase of HURT will provide sensor controllers the ability to vary the degree of control they will relinquish to the automated tasking and planning system. This strategy has already demonstrated that operators will quickly relinquish asset control to the algorithm as they discover the net benefit of multiple platform access to satisfy their needs (i.e., net system performance increased).

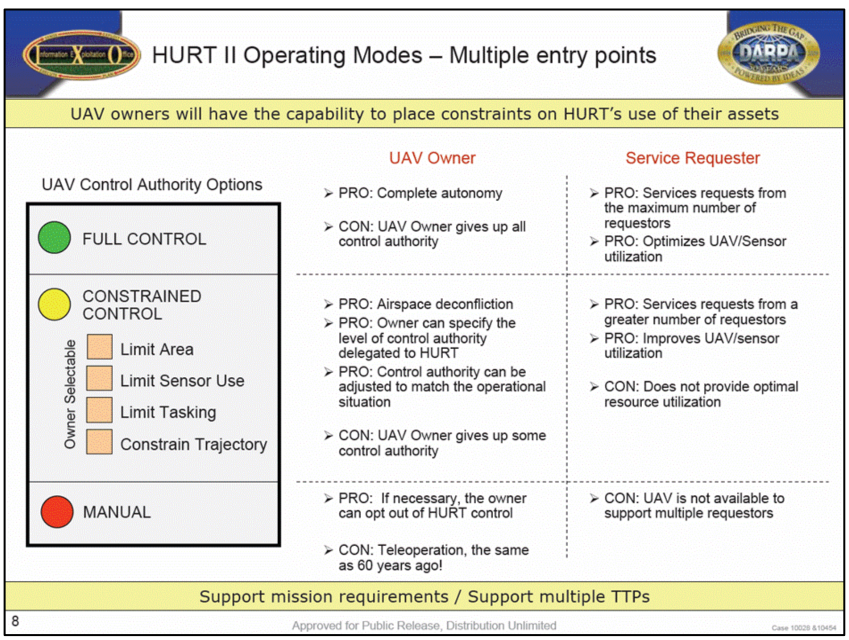

Figure 11: HURT II Operating Modes - Multiple Entry Points

In addition, HURT developed data formats to determine the minimum communication requirements for sharing tasking and defined constraints around the network to allow integration of coordinated tasking systems. HURT operating modes show operator ability to dial in full manual control of assets to full autonomous control, with intermediate levels of constrained control possible. Pros and cons of each level are shown in Figure 11.

The HISIT program demonstrated that simple rule sets could be automatically applied to meta-data tagged intel data to result in rapid generation of tasking requests. Although not fully implemented end to end, it was shown that this straightforward technology could be used to drastically reduce time to request tasking. The HISIT process is shown in Figure 12. More information on the HISIT program can be found in Appendix F.

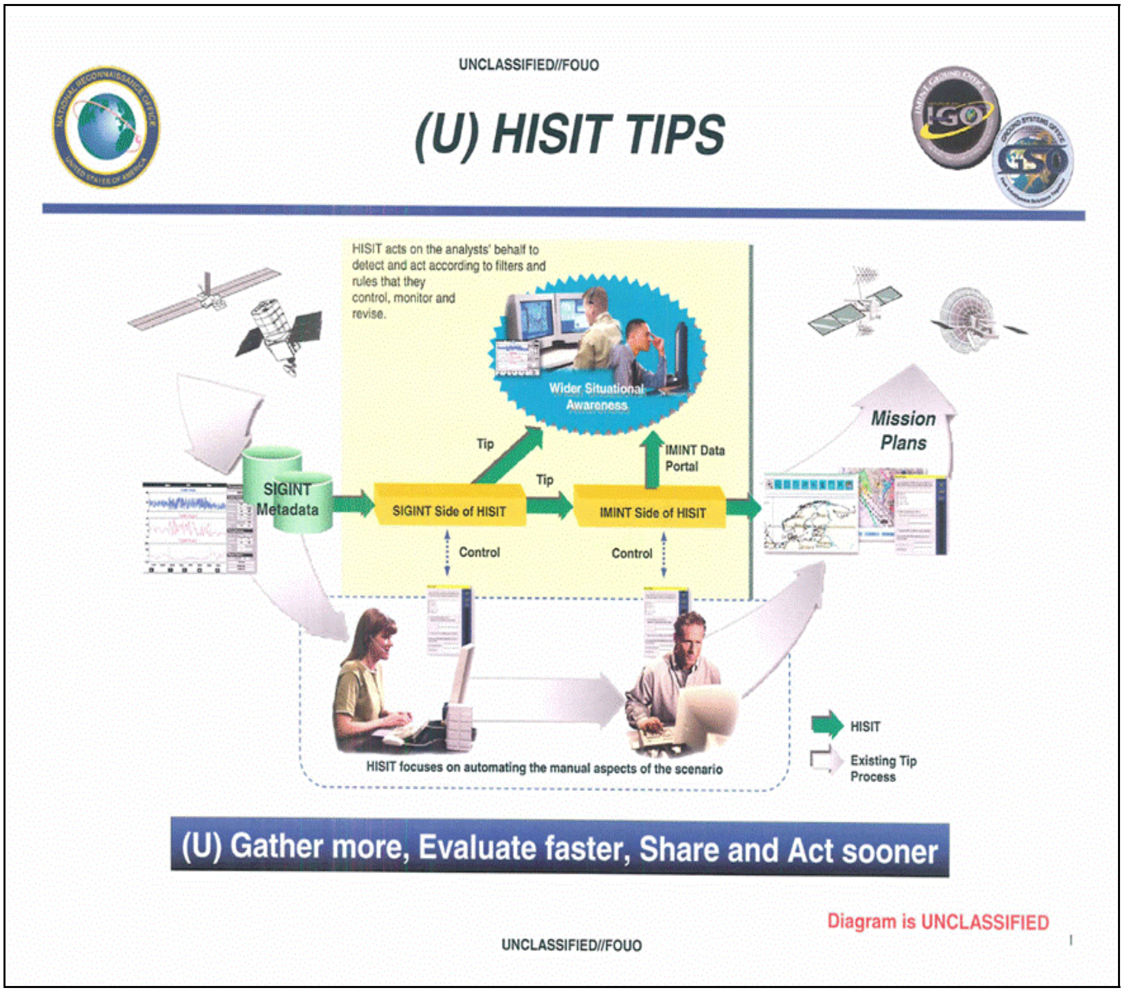

Figure 12: HISIT

Modeling activities, such as the National Exploitation Factors (NEF) data base and the Advanced Geospatial Intelligence Exploitation Toolkit (AGITK) show that detailed models can be used to inform collection requirements across multiple sensor types, geometries and spectra, although only if reliable calibration data is available. These capabilities have been demonstrated in operation.

The Geo Cell activity showed that co-location and coordination of cross-INT specialists results in cross-INT collection plans supporting information needs. Geo Cell enabled upstream feedback and control much faster than after final production. The major friction experienced was focused on INT-specific networks. Detailed information on the Geo Cell activity can be found in the Appendix F.

The collection of these activities demonstrates that the expected performance gains of sensor integration can be made efficient and deliberate using technology that has already been demonstrated, and that operators' confidence in relinquishing control of dedicated assets in exchange for the greater benefit of integration can be increased through participation in exercises.

5.4 Tasking Findings

Integration benefits resulting in higher system sensitivity, faster response times, and greater persistence are only possible if multiple sensors, which are currently managed independently operated, are tasked in a coordinated manner. The task force found that, except for a few experimental and technology development programs, current Tactical and National tasking processes do not support the required level of coordination.

One fundamental limitation inhibiting coordination is the lack of collection plan exposure at every level in the collection planning process. If one cannot determine where sensors are and what their system and mission constraints are, one can not begin to determine the feasibility of an integrated collection plan.

Another fundamental limitation is inconsistent feedback on collection assignments and results. The study found that it is frequently the case that an intelligence customer is not able to determine if a request actually resulted in a tasking order, and that the order was executed. Providing transparent processes, facilitated by accessible data, provides the minimum capability to begin coordinating tasking for integration.

The task force also found that, even if tasking information was exposed across stove-piped collection systems, the models and tools to allow operators to make informed decisions on logistical feasibility, cost, expected benefit and desired geometry and timing for coordinated tasking do not exist operationally, and they have been demonstrated only partially in R&D activities. Multi-INT sensor models, anisotropic target models, timely accessible collection meta-data from prior collects, and collection value models, and the analysis tools that use them are needed for operators to develop target-aware multi-INT collection plans across information needs. The required target and sensor models and analysis tools overlap the technology base needed to exploit the resulting collected data.

Sensors are tasked to satisfy collection requirements without passing on the original context of the information requirement that generated the tasking; however, context is needed by collection managers to prioritize and synchronize multiple sensors for a given problem. As a result, too often sensor integration occurs only when multiple sensors have coincidentally (accidentally) collected complementary data, and the results of that collection were serendipitously discovered to provide a benefit.

On a limited scale, operational experiments and ad-hoc integration centers such as HISIT and ARTT have demonstrated that coordinated tasking results in mission performance gains for time critical targeting and overall system sensitivity gains. In addition technology demonstration programs, such as HURT, have preliminarily shown that operator confidence to relinquish control of their resources into a common pool in exchange for the performance and coverage benefits of integration can be increased through participation in experiments.

5.5 Tasking Recommendations

SECDEF and DNI should take immediate action to establish procedures and policies for cross-INT tasking at lower levels in their agencies. This will require significant changes from current practice, system capabilities, and culture, and will require multi-agency agreement on definitions of intelligence value and priority. Therefore, the Defense Intelligence Operations Coordination Center (DIOCC) should lead a joint DoD/IC activity to study how to set tasking priorities, develop technologies and procedures, and establish policies for cross-INT, cross-agency tasking. The results should be reported to the directors of the constituent agencies. The study should take into consideration the need to eliminate additional layers of coordination above the CRSC at NSA and Source at NGA, the processes and technologies needed for coordination and transparency between operators and intelligence analysts, and the need to continue developing and providing career paths for individual INT experts. A clear set of metrics to evaluate end-to-end performance at the intel topic level is necessary to assess effectiveness and priorities, and should also be considered.

Greater visibility of collection plans will be required for coordinated tasking. The DoD and DNI should begin to integrate INT-specific networks, tools and business practices into a common infrastructure to provide transparent, rapid access and feedback to collected data, collection plans, and intel prior to final production.

Combined INT tasking successes should be continued and institutionalized to obtain the demonstrated benefits of sensor integration. In particular, The Directors of NGA and NSA should accelerate and institutionalize implementation of lessons learned from GeoCell. Agency directors should ensure that both agencies are deploying staff in equal proportion in these joint operations. DNI should also issue policy guidance to intelligence agencies requiring, and outlining minimums for, participation in the Intelligence Community Analysis and Requirements System (ICARS), which provides visibility into requirements and tasking across participating components. HISIT is another significant success (see appendix F). The Director NRO, in coordination with NGA and NSA, should immediately implement an operational pilot program incorporating HISIT capabilities.

Both DoD and DNI should continue to develop processes, experiments and training exposing the net performance benefits of relaxing total control of assigned sensors to encourage cultural evolution towards greater sharing. Programs such as the DARPA Heterogeneous Urban RSTA Targeting (HURT) program, Empire Challenge exercises, and EIX exercises are all good examples. The supporting technologies for coordinated tasking should be developed by DARPA, IARPA and military R&D agencies in partnership with sensor operators and INT consumers.

CHAPTER 6: LEVERAGING PROCESSING AND EXPLOITATION

Chapter 2 described how integrating sensor-collected information can improve the detection, geo-location, identification, and tracking of targets. Many of these benefits are afforded by processing the data from multiple sensors in combination closer to the sensor or otherwise exploiting the results of one sensor to tip or cue another. In this chapter the focus is on the task force's findings and recommendations relative to how processing and exploitation can yield further advantages as the assured broadband communications (Chapter 3) and meta-data tagging (Chapter 4) enablers are put in place. Processing and exploitation form a key lynch pin between the more agile tasking and collection approaches described in Chapter 5 and the need in the future for more systematic persistent and close-in sensing approaches described in Chapter 7.

6.1 The Role of Enhanced Processing and Exploitation

Data files generated by ISR sensors often are very large. Handling and filtering these data are a challenge for the sensor system and the platform, and the storage and bandwidth needed to communicate and post this information can be daunting. In some bandwidth-starved environments, it is recommended that sensor data be processed as rapidly as possible near the sensor front-end (referred to as forward), letting communications-disadvantaged users to pull only the data they need in near real-time. At some later time when communication channels are less congested, or upon request by a critical user, the raw sensor data can be down-linked through the channel. An example of note is the Rockwell Collins' STONE project, which addresses data flow for critical situation awareness. The STONE processor uses optical correlation to locate and identify targets and reduces the information to a few related pixels.

Forward processing of data from multiple sensors is often termed "fusion," however there are some distinctions that should be drawn here. Data from multiple sensors (identical or complementary) can be fused or integrated immediately upon generation to improve signal-to-noise or to extract certain target features. This fusion is helpful if data are to be used in a singular way, but some information that might benefit the larger community could be lost. Generally, forward data processing can also include techniques (correlations, disparate sensor overlays, pattern recognition), that traditionally are not considered fusion, but improve feature recognition and reduce the information handling needs.

Information latency is one of those critical issues that can be improved or hampered by integration and processing. For sensor data that is immediately communicated through wide-bandwidth links and is useful in its raw or lightly processed form, further automated processing and exploitation can delay utility. An abundance of forward processing is not needed. However, there are some mobile and stationary platforms with numerous sensors where the information cannot be retrieved until the mobile vehicle returns to a base station or the sensor system is recovered. Various reasons may exist for these sensors/platforms: communication systems are too power hungry or are not compatible with the sensor data or the sensor electronics, systems must operate "quiet" and cannot continuously broadcast, etc. Automatically processing the sensor data to reduce the critical information to a smaller packet or to provide a go/no-go response could improve reaction time.

Data integration and processing can provide a means for "covering tracks" or breaking the link with the data source. This can be helpful in protecting sensitive or vulnerable assets. Applying layers of information processing often precludes recovering the original data from the end product.

6.2 Emerging 3-Layer ISR Exploitation Paradigm

First, it is important to observe how the emergence of layered, service-oriented ISR architectures affords much more flexibility to support sensor information integration and future technology transition of improvements in processing and exploitation than previous monolithic sensor processing and exploitation systems. Programs like NGA's GeoScout, DIA's ALIEN, and the DCGS family of systems are separating the data, processing, and presentation layers with standard interfaces between them. The bottom data layer, which is concerned with the accessibility and discovery of sensor data, was treated in the meta-data discussion in Chapter 4. This chapter is concerned with the processing of sensor data by computers to convert it into information or the further exploitation of sensor information by intelligence analysts at the top presentation layer. This section describes this processing and exploitation dichotomy in more detail after first noting some important commercial trends that are occurring at the presentation layer, where the results of the ISR processing and exploitation are visualized and presented to users/operators.

6.3 Presentation Layer

6.3.1 Findings

Emerging Web Presentation Technology – Geospatial Information Systems (GIS) have been used for some time to present geospatial data against map or image backgrounds. Once the purview of specialized tool environments used by specially trained analysts; this capability has become mainstream with the appearance of web-based applications like Google Earth and ArcIMS, a web-based version of ESRI's GIS product line. The notion of locating and organizing all different kinds of information—Google's push pins—into layers, which the user can turn on and off, makes it possible to present ISR information in tools that users/operators are used to seeing on the Internet, virtually diminishing the need for training. This is a serious trend as witnessed by the use of this commercial web-based GIS technology by STRATCOM to create a user-defined operational picture and at the Counter-IED Operations Integration Center (COIC) to perform multi-layer integration of intelligence information.

This commercial web trend will make it possible for end users to more easily visualize raw data and the products produced upstream by others. While this may translate into more "on-the-spot" exploitation by the end user, it also portends the use of more "machine-readable" formats to transfer geospatial intelligence (GEOINT) products produced by professional exploiters/analysts to end users. This will obviate the need to convert and transmit information in the form of static PowerPoint slides, which can be burdensome to produce and difficult to understand. Instead the end user will be able to manipulate the GEOINT product as one more layer in an intuitive visualization system. PowerPoint's ubiquity means that it will not be replaced in all instances. But the growing popularity of commodity GIS, e.g., Google Earth, means a similar ubiquity will support increasingly "active" ISR information sharing across diverse communities.

A number of industry formats, e.g., Google's Keyhole Markup Language (KML) and ESRI Shapefiles, have become de facto industry standards supported by a wide range of presentation tools. More broadly, the Open Geospatial Consortium, Inc (OGC) is an international industry consortium of 358 companies, government agencies and universities participating in a consensus process to develop publicly available interface specifications. OpenGIS® specifications support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. The specifications empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications.

The strategic members of the OGC are BAE Systems - C3I Systems, ERDAS, Inc., Lockheed Martin, Northrop Grumman Corporation, the U.S. Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), and the U.S. National Geospatial-Intelligence Agency (NGA). In particular, NGA has played a very active role in promoting the definition of open standards and in the testing of product interoperability among products from diverse suppliers.

There will continue to be interest in exploring the application of high-end visualization systems for some difficult problems, a subject to which we turn next.

Effective Human-System Collaboration – The task force recognizes that full automation of ISR exploitation will not be feasible for a long time, if ever, and that significant human expertise is routinely required in ISR product generation. Accordingly, we have emphasized the improvement of the productivity of the human analysts who will be in the critical path for the production of the ISR information products.

Geographically dispersed collaboration among analysts will be required since not all relevant expertise will be in one analysis center location. Accordingly, high performance networking will be required to share information required to create analytical products. Several broadband multimedia technologies will be required to enable this collaboration. These will include highly secure and robust multicast protocols that enable selective broadcast of information to a specified community of analysts. Streaming multimedia protocols that enable efficient transmission of video, audio, and other large files will also be important. Streaming protocols are commonly used in commercial Internet applications, but they do require broadband connectivity for successful applications.

Mobile command centers have been developed and deployed in selected theater actions, but they will be more widely required in the future. These mobile facilities are designed for rapid construction and teardown and contain processing capabilities for local analysis and operations, as well as high performance connectivity to the GIG communications core for reachback to additional resources.

State of the art workflow processing is essential for ISR analysts and system operators to meet mission objectives. This is a key part of productivity enhancement and is required to make efficient use of the limited number of human experts. The workflow processing will implement well-defined analytical and operational processes and will enable collaboration by automating production processes.

Future command centers will require new operational concepts to meet the highly dynamic mission requirements for upcoming military operations. These operational concepts include both new methods of human social interaction and collaborative analysis and decision-making, as well as concepts of operating new technologies.

The improved social architecture will notably include distributed collaboration through new telepresence technologies. These technologies are well beyond current video conferencing facilities and include much higher resolution displays, 3D audio, dynamic automatic camera control, and highly interactive information processing systems to render a much more functional social environment than is possible by traditional video conference systems that are largely "talking heads" and simple presentation displays. These new telepresence systems are beginning to be sold commercially, but the DoD applications will require much higher capabilities for robustness and security than is currently available. However, the improved technologies can be rapidly implemented once the supporting DoD infrastructure is in place.

One promising telepresence technology for enabling collaborative analysis of geospatially distributed data across the network is the "touch table" shown in Figure 13. The touch screen table top allows the analysts to interact very efficiently with the networked data sources to create their products. These tables can be networked over wide area networks to facilitate remote collaboration.

Figure 13: Table top collaboration

Several technologies are critical and assume that sufficient broadband networking capabilities will be available for DoD and IC use. Very high resolution interactive displays and broadband networks will be essential to enabling the necessary highly productive collaboration among the analysts. They will also require very high performance access to relevant information. This implies that the DISA NCES will need to be realized in time.

6.3.2 Recommendations

Based on its findings, the task force recommendations relative to ISR data presentations are:

- Promote the adoption of commercial Internet geospatial analytical and display technology wherever possible.
- Promote the use of standard formats to convey geospatial products versus converting to PowerPoint.
- Promote the use of web-based technologies at the presentation layer in general and of standards by the Open Geospatial Consortium in particular.

- Promote the efficient interaction of the presentation layer technologies with broadband collaboration technologies through the development of multi-layer protocols.

The next section returns to the heart of the matter for integrating sensor-collected information—the processing and exploitation phase.

6.4 Processing and Exploitation

Many of the traditional sensor integration cases described in the examples in Chapter 2 involve well understood mathematical algorithms that combine sensor information to improve geo-location accuracy or increase the probability of detection of targets. The challenge in this case is in getting the data at the right times and places to support this processing. In contrast, contemporary challenges associated with asymmetric warfare involve the integration or combination of information from a wide range of sources—technical sensors to HUMINT and open sources. The challenge in this case is making judgments to reach the right conclusion based on the evidence at hand. Figure 14 shows a spectrum of activities associated with the integration of sensor-collected intelligence: quantitative activities involving processing on computers and qualitative activities involving exploitation by people.

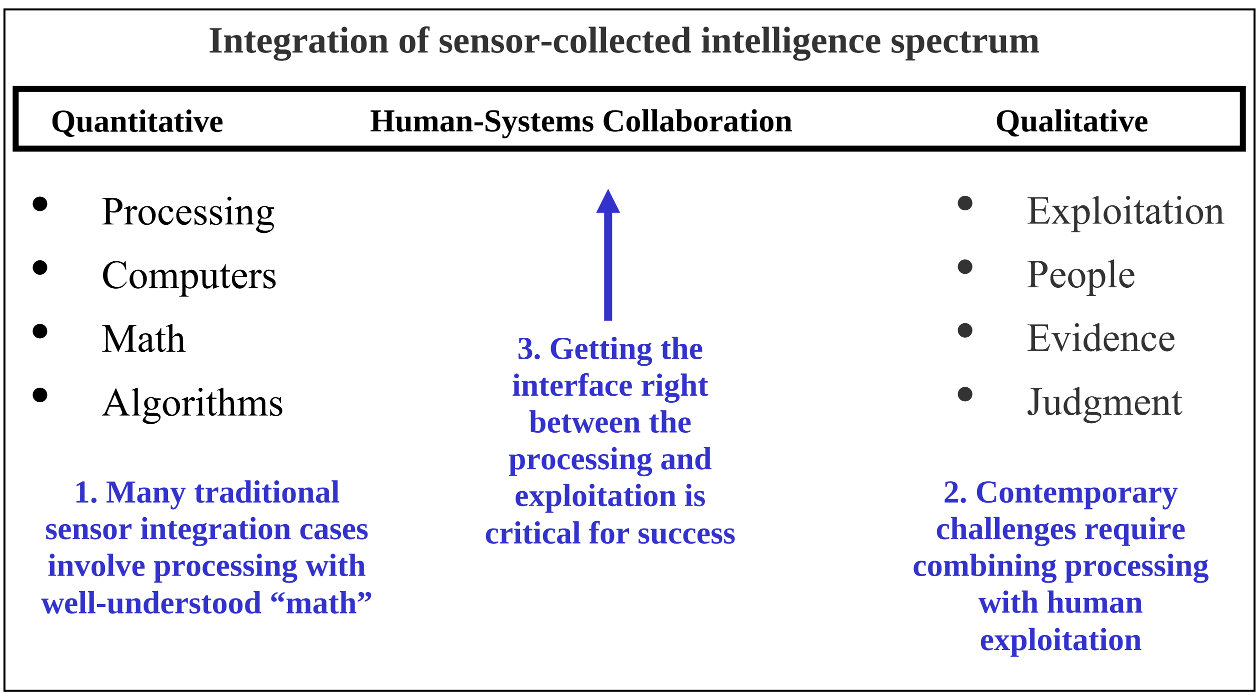

Figure 14: Integration of Sensor-Collected Intelligence Spectrum

A critical success factor is getting the interface correct between the computer processing and the human exploitation; in other words, the use of computer processing to attempt to automate what people have traditionally had to do. Automatic target recognition is a good example of the past issues that have come up in striking the right balance between computers and people. Past attempts at automatic target recognition in synthetic aperture radar, for example, have worked well in the laboratory but have not enjoyed the same level of success when deployed. This has been a case in which the current state-of-the-art in computer processing was not up to the task. In contrast, the notion of assisted target recognition where prescribed areas, like known airfields, are surveyed periodically for changes to produce cues for the analyst to investigate has been much more successful. Establishing the correct level of human-systems collaboration and finding mechanisms so R&D efforts can make real advances in increasing automation that analysts trust are prerequisites for increasing the efficiency of the exploitation process as more and more data is made available.

6.4.1 Keys to Sensor Integration: Time and Location

Throughout the deliberations of the study, the task force kept coming back to the prominent role that time and location play in the integration of sensor-collected information. Members of the task force asked if there were a third such important dimension, but came up empty as far as having the same universal appeal as time and location. Figure 15 attempts to organize all the sensor-integration cases under consideration for two sensors using the simple keys: location - where are the two sensors looking? And time - when are the two sensors looking?

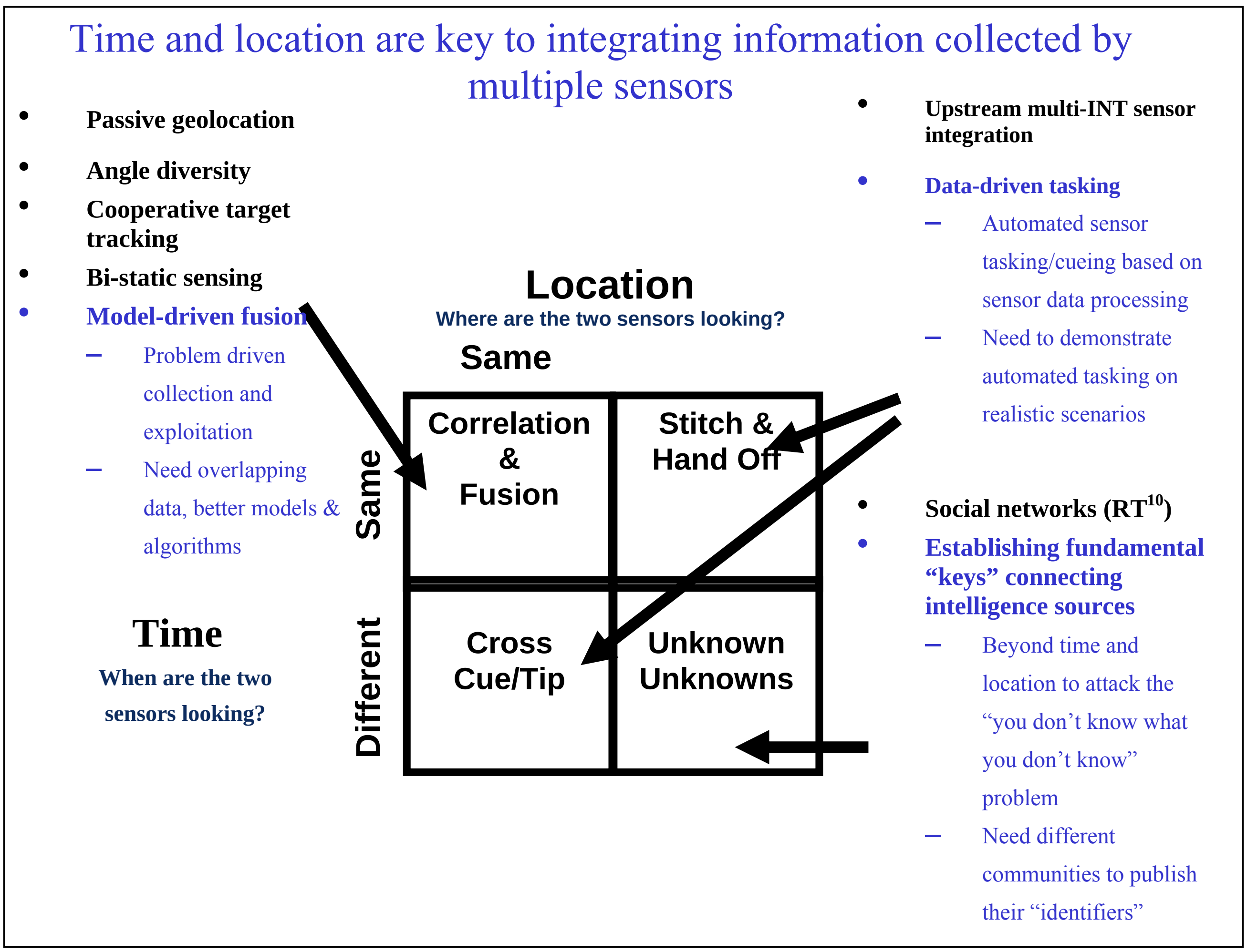

Figure 15: Keys to Sensor Integration: Time and Location

The classic case of correlation and fusion corresponds to when the two sensors are looking at the same location at the same time. The quantitative examples discussed in Chapter 2 of passive geolocation, angle diversity, cooperative target tracking, and bi-static sensing fall into this category. This category is also associated with the important topic of *model-driven fusion* (see section 6.4.2), in which the problem breakdowns into its constituent pieces and signatures inform collection and exploitation requirements. The challenges in this case are the collection of overlapping data at the appropriate times, better models for the intelligence problems of interest, and better processing algorithms.

The case of the same time, but different locations corresponds to "stitch and hand off" scenarios in which two sensors optimized to cover different types of terrain can be combined to provide end-to-end coverage of targets as they navigate from one sensor coverage footprint to the other. The case of the same location, but different times corresponds to cross-cueing or tipping of sensors as well as the example discussed in Section 2.3 - "upstream multi-INT sensor integration." Both the cross-cue/tip and stitch-and-hand-off cases could be further optimized if data-driven tasking (see section 6.4.3) was supported by having different sensors in a constellation tasked based on what is happening in the scene.

This leaves the case of sensors looking at different locations at different times. At first glance, this seems incongruent with what is normally thought of when integrating sensor information. But this case is actually quite important because it portends the discovery of the unexpected—the case of the "you don't know what you don't know." Integration of two such sources of information depends on some other key beyond time and location to connect them. Examples might include a telephone number used to connect a source of HUMINT collected at time T and location L with a source of SIGINT for a totally different time and location. Another example could be capturing a vehicle on video at two different times and locations, but correlating through the same license plate number. These identifiers (telephone numbers, passport numbers, vehicle identification numbers, etc.) do not have the universality of time and location, but become essential for relating the same entity that is being sensed or tracked by different communities, e.g., HUMINT and SIGINT. This is the area of social network analysis (RT[10]) discussed in Appendix D.

The universality of time and location as meta-data elements is in both the Department's Discovery Meta-Data Standard and the evolving Universal Core. See Chapter 4 for relevant recommendations. Rather than waiting to attain universal agreement on additional fundamental keys beyond time and location, the task force recommends:

- COIs should establish and publish their semantically lightweight identifiers in whatever formats are currently customary.
- DoD and the Intelligence Community should perform a crosswalk of the resulting semantically lightweight identifiers to identify commonalities and opportunities for near-term cross-COI information integration to address current "unknown unknowns" challenges.

6.4.2 Model Driven Fusion

In the model driven fusion approach, a complicated intelligence problem is broken down into its constituent pieces with the goal that understanding or confirming the existence of these parts can be integrated together to address the original question. This ties back to Chapter 5 as these models will identify what is needed to discern the appropriate details of the target; what is required to characterize it; and how that could/should be accomplished with the sensors at hand—model-driven tasking of sensors to support model-driven processing and exploitation.

The following example illustrates the model driven fusion approach. The facility shown in Figure 16 may be a potential chemical weapons manufacturing site. However, there are no unique signatures and there are several alternative hypotheses for legitimate activities at the site (e.g., baby food production).

Figure 16: Model-Driven Fusion Example: Suspected Chemical Weapons Facility

To begin to effectively analyze the site model(s) are needed to determine what goes on at the site. This would include estimates of the type and quantities of inputs and outputs from the site. The estimates would include the obvious material outputs but would also include things like power requirements, communications, manpower and particular expertise. The model would also have to address the processes that might be taking place in terms of temporal sequences. This often must be done not only for the threat scenarios but also for competing scenarios so that alternate hypotheses can be appropriately evaluated.

The process based model(s) must then be translated into potential observables. This includes the obvious physical observables (e.g., tank trucks in and 50 gallon drums out), as well as, many more subtle observables. For example, chillers must have heat released from a heat exchanger/cooling tower; exothermic reactions will heat up reaction chambers; movement of hot and/or cold materials in pipes may have thermal signatures; waste gas releases may be observable at certain times; specialized equipment might generate electronic signals; and communications might make reference to a small number of experts needed to supervise or observe activities.

These activities lead to a generic process model description of the potential signatures from a chemical weapons facility and for alternate uses of a site. These models would typically be developed well in advance of their application to a specific site by a mix of domain experts and intelligence community scientists. Figure 17 shows a process model scheme.

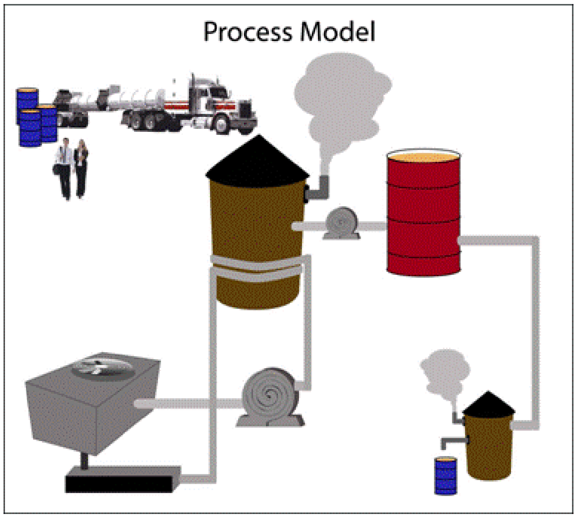

Figure 17: Process Model Schematic

Once a potential site is identified the generic model is applied to the specific site. This process would involve matching a generic process model template to a specific site to try to identify where signatures would be manifest at that site. For example, what pipe should get hot/cold and when; what cooling tower should get hot and when (how hot); what stack or hood should release gases and with what signature (when, how much, how long); what physical observables (trucks, spills, etc.) should occur (where and when), etc.

Based on the site specific model all relevant data (EO/IR, SIGINT, HUMINT, etc.) would be searched and analyzed to build a match to the site template hypothesis. Inevitably there will be places where no data exists and additional tasking and data acquisition can be driven by the model.

As data builds there will be places where the model matches, places where there are no data and places where the model and observation disagree. This leads to comparison of the match with the alternate hypothesis or revision of hypothesis or models.

At any point where more data becomes available it can be added to the site specific model. This includes both a model of the suspect and alternative processes, as well as, physics based models of these processes which can manifest as observables to the full range of sensors that can be brought to bear on the target.

For complex, subtle intelligence problems the wealth of data can easily overwhelm an analyst. This model based approach provides a way to organize and apply multi-sensor data in a fashion that guides analysis and can provide a means to generate confidence in supporting or rejecting a hypothesis. It also provides a clear way to guide additional tasking and analysis to illustrate or confirm alternative hypotheses. The complex problems facing analysts will seldom yield to a single measurement or modality. Flooding analysts with all available data without a means to effectively sort and organize the data is likely to provide little improvement. Model based fusion offers the potential to provide the analyst with a means to effectively attack complex problems whose solution requires multi-sensor/multi-modal observations.

Without access to the full range of signatures these approaches cannot succeed. More samples from more modalities is often more important than one exquisite acquisition at the wrong time.

This approach feeds on data from a wide array of sensors provided the data are effectively tagged and accessible.

The task force recommends focusing research and development on two areas:

- Development of improved models of hard target problems coupled to multi-dimensional signature models. Also support is needed for advanced algorithms to exploit multidimensional data and to merge multidimensional data and target/process models to achieve improved detection and automation and to probe hard target problems modalities.
- Development of processing tools for multi-source data that take advantage of models of intelligence problems, in particular tools capable of the upstream combinations of data to improve performance, tools that deal with less than complete data sets (i.e., partial template mapping), and tools that establish the value of integrating pre-detection information from multiple sensor modalities.

6.4.3 Data-Driven Tasking

In some dynamic situations, the correct next sensor to apply will be dependent on the current context. A simple fire alarm monitoring/notification example illustrates the point: if there is a fire alarm, automatically notify the fire department; if there is a smoke alarm, which are prone to false alarms, call the dwelling to verify; if no answer, notify the fire department.

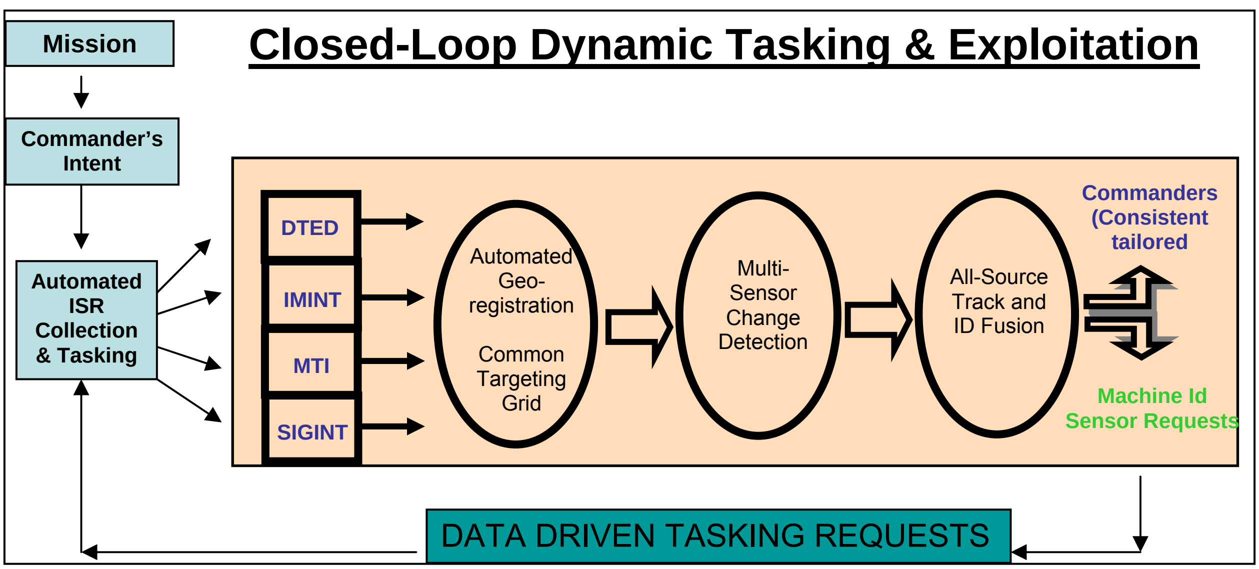

Figure 18: Closed-Loop Dynamic Tasking and Exploitation

Figure 18 illustrates the closed-loop dynamics of data-driven tasking and exploitation. The mission and the commander's intent are the driving factors, as well as the ability to automate certain parts of the process so that if the machine detects that the situation demands certain information it can automatically task available assets or re-task lower priority collections. Introducing automation into the tasking area must be done with care to overcome cultural and control issues, as was discussed previously in section 5.3 related to the DARPA HURT program. The right-level of human-system integration that introduces accurate automation as an aide to human decision making is a key to success.

Dynamic data-driven sensing is needed to support persistent surveillance concepts described in Chapter 7. For example:

- If a certain pattern is observed by a low-resolution broad-area activity sensor, such as an airborne ground moving target indicator (GMTI), it should be possible to task a medium-resolution imagery sensor that can be quickly cued to take a picture of the spot in question. If that sensor indicates potential activities of interest (e.g., involving people rather than animals), then it would be desirable to vector a high-demand UAV with full motion video into place. This multi-resolution collaborative sensing vision presupposes that algorithms exist that fairly accurately detect activities of interest. These algorithms do not need to be perfect, especially if the verification is low cost. When the adversary is adaptive, these activity detection algorithms must be similarly adaptable.
- It may be possible to automatically hand off a radar GMTI track from a suburban/rural area to a Constant Hawk track in an urban area, and potentially cueing a UAV full motion video sensor. This will require significant advances in ground-based tracking and the association between tracks.

R&D progress against these processing challenges will require data containing realistic background activity. Of especial interest are the large format EO sensors such as Constant Hawk and Angel Fire that are deployed today and the DARPA ARGUS platform in the future.

The task force recommends focusing research and development for data-driven tasking on two areas:

- Processing to support data-driven tasking through the detection of patterns of interest in the data to support alerts, tip-offs, and cues.
- Assisted tracking of ground moving target indicators (GMTI) derived from either radar or large format "near-video" electro-optical platforms, and handoff of tracks across the radar and EO/IR modalities.

6.5 Enabling Processing and Exploitation R&D

6.5.1 Findings

Much research has been conducted in the past in an attempt to automate exploitation—pushing the processing-exploitation interface described earlier in Figure 14 to the right—but with mixed results due in large part to the dependence on the use of synthetic or unrealistic controlled data for assessing the performance of algorithms. Unfortunately the performance of these research systems suffered when applied to real data, and so the research never transitioned. The recent events in Iraq and Afghanistan have resulted in a large amount of sensor data being collected and archived with a modicum of ground truth that comes from persisting over the same area for long periods of time. Examples include archives of full motion video from UAVs, GMTI from airborne radar, and large format "near-video" electro-optical collections (e.g., Constant Hawk, Angel Fire).

As a result, there are new opportunities for research and development to address important sensor processing challenges that will translate into more effective and efficient use of integrated collections of sensors. And as a bonus, any processing algorithms that pass muster in realistic objective evaluations can be more easily inserted as a service in the middle processing layer of the 3-layer ISR exploitation paradigm. Technology transition will also be facilitated by allowing analysts to "dial up" the degree to which they are willing to trust the computer-based automation similar to the DARPA HURT approach described in Section 5.3.

6.5.2 Recommendations

Previous sections provided the task force's recommendations for particular processing and exploitation R&D topics. This section provides more general suggestions to help make it more likely that this R&D will transition to practice. In particular, the task force recommends DoD:

- Continue to conduct experimental data collections such as the recent OSD-sponsored Bluegrass collection (Sept 2007) that combined overlapping LSRS, JSTARS, and Constant Hawk sensors against multiple challenge scenarios to provide the research and development community critical real data with realistic background confusers to explore processing and exploitation challenges.
- Continue to use realistically scripted military and intelligence experiments/ exercises, for example, Empire Challenge, to demonstrate the military and intelligence value of collaborative tasking, processing, and exploitation across multiple sensor modalities.
- Promote the inclusion of automation into exploitation tools through the use of analyst interfaces that support the "dialing up" of the amount of automation employed to allow for the incremental build up of analyst trust based on the processing results.
- Promote the development of processing services that stand alone from the end-user desktop tool. Give extra credit to proposals that develop processing techniques that can be demonstrated as services that multiple desktop exploitation tools can access.

CHAPTER 7: SENSOR GAPS AND SHORTFALLS

Today's stressing ISR missions are challenged by the hard sensor problems the DoD has faced for decades. They range from the detection, surveillance, tracking and identification of moving vehicles in various clutter environments; to the surveillance of individuals moving in normal every day urban environments. The classic problems of adversaries using the natural environment to hide, for example under foliage, still face the fundamental limits imposed by the physics of electromagnetic scattering from trees and other material that attenuates the sensor signals. Detection of WMD is also a very challenging problem due to small signals, high background clutter, and the ability to mask signals with shielding materials. To overcome these challenges, improvements in sensors, collection platform access and timeliness as well as the all important integration of multiple sensors are needed.

The task force did not conduct an extensive review of current and planned ISR sensor programs. However, it did observe that there are robust plans for acquisition and deployment of airborne ISR, with particular emphasis on unmanned platforms. Even with increased availability there is a growing demand for these airborne systems, especially those that provide full motion video in support of current operations. On the other hand, the situation relative to satellite-based ISR is much more fragile. There was a purposeful drawdown of these systems following the Cold War and modernization programs were planned to replace only a fraction of the former assets. Further, well-documented execution problems have left the U.S. behind its overhead ISR plans. Changing world events have increased demands beyond those of the planned capability. Appendix G provides a classified discussion of the task force's assessment of the gaps and shortfalls in these plans.

The task force specifically investigated four topics:

- Providing persistent surveillance, with a focus on the increasing demand for full motion video sensors
- Close-In sensing
- Status of sensors to detect difficult signatures
- Acquisition strategies to leverage sensor integration

7.1 Persistent Surveillance

Current operations in Iraq and Afghanistan are dramatically increasing the demand by operational commanders for persistent surveillance with full-motion video optical sensors. This demand places huge burdens on communications and image processing infrastructure. While full motion video is an attractive option because of its compatibility with video monitors and commanders' familiarity with viewing television, **the task force recommends that a systems perspective be adopted relative to persistent surveillance requirements.**

An integrated ISR approach containing a balanced system design will allow observing an area of interest with sufficient frequency and resolution, but will not result in an over-sampling of the area (which would cause an inefficient, more costly, and unproductive use of ISR assets). Thus, rather than requiring the sampling rate (32 frames/sec) of full motion video for all situations, the sensor system design should be based on the expected dynamics (rate of change) for the targets of interest.

To prevent such over-sampling and thus less-than-efficient use of assets, it is fundamental to remember that we seek to detect change or events by using sufficient temporal or spatial resolution to resolve ambiguities. By doing so, the change or event becomes more prominent from one product to another, versus appearing "subtle" as it might with over-sampling. This relatively subjective statement is backed by the objectivity of Nyquist Theory (depicted in Figure 19) which negates the need for continuous coverage by supporting a limited amount of sampling—at 1.5 to 2 times the maximum frequency defining the event—because further sampling will not yield any new information regarding the event.

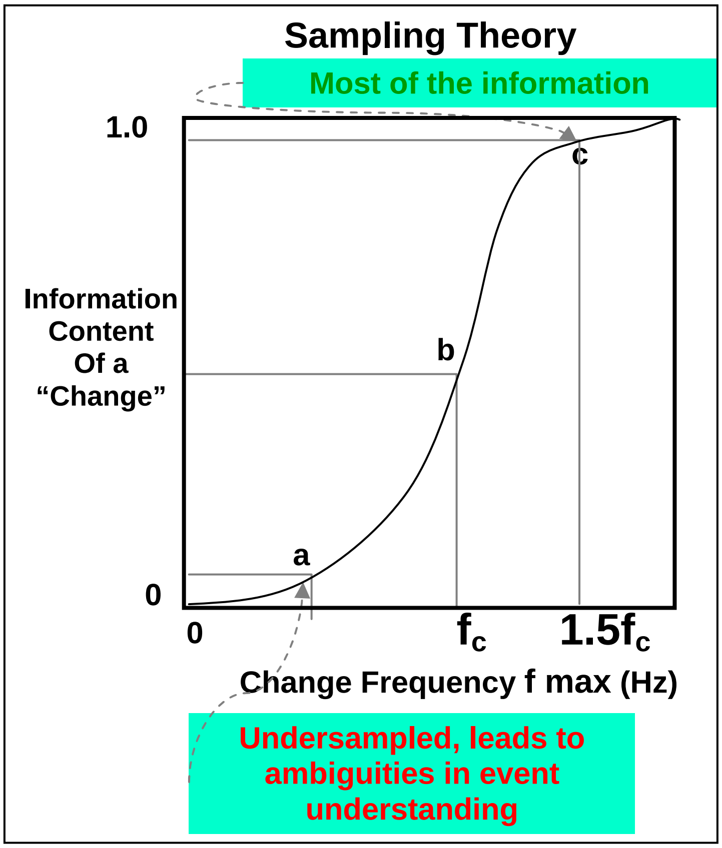

Figure 19: Sampling Theory

In addition to its lack of utility, over-sampling also has the negative warfighter impact of requiring more communication bandwidth, but yielding little if any additional value. It is important to ensure sampling often enough to detect and possibly impact an adversary's freedom of action through effective change and event detection.

Overcoming the challenge of persistent surveillance, which is the near continuous observation of a region for an extended period of time sufficient to resolve targets in their environment and track their movements, requires looking in the right place at the right time for some period of time. It also requires a sensor that "sees" in the right part of the electromagnetic spectrum, with the right polarization and with sufficient sensitivity. This combination of a platform that gives the required access with a favorable geometry and sufficient access to temporally resolve the activity is just as important as having the right sensor. Figure 20 outlines the system-level trades that must be conducted to find the optimum combination of sensor observables and platform access that are synergistic with each other and enable optimum chance to understand the situation.

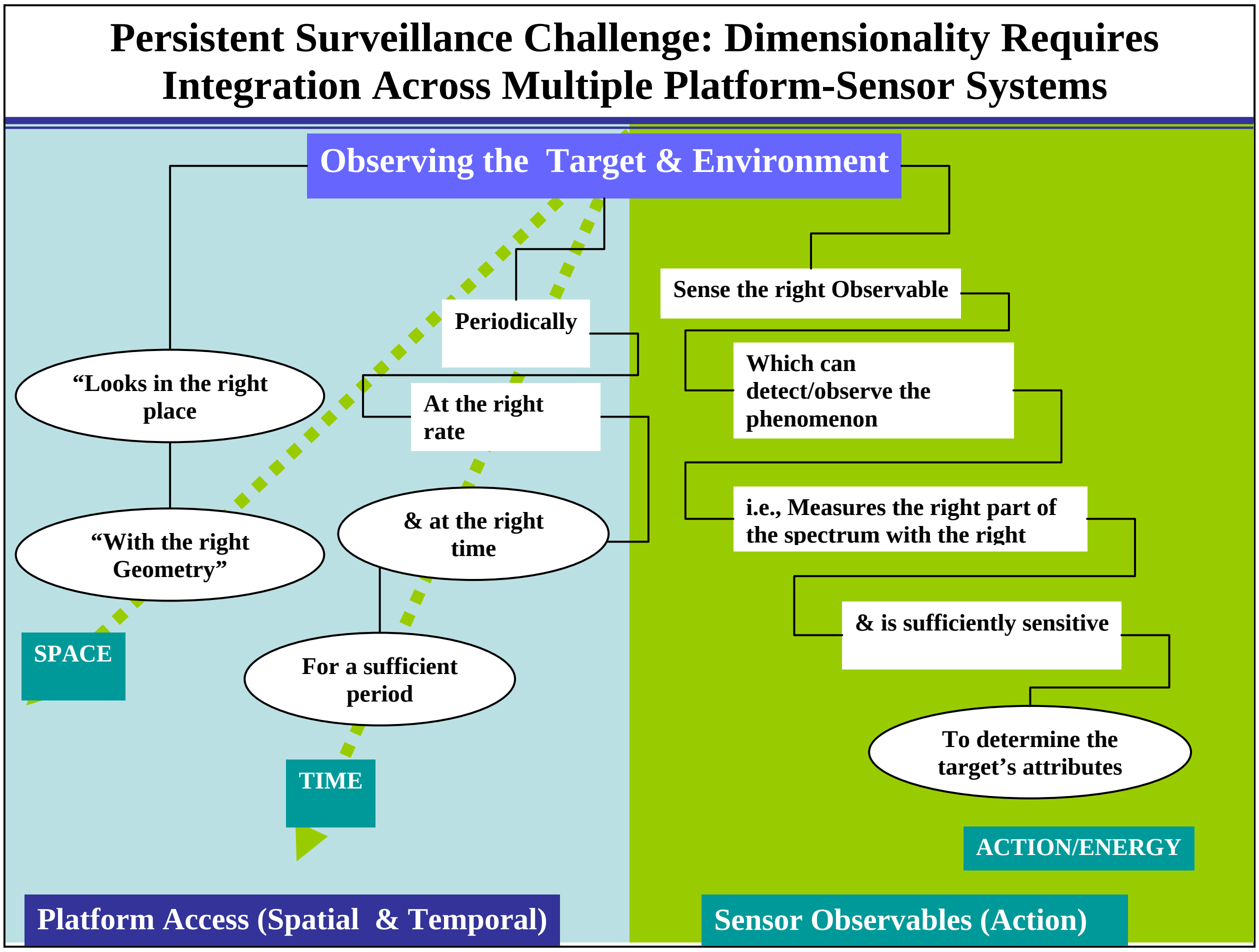

Figure 20: Persistent Surveillance Challenge

The array of UAVs available for use as a surveillance sensor platform allows optimization of sensor performance. The platforms can provide a wide selection of speed, altitude, payload capacity and range/endurance to meet mission objectives at the best price/performance. Vertical takeoff capability for sensors allows for a near zero velocity platform to minimize the apparent Doppler shift seen by the radar sensor from the now stationary clutter. This near zero measurement reduces the clutter noise that can mask a target signal in a ground moving target indicator radar. In effect any target motion stands out from the stationary clutter surrounding the target and truly attains a zero minimum detectable velocity for targets. The platform with zero velocity complements the moving target radar sensor to achieve the most sensitive total system.

7.2 Close-In Sensing

Many difficult signatures, including detecting WMD and its precursor agents, tracking people and characterizing deeply buried facilities, require dedicated sensors positioned in close proximity to the target, either because the signature decays rapidly in range, the signature is obscured from standoff sensors by cultural features, or because the signature exists only for a short time.

Close-in unattended ground-based sensors (UGS) can provide useful alerts for a wide spectrum of signatures. These alerts can be cued to trigger other high demand/low availability sensors whose data can be integrated with the UGS alerts for higher confidence decisions. UGS can also be remotely controlled to collect more frequently. It also possible to configure the system to report wide-bandwidth information only when cued by alerts generated from theater sensors, thereby preserving energy for when it is most needed. UGS can also be used to determine when atmospheric conditions are best suited for observation from airborne platforms.

There are many challenges to using close-in sensors. Because of size, power and sensor phenomenology, they are inherently short range, limiting their use to choke points and fixed areas of interest. As a result the number of units required can be large even to cover modest (few square km) areas. Once deployed, little or no flexibility is available to correct pointing and deployment configuration problems. Further, the need for local infrastructure to support data ex-filtration complicates the logistics for employment, and the low bandwidth output limits ability to integrate these sensors with other remote sensors. In most cases, these close-in sensing missions have been planned on an ad hoc basis and have been matched to a specific scenario.

To improve close-in sensing capability, technology is needed to extend duration and reduce the number of sensors required. New integration algorithms are needed to realize performance improvements of the close-in devices through combination with longer-range standoff sensors. Sensor costs needs to be reduced and new methods of low-cost, standoff delivery are needed to make deployment over a wider scale affordable. On-board processing capability must be developed to allow the close-in sensor to not parrot raw data according to fixed schedules, but instead, to use smart algorithms to exfiltrate cueing information and to send raw data when requested for remote correlation processing. Technologies must be developed to allow close-in sensors to consume significantly less power and to have power systems able to provide deployment durations of many months without needing to replenish batteries or redeploy fresh sensors. Close-in sensors need to be made mobile to be able to provide optimal orientation in response to a time evolving situation, to be able to reduce the number of sensors needed per unit area, and to provide the ability to optimally position for communications.

The task force found evidence that progress is being made across several of these objectives. For example, consider a tagging, tracking and locating (TTL) mission and the algorithm and system architecture trades possible using smart algorithms for GPS processing.

GPS Acquisition Energy		
Phenomenology	Concept	Energy per cycle
Distributed GPS	Field unit periodically wakes, digitizes and stores GPS RF spectrum. Data either exfilled or recovered, processed.	~1 millijoule.
Local GPS	Field unit periodically wakes, digitizes and processes to fix.	~5 joules.

Figure 21: GPS Acquisition Energy

The processing energy (Figure 21) to compute a single GPS fix with external aiding of course position can be done for about 5 joules in an efficient embedded digital signal processing chip. The resulting information message can code location in about 100 bits. For long–range exfiltration with small, inefficient antennas in disadvantaged locations, the transmission energy will dominate even for this modest message. With an appropriate receiver, unprocessed GPS signals can be sampled and retransmitted for 1/1000 of the full fix processing energy, but this option requires about 1000 times more samples to be transmitted. If the device needs to communicate these unprocessed GPS signal samples more than a few 10s of km, or using a poor antenna, or though canopy, this repeater architecture fails because propagation losses overwhelm the processing energy savings. With the proper system design trades, it is possible to intelligently use one mode of operation or the other and optimize overall performance.

Another such system-level trade is associated with the balance between processing energy to compress the detected signal and the energy to transmit the resulting data stream. For speech, Figure 22 shows the linear compression rate versus energy for various compression algorithms producing the same mean opinion score (a domain specific measure of distortion) currently implemented in deployed systems or in R&D. The data shows that there is a particular energy cost (computed based on embedded processor instruction cycles) to achieve a compression ratio. The cost/benefit of these varies. Because propagation loss versus range is at best inverse quadratic (with R**4 close to the ground, and additional losses for fixed obstructions like trees), it is often worth spending the energy on as much compression as possible. More energy efficient technologies for compression are needed with acceptable distortions for various phenomenologies and signatures of interest to close-in sensors.

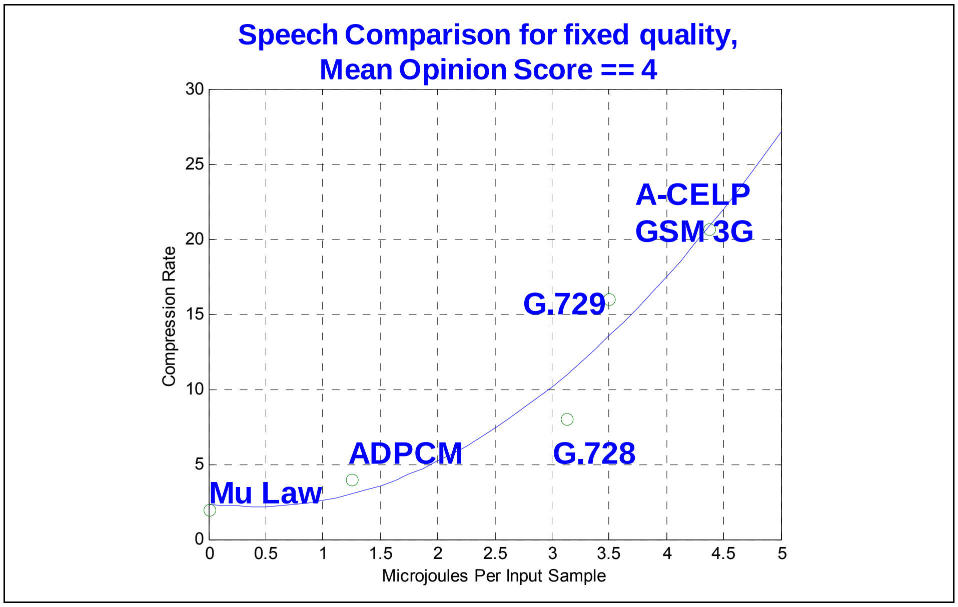

Figure 22: Speech Compression Rate vs. Energy

Memory density and cost are both trending favorably to develop close-in sensor systems with TIVO-like capabilities in which highly compressed data is transmitted, but all data is archived in pure sampled form. The system architectures that exploit these technologies must work with both low and high fidelity data and there must be control techniques to exfiltrate the high fidelity data only when it is needed based on indications in the low fidelity data or cues from other sensors.

The task force recommends that a broader systems view discussed above be adopted in addressing close-in ISR requirements. Further, this perspective should consider the infrastructure issues of delivery and ex-filtration across a range of close-in collection missions rather than addressing each requirement uniquely.

Research efforts to improve close-in ISR should focus on:

- Exploiting the DOE exploratory research in dense networks of inexpensive sensors.
- Integration of persistence airborne sensors with close-in sensors.
- Development of large IR focal plane arrays for UGS.
- Surface-based, integrated network of video cameras for autonomous ID and track of vehicles and people.
- Networked micro-UAVs which can perch and stare.
- Tracking algorithms and enhancements.
- Development of robust pattern recognition and interpretation techniques.
- Development of tools to enable dynamic tasking of close-in sensors to include the support of a rapid tip and cue of high resolution UGS video.

7.3 Status of Sensors to Detect Difficult Signatures

The hard problems which challenge our ability to see the adversary are being attacked with multiple approaches. Table 1 shows nine sensing techniques and their applicability towards 5 key hard problems. Developmental status is shown as well. As can be seen from the table, many of these difficult targets present real technical challenges for sensors that can detect the low magnitude and/or noisy signatures that they emit. Many of these challenges, such as detecting weapons of mass destruction and their precursors or characterizing deeply-buried targets, have been research topics for many years with only modest development success. The task force believes, however, that it is important to continue this research because of the criticality of the associated ISR collection needs.

Hard Problems	Continuous observation and recording	Active Nuclear Detection recording	Short Range or In-Situ Sensing	Coherent Change Detection	Zero Velocity GMTI	Quad Polarization Radar Imager	Active Laser-Mater interaction	Multi-Static, Multi-look	Hyper-Spectral
Counter Denial-Deception	R			D		R		D	R
Tracking People	D		D		D	R		R	
WMD		R	D				R		R
Foliage Penetration			D		D	R		D	R
Buried Targets			R	D		R			R

D = Develop, R = Research

Table 1: Hard Problems and Applicable Sensing Techniques and their Status

While single senor phenomenology for many of these targets is extremely difficult to reliability detect, there are potential benefits from integrating data from multiple sensors. To illustrate the value of sensor integration for these hard targets, the rest of this section discusses sensing in urban environments, where the biggest current challenge is tracking people, and sensing in environments that have dense foliage. Other examples are discussed in Appendix G.

7.3.1 Sensing in Urban Environments

Tracking targets, particularly people, in urban environments is critical to current stabilization and counter-terrorism missions and it continues to stress the present capabilities of our forces. The second challenge is to find the suspected targets under a high degree of clutter (urban clutter) in a large population.

Sensors need an integrated architecture because they are limited by visibility, clutter, people and vehicle high traffic density, etc. Some successful capabilities to date include utilizing video surveillance for forensic backtracking. An integrated sensor architecture with multi-modalities (EO, SIGINT, MOVINT, etc.) offers great potential to mitigate the challenge.

Integration of sensors on multiple platforms which have complementary capabilities will be required for surveillance in urban and near-urban domains. Radar sensors on large airborne platforms (e.g. JSTARS and LSRS) will be required to provide surveillance in rural and suburban areas to detect and track moving targets over a large area, but in low to moderate traffic densities. Improvements in time-on-station using long endurance UAVs will increase the coverage areas and help reduce the cost of persistence.

In the high traffic density associated with the urban environment, the rapid revisit time (~ 2 per second) associated with EO surveillance systems such as Constant Hawk supports tracking of moving targets. Long endurance Vertical Take-off and Landing (VTOL) UAVs which can complement the sensor needs will provide vertical agility and hover capabilities to optimize sensor starring geometry.

Continuity of target track between the rural/suburban to urban domain will require handover from ground moving target indicator (GMTI) to optical trackers. SIGINT can contribute to improved track association for this purpose, as well as target ID. For closer observation of a suspect site, a UAV-mounted video sensor can be cued to collect high resolution full motion video of possible dismount activities. However, as discussed in Section 7.1, the sample rate of video is likely higher than required by the rate of change in the scene.

Short range radars (GMTI/SAR) integrated on small or micro scale UAVs can provide surveillance in urban terrain during bad weather and at night to complement urban EO surveillance. The reduced level of normal activities also helps in identifying suspicious activities as well as tracking suspect vehicles. These radars can also be cued to detect, and potentially characterize, dismount activities through spectral analysis of the Doppler return.

Wide area near-urban surveillance provides cordon surrounding the urban area to provide continuity of coverage of activities that originate or terminate in the urban terrain, e.g. visits to and from weapons caches, and IED emplacements.

When vehicle tracks continue into an urban area, the track is handed over to higher revisit rate EO sensors integrated into VTOL UAVs which are well suited for the urban terrain (steep look angles favored by EO sensors ensure high visibility). Target tracks can be exploited to detect activity patterns and associate them with potential insurgent activities and key locations (e.g., a bomb maker).

Accumulated knowledge of suspect sites can also be used to tip and cue Narrow Field Of View sensors (video) to gather real-time information on potential insurgent activities. This knowledge can also serve to focus HUMINT collections and exploitation. Accumulated evidence, combined with real-time observation, can inform the decision making process and provide vital information prior and during actions against the enemy. The task force observed compelling examples of these capabilities from the war efforts in Iraq and Afghanistan. However, most of these examples have been integrated rapidly with available technology in response to urgent needs from the theater. Many are prototypes or rapidly constructed experiments. **The task force recommends that the results from these efforts be used to inform system-level designs capabilities to be developed and deployed broadly across all of the DoD areas of responsibility.**

7.3.2 Foliage Penetration Sensing

Foliage obscuration represents a major challenge to ISR sensors in key regions of the world. Penetration of foliage by sensors to detect and characterize targets and activities of interest is a principal component of this challenge

Foliage penetrating (FOPEN) sensors have to operate at relatively low frequencies (UHF and VHF) compared to open terrain sensors. Such sensors are limited in the resolution they can achieve and in the ability to detect slow moving targets. This makes it difficult to detect and to distinguish targets and sites of interest from the multitude of other very similar “confuser” sites and targets.

The focus to date has been on UHF/VHF SAR technology and imagery exploitation for tactical military targets and significant progress has been made in this area. Civilian targets (associated with terrorist and drug activities) present a new challenge that needs to be addressed. Other sensor modalities, primarily in the use of laser technology, are emerging, but CONOPS and integration into an overall system architecture need further investigation

Wide-area, high rate FOPEN GMTI for detecting vehicles and dismounts through the foliage canopy requires large airborne platforms to accommodate antennas of sufficient size to achieve necessary low minimum detectable velocity (MDV) for these fast platforms. Advanced antenna concepts (e.g. Multiple Input, Multiple Output (MIMO)) are being explored for this purpose, but additional R&D is required to improve and validate performance.

If large area coverage/rate is not required, achieving a low MDV target detection and tracking is facilitated by using a hovering helicopter (i.e. stationary) platform. This approach is implemented in the DARPA FORESTER program which uses the DARPA A-160 long endurance unmanned helicopter.

For detecting stationary vehicles and structures, UHF and VHF SAR imaging is used in an integrated system CONOPS that leverages the better penetration of VHF and the higher achievable resolution of UHF.

In cases where gaps exist in the foliage canopy, Hyperspectral Imaging (HSI) has been explored for identifying materials and effluents indicative of human activities and habitats. Similarly, LADAR can also be used to exploit gaps in the foliage. Fine angular resolution coupled with high range resolution achievable with LADAR provides 3-D images that can be used for target identification. However, coverage is very limited and the LADAR needs to be cued from other sources.

As in other missions, the key objective of FOPEN sensing is to collect data that support the accumulation of information and knowledge leading to actionable intelligence and actions in environments where foliage cover is a significant factor. Accomplishing this objective requires sensor modalities that span the spectrum, from finding and locating potential targets, to discriminating between background clutter induced false alarms and actual targets, classifying the type of target and/or kind of site, and presenting this information to decision makers for possible actions. This is yet another example of the benefits of multi-sensor integration for addressing challenging ISR problems.

7.4 Acquisition Strategies to Leverage Sensor Integration

DoD's hard problems will require integration of a broad set of sensor capabilities and modalities, an increased use of robotic and unmanned systems to provide access and persistence, and a data communication capability to make information visible, accessible and understandable across the information environment. For current and future acquisition programs, DoD should procure sensor systems which are designed to be netted together, are adaptable after being fielded and can be integrated together functioning as one system. This will provide an added degree of performance for a marginal additional cost. Additionally, by providing the ability to reprogram the system after it is fielded, the time constant to change a system will now be determined by the time to adapt the ground segment and not the time to develop and field the platform (i.e., space or airborne) segments.

The task force recommends that future acquisition programs disaggregate sensors from platforms with the goal of acquiring more platforms with potentially less capable and therefore less costly, sensors and plan to achieve increased performance by integrating data from multiple sensors/platforms. There are two important prerequisites for this acquisition strategy, which should be adopted for as many programs as possible (this should include adding these requirements to existing systems). The first is to buy sensor calibration data from the development contractor (much of this is already generated for development testing). The second is to add meta-data tags to the sensor data as close as possible to the point and time of collection and to ensure that the meta-data includes the sensor calibration data.

Figure 23 illustrates the value of this sensor disaggregation by showing the synergy of integration across the two systems, one of which uses a high resolution sensor to provide identification and another that uses a low resolution sensor for tracking. A second example can be seen by using one system to provide high resolution to counter spoofing and the persistent system to counter moving into cover. By working together the integrated system performance is improved.

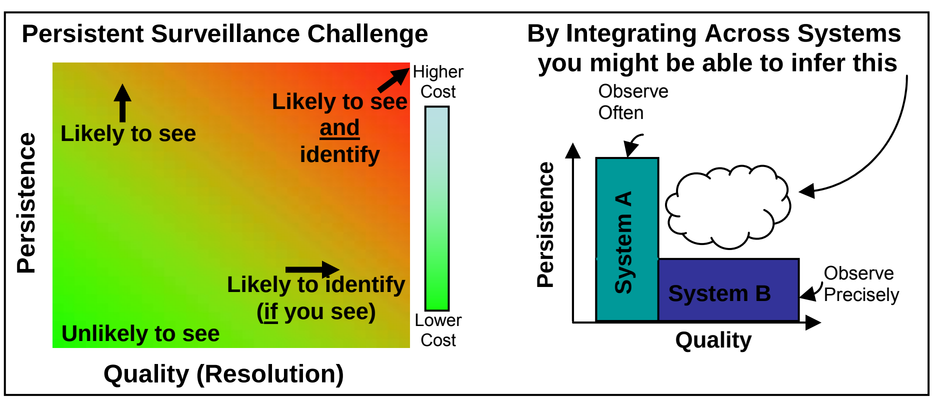

Figure 23: Examples of synergy integration across systems

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CHAPTER 8: TASK FORCE FINDINGS AND RECOMMENDATIONS

Sensor-collected Intelligence/Surveillance/Reconnaissance (ISR) data have proven invaluable to both national decision makers and to battlefield commanders. Despite significant increases in the number of sensors, largely on unmanned aerial vehicle (UAV) platforms at both the theater and tactical level, demands for information, particularly to support operations in Iraq and Afghanistan, continue to increase. The task force was charged to determine what improvements are needed in collection, processing, data storage and fusion, exploitation, and dissemination of information collected by ISR systems.

The task force observed that there are robust plans for acquisition and deployment of airborne ISR, with particular emphasis on unmanned platforms. Even with increased availability there is a growing demand for these airborne systems, especially those that provide full motion video in support of current operations. On the other hand, the situation relative to satellite-based ISR is much more fragile. There was a purposeful drawdown of these systems following the Cold War and modernization programs were planned to replace only a fraction of the former assets. Further, well-documented execution problems have left the U.S. behind its overhead ISR plans. Changing world events have increased demands beyond those of the planned capability. As a result, we concluded that existing capability is under stress and significant gaps are likely to develop.

Despite increased investment in ISR collection platforms, additional sensors alone are not the answer to the increased demand for ISR information. The rapid proliferation of sensors both enables and overwhelms the current ISR infrastructure. The number of images and signal intercepts are well beyond the capacity of the existing analyst community so there are huge backlogs for translators and image interpreters and much of the collected data are never reviewed.

Further, decision makers and intelligence analysts have difficulty knowing what information is available. Most collection requests, particularly for sensors beyond the commander's control, go to central tasking systems that provide little feedback on whether or when the request will be satisfied. Access to ISR information is equally problematic. Large staffs, often numbering in the thousands, are required in theater to accept and organize data that are broadcast in a bulk-distribution manner. These analysts spend much of their time inefficiently sorting through this volume of information to find the small subset that they believe is relevant to the commander's needs rather than interpreting and exploiting the data selected on current needs to create useful information.

The investment made by the Department of Defense and the Intelligence Community over the last decade in creating the infrastructure for network-centric operations provides a way to address many of the problems with ISR data collection and processing. The task force concluded that this new approach to handling the increasing volumes of ISR data depends on two infrastructure investments: an assured, broadband widely-accessible communications system and implementation of the Department's data strategy, which calls for separation of data and applications and meta-data tagging. When this investment has been made, the opportunity will exist to significantly improve the overall performance of the ISR system by integrating data from sensors with different characteristics and from different sensor platforms.

8.1 Task Force Recommendations

To achieve the benefits of sensor integration, the task force offers two sets of critical recommendations that are essential for enabling the envisioned ISR sensor integration architecture. We also present three sets of performance improvement recommendations that build on the critical enabling infrastructure to achieve the full benefits of ISR sensor data integration.

8.1.1 Critical Recommendations

1. Provide Assured Broadband Communications

   A robust, reliable and secure broadband IP-based communications infrastructure is essential. To achieve this infrastructure the task force recommends DoD:

   - Deploy TSAT[10] as soon as possible to provide the assured high-capacity communications for moving ISR data to the backbone and to provide assured networking-on-the-move for mobile tactical users.
   - Integrate the core Intelligence Community transport networks (such as the National Reconnaissance Office (NRO) fiber backbone) with the DoD broadband backbone to ensure that anyone connected to any of the networks can discover and search all the meta-data using applications such as the DCGS Integration Backbone (DIB). Subsequently, selected data should be available to all authorized users.
   - Ensure that intra-theater communications for ships-at-sea, small units and forces-on-the-move are compatible with the integrated sensor-collected intelligence architecture by quickly providing assured IP access to in-theater concentrators that access the DISN backbone. This initial capability will serve as a backup to TSAT after its deployment. Development of a flexible software-defined radio, such as JTRS, is an important capability to provide the required intra-theater connectivity.
   - Require all forces to plan for and exercise in degraded communications and degraded/corrupted information access environments because the recommended ISR data access and associated reach-back processing functions are critically dependent on these capabilities.

2. Implement the Net-Centric Data Strategy

   A net-centric data strategy must make data, applications and value-added services visible, accessible, understandable, and trusted. To achieve this net-centric data strategy, the task force recommends:

   - Tag sensor-collected data with meta-data as close to the sensor as possible using meta-data that includes, at a minimum time, location and sensor calibration.
   - Empower and fund Communities of Interest focused on aligned vocabularies and pilots for ISR data integration. In this effort, leverage the work of national and international standards bodies.

[10] Transformational Communications Satellite

- Establish goals and incentives to address behavioral and social impediments to information sharing.
- Push for enterprise services and search tools. Tag both applications and value-added services with meta-data to enhance their discovery.
- Support the single DoD/DNI data strategy governance structure and enforce its execution.

Finally, the task force encourages the Department and Agencies to do everything possible to get data into the hands of the users, including:

- Adding a capability for users to tag data and for using these user-generated tags for discovery.
- Incorporating access to tagged repositories currently in use in theater into the registries and making these data stores discoverable and accessible.

8.1.2 Performance Improvement Recommendations

1. Make Sensor Tasking More Flexible

   Sensor tasking must be more transparent and provide feedback to users on the status of their requests. The task force recommends that the Department and the Intelligence Community:

   - Post collection plans and status for all strategic and tactical ISR assets to a shared space and meta-data tag the data so that it is discoverable by all authorized users.
   - Revise the approach to collection management from the current sensor modality (i.e., IMINT, SIGINT …) perspective to the intelligence need level to allow the collection system to be more dynamic and supportive of cross-platform/INT coordination.
   - Develop techniques for closed loop dynamic tasking to take advantage of operational sensor integration through tipping and cueing.
   - Develop value models and tools for ISR sensor tasking optimization that are informed by physics-oriented sensor, target and phenomenology characteristics.
   - Conduct frequent integrated tasking exercises, such as EIX-08 and Integrated Collection Management (ICM). Design these experiments and exercises to encourage collaboration across organizations to build trust and confidence in the tasking system by all stakeholders.

2. Improve Processing & Exploitation with Appropriate Human-Systems Collaboration

   Data processing and exploitation technology must continue to advance to support multi-sensor integration

   - Promote the separation of data, processing, and presentation – use commercial web-based presentation tools where possible.
   - Allow multiple value-added services to access and process the same data for different analytic purposes and ensure that the results of all processing are posted.

- Provide realistic data and operationally-relevant processing and exploitation challenge problems to the community.
- Focus R&D on the processing-exploitation boundary and exploit advances in human-systems collaboration.
- Develop model-based exploitation techniques that use models that leverage those employed for physics-based tasking optimization.
- Continue to use military and intelligence exercises (e.g., Empire Challenge) to demonstrate progress.

3. Acquire New Sensors to Leverage Integration and Fill Gaps

   Difficult ISR problems remain that require advances in sensor capability and associated collection system architecture.

   - WMD, deeply-buried targets and tracking specific people require close-in sensing platforms, specialized sensors and tailored data ex-filtration. A broader systems perspective should be taken in addressing close-in ISR requirements as opposed to the uniquely mission-tailored approach that is currently employed.
   - Continue sensor R&D to address gaps especially detecting WMD signatures and characterizing deeply-buried facilities.
   - Must recognize that “persistence surveillance” is a systems concept that needs to recognize time-dynamics of the target and trade resolution and imaging (revisit) rates.

   Acquisition strategies for future sensor-platform systems should leverage the benefits of the sensor data integration infrastructure.

   - Disaggregate sensors, acquire more potentially less capable sensors and plan to integrate the data.
   - Buy sensor calibration data and include it in the meta-data tags with the sensor data at point of collection.

APPENDIX A: TERMS OF REFERENCE

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION, TECHNOLOGY AND LOGISTICS

FEB 27 2007

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference -- Defense Science Board (DSB) Task Force on Integrating Sensor-Collected Intelligence

You are requested to establish a DSB Task Force to assess the sufficiency of support for U.S. military forces by current and planned intelligence, surveillance and reconnaissance systems.

The principal objective of this study is to determine what improvements are needed in tasking, collecting, processing, data storage and fusion, exploitation, and the dissemination of information collected by ISR systems. Secondarily, and as foundation for its assessment of the state of ISR integration, the Task Force should also examine the mix and balance of sensors across the entire spectrum with a view to identifying critical coverage gaps and areas of redundancy. Finally, the Task Force should examine current and planned systems for vulnerabilities, new opportunities and potential problems associated with emerging opportunities, and consistency with the Department's net-centric strategy.

The 2006 Quadrennial Defense Review acknowledged the importance of ISR, and, following its completion, a number of studies were initiated by OSD and were completed by fall 2006. These studies address selected individual elements, principally in the airborne and space ISR regimes. Further, the Director of National Intelligence, in cooperation with the DoD, has a process, "Integrated Collection Architecture," which continues to contribute to programmatic decisions. The Task Force should review the findings of these efforts as a part of its assessment.

The study will be sponsored by me as the Under Secretary of Defense for Acquisition, Technology and Logistics, the Under Secretary of Defense for Intelligence, the Commander, U.S. Strategic Command, and the Director for Force Structure, Resources and Assessment (Joint Staff). Mr. John Stenbit and Mr. James Shields will serve as the Task Force co-chairmen. Ms. Erin Connors, OUSD(I), will serve as the Executive Secretary, and Major Chad Lominac, USAF, will serve as the Defense Science Board Military Assistant.

The Task Force will be operated in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DoD Directive 5105.4, the "DoD Federal

Advisory Committee Management Program." It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of title 18, U.S. Code, section 208, nor will it cause any members to be placed in the position of acting as a procurement official.

Kenneth J. Krieg

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APPENDIX B: TASK FORCE MEMBERSHIP

CO-CHAIRMEN

Mr. Larry Meador	*MGI Strategic Solutions*
Mr. James Shields	*The Charles Stark Draper Laboratory, Inc.*
Mr. John Stenbit	*Private Consultant*

MEMBERS

Dr. Robert Brammer	*Northrop Grumman Information Technology Sector*
Dr. Richard Cernosek	*Sandia National Laboratories*
Brig Gen. Duane Deal, USAF (Ret)	*JHU Applied Physics Laboratory*
Dr. Richard Games	*Mitre*
RADM Robert Gormley, USN (Ret)	*Private Consultant*
Ms. Priscilla Guthrie	*Institute for Defense Analyses*
Mr. Jeffrey Harris	*Lockheed Martin*
Mr. Timothy Hoechst	*Agilex Technologies*
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Mr. Peter Marino	*Private Consultant*
Mr. David Martinez	*MIT Lincoln Laboratory*
Mr. Paul Rosenstrach	*The Charles Stark Draper Laboratory, Inc.*
Dr. John Schott	*Rochester Institute of Technology*
Mr. Alan Wade	*Private Consultant*
Dr. David Whelan	*Boeing*
Lt Gen John Vines, USA (Ret)	*Private Consultant*

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Mr. Thomas Behling	*Government Advisor*
Mr. Mitch Fry	*Government Advisor*
Mr. Paul Lepine	*Government Advisor*
Mr. Kevin Meiners	*Government Advisor*

EXECUTIVE SECRETARY

Ms. Lorraine Wilson	*Office of the Secretary of Defense*
Ms. Erin Connors Bromaghim	*Office of the Secretary of Defense*

DSB SECRETARIAT

Maj Chad Lominac	*Defense Science Board*

SUPPORT

Ms. Michelle Ashley	*SAIC*
Ms. Diana Conty	*SAIC*
Ms. Amely Moore	*SAIC*
Mr. John Snevely	*SAIC*
Mr. M. Brett Sterlacci	*SAIC*
Ms. Lauren York	*SAIC*

APPENDIX C: BRIEFINGS RECEIVED

March 12, 2007

Air Force Intel Program	Mr. Bruce Nelson	DISL/A2
USMC Intel Program	LTCOL Jim West	USMC
STRATCOM Perspective	Lt Gen Kehler	STRATCOM
DSB Task Force on Time Critical Strike	Mr. Greg Hulcher	OSD(AT&L)

March 13, 2007

DIA Intel Program	Mr. Joe Fasching	DCFE/DIA
IR&G Portfolio Management	Ms. Jane Rathbun	OSD(AT&L)
Navy Intel Program	Mr. John Scali	N20
Army Intel Program	Mssrs. Agee/Pfoltzer	G2/G8

April 17, 2007

Persistent ISR JIC CBA	CDR Jim Hildebrand	J2
A2 Transformation Plan	Lt Gen Dave Deptula	USAF
NGA Program	Mr. John Schuhart	NGA
NRO Program	Ms. Betty Sapp	NRO
ICA Outbrief	Mr. Greg Smithberger	ODNI

April 18, 2007

NCCT Program Overview	Maj Steve Sunderlin	USAF
CENTCOM Targeting Brief	CDR Frank Whitworth	CENTCOM
NSA Program	MG Richard Zahner	NSA
TTL CBA Outbrief	Mr. Mike Ponti	OSD

May 7, 2007

Navy Comms Architecture	RADM Kenneth Deutsch	Navy
GNCST Program	Mr. Mark Berlin, Mr. Ted Cody, Mr. Matt Sorenson	NGA
RT-10	COL Robert Harms	NSA
ISR Surge Strategy	Mr. Tom Behling	OUSDI
Space Situational Awareness	Col George Eichelberger	USAF

May 8, 2007

TSAT and Comms Update	Dr. Ron Jost, Troy Meink	OSD
GEOSCOUT Program	Mr. Dave Burns	NGA
Army Operational Perspective	Col David Gray	JCS
Buckeye Program	Dr. Eric Zimmerman	DARPA
DCGS-A	Ms. Patricia Guitard	Army G-2 (DAMI-IM)
POSSE Program	Dr. Bob Tenney	DARPA

May 31, 2007

Meta-data Communities of Interest	Mr. Mike Krieger	OASD(NII)/DoD CIO
USCENTAF CAOC ISR Perspective	Maj Michael Stevenson	NSA
Marine Corps Operational Perspective	COL Stephen Davis	USMC
Navy Operational Perspective	RADM Al Myers	DARPA
Integrated Ground Architecture	Mr. Scott Large	NRO

June 1, 2007

TURBULENCE Portfolio Architecture	Dr. Patrick Dowd	NSA
JIOC Assessment/ISR Integration at JFCOM	CAPT Susan Chiaravalle, CAPT Kevin Frank	NGA
DTCWC	Dr. Glenn Mitzel	JHU/APL
On the Way to Large, Autonomous, Persistent Sensor Networks for GWOT	Dr. Bobby Junker	ONR
Navy Research Labs	CAPT Dan Gahagan	NRL

July 19, 2007

Signatures Management	Mr. Ron Fleming	
Task Force ODIN	LTC Adam Hinsdale	
Advanced Geospatial Intelligence Toolkit	Mr. Stan Grossman	
Cyber Initiative	Mr. Dennis Bartko, Mr. Jim Richberg	
NRO S&T	Dr. Pete Rustan	NRO

July 20, 2007

Preliminary Analysis of Benefits of an Integrated Sensors Architecture	Mr. David Martinez	MIT Lincoln Laboratory
P-ISR FNA Capabilities Gap	CDR Jim Hildebrand	JCS/J2S
HVT Analysis	Col DeLaPena	OUSD(I)
Airborne Overhead Integration Office	Col McKethan	NRO
INNOVISION Program Office	Theron Anders	

September 25, 2007

ICM: EIX-08	Mr. Jeff Iannazzo, Mr. John Sunray, Mr. Peter Rowley, Ms. Sue Duclos	NGA
Rosetta/Stone	Mr. Patrick T. Thornton	Rockwell Collins

September 26, 2007

Defense Intel Operations Coordination Center	Mr. Neil Tipton	DIOCC
Integrated Collection Architecture	Gil Klinger	ODNI

October 16, 2007

Persistence	Dr. Joe Markowitz	Private Consultant
UAV Issues - Spectrum, Standards, Deconfliction	Mr. Dyke Weatherington	OSD (AT&L)
DCGS-IC	Mr. Eric Mohney	NRO
Empire Challenge	CDR Joseph Smith	NGA

October 17, 2007

DoD/IC Data Strategy	Mr. Mike Krieger	NII/DoD CIO

November 19, 2007

HITS	Wayne Bratt	PEO C41
Joint Staff J6 COCOM/Theater Issues	Mr. James Gaetjen	JCS
CEMO Tasking Study Cyber Initiative	Thomas Lentscher	NSA
Shadow Harvest	Mr. Phil Molle	DIA
From Mush to Gold: Information Exploitation Meets the Real World	Dr. Bob Tenney	DARPA

November 20, 2007

Unified Ground Opportunities & Challenges	CAPT Nick Buck	NRO
INSCOM briefing	Randy Garrett	

APPENDIX D: BENEFITS OF SENSOR INTEGRATION

For access to Appendix D contact the Defense Science Board office at 703-571-0081 or DSBOffice@osd.mil.

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APPENDIX E: ENHANCING ISR COMMUNICATIONS

Evolution of GIG Communications

The Global Information Grid is the DoD's information, information technology, and associated people and processes that support the Department's personnel and organizations in accomplishing their tasks and missions. The centerpiece of the TCA is the GIG's communications component, a very high capacity network comprised of a terrestrial fiber backbone (Defense Information Systems Network – DISN), high capacity communications satellites, and both narrow and broadband ground and air radio networks as well as associated IT equipment, applications and services. Typically, however, it is the multiple-node fiber network in the U.S. and overseas that many people think of when the GIG is discussed.

The GIG, as depicted in Figure E-1, is the globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, and managing information for the DoD. It is essentially a very large intranet, with a presence in 88 countries. The GIG includes over seven million computers, operates 24x7, and runs thousands of warfighting and support applications. It includes both classified and unclassified networks, and supports all 3,544 DoD bases and other facilities worldwide. Further, the GIG supports deployed units of all the Military Services and regional combatant commanders, including mobile forces engaged in combat operations. The U.S. Strategic Command is responsible for operating the GIG, with the Defense Information Systems Agency a major participant. The GIG is an essential enabler for net-centric operations and, as such, must be defended.

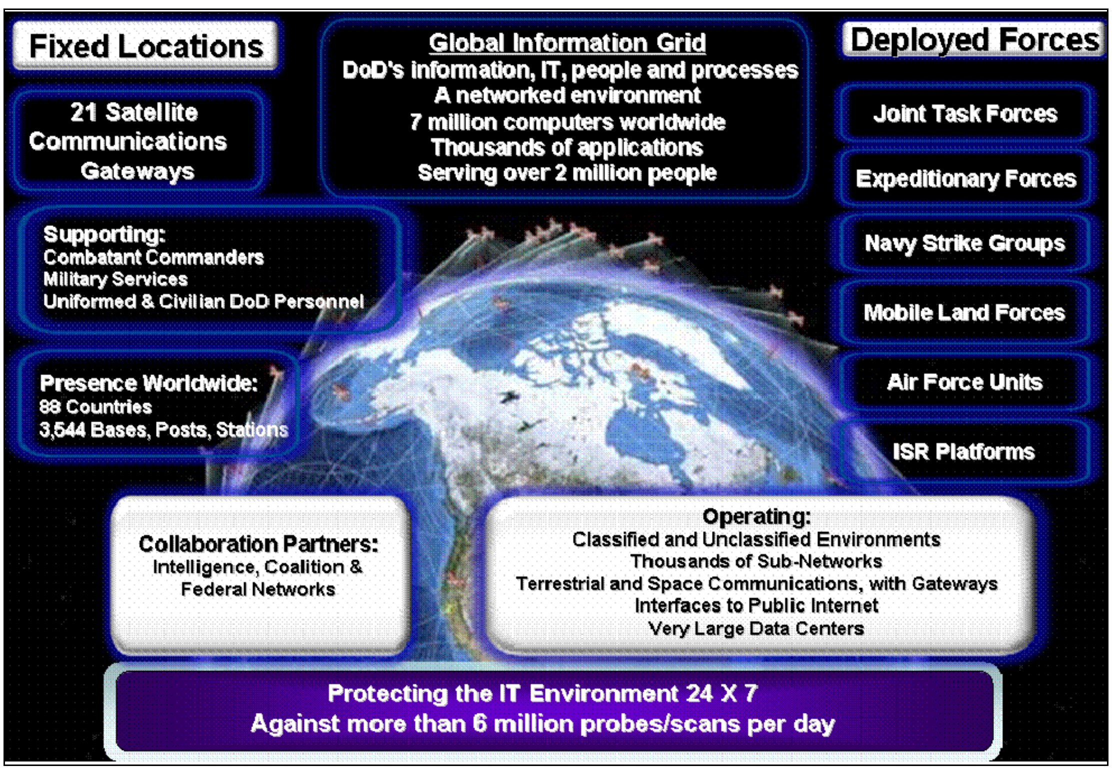

Figure E-1: The GIG Today

GIG Communications Architecture Today

The existing communications architecture within the DoD is still largely circuit-based and uses link encryption, as required. Most local networks are managed as separate enclaves, precluding enterprise-wide access to data and services.

With completion of the GIG-BE, the "wireline backbone" of the DISN is moving towards the environment envisioned in the TCA. The DISN, with HAIPE, constitutes the terrestrial core of the TCA. The Local Area Networks (LANs) and Metropolitan Area Networks (MANs) will connect to this core.

The space segment of the GIG is comprised of military and commercial assets, which will be replaced and/or supplemented by the TSAT system to support the requirement for assured, high capacity satellite communications support for on-the-move platforms.

As the TCA matures, JTRS will provide the primary communications for small-unit tactical users. The current GIG communications architecture is represented in Figure E-2 below.

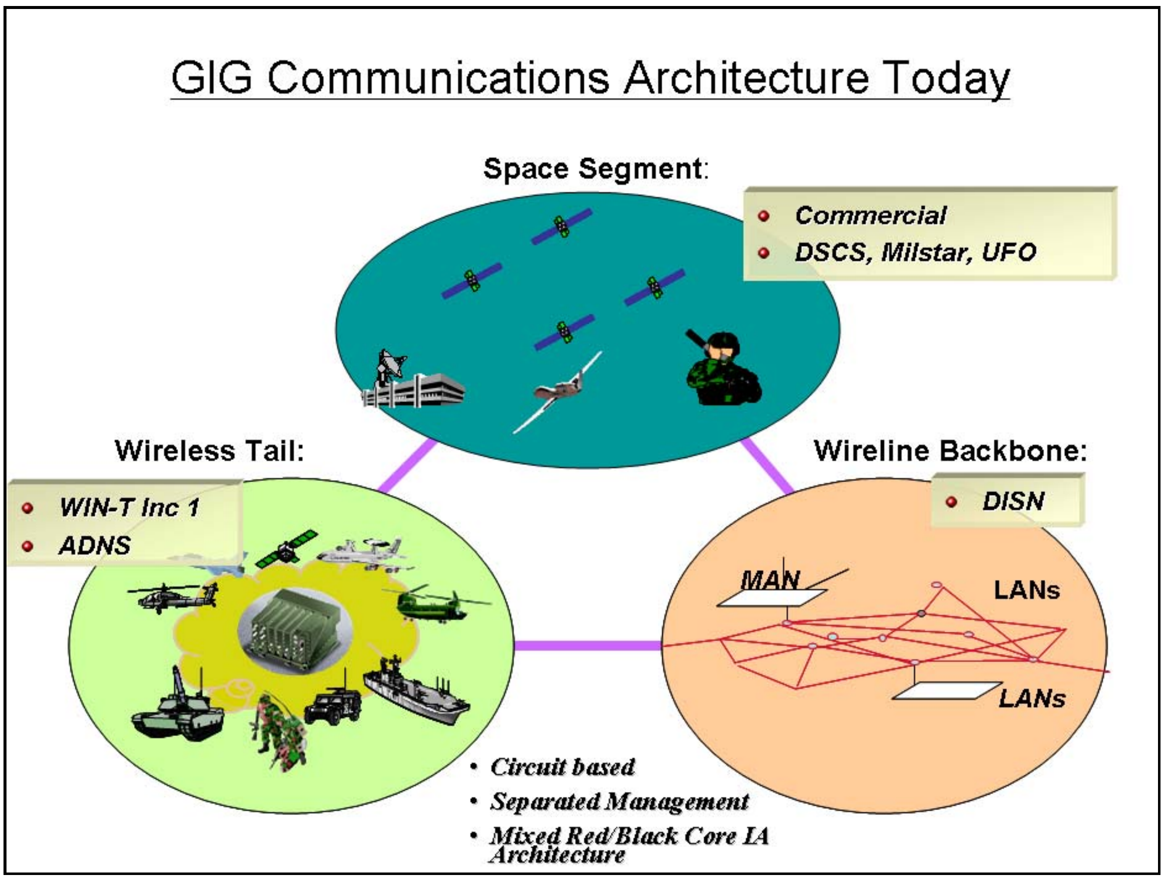

Figure E-2: Current GIG Communications Architecture

GIG Communications Architecture ~ 2010

An interim step towards realization of the TCA is shown in Figure E-3. Communications will still be a mix of circuits and Internet Protocol (IP). Environments will still be separately managed, without an effective federated approach to enterprise-wide Network Operations (NetOps). Communications security will be a mix of red and black; however, HAIPE will have been delivered and in use. NCES will be operational and will start to provide enterprise-wide services, with a more "internet-like" feel. The wireline backbone will be unchanged, although considerable effort is going into creating effective tools and processes for NetOps.

In the Space Segment, the Advanced Extremely High Frequency satellite (AEHF), Wideband Gapfiller Satellite (WGS) and Mobile User Objective System (MUOS) will be operational, replacing the Defense Satellite Communications System (DSCS), Milstar and Ultra High Frequency Follow-on satellite (UFO). TSAT will still not in place, so the environment will be missing assured communications with mobile assets, except for special C2 circuits. The Wireless Tail will include some JTRS to support tactical users.

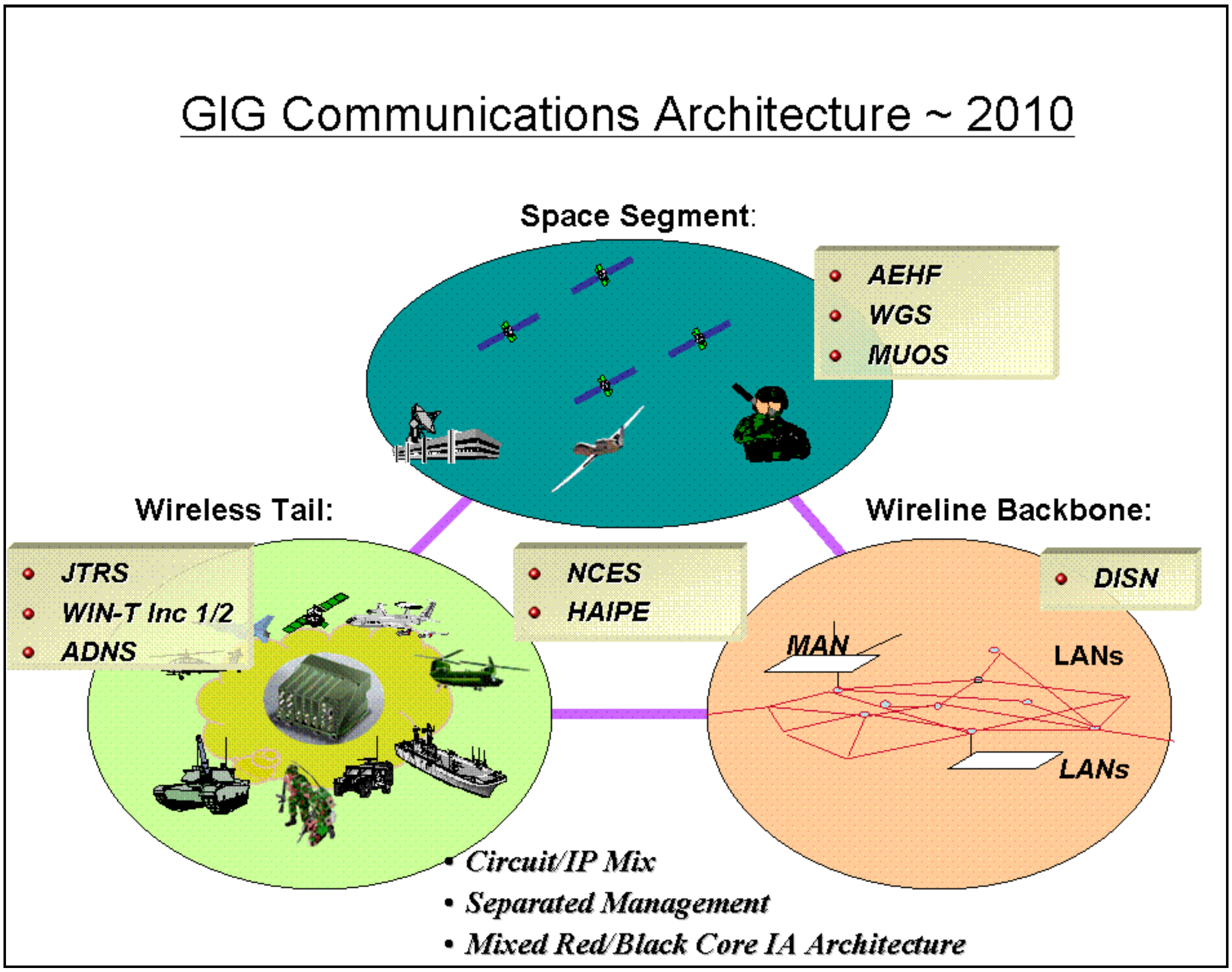

Figure E-3: GIG Communications Architecture ~ 2010

GIG Communications Architecture ~ 2018

The goal of the TCA, as originally envisioned, is shown in Figure E-4. By 2018, communications will be IP-based and managed as a federated enterprise. HAIPE will provide IP encryption and core communications will be black. NCES will be operational, enabling collaboration and internet-like discovery and access to data by authorized users throughout the enterprise. MANs and LANs will connect to the terrestrial Wireline Backbone communications core at DISN nodes.

The Space Segment will be largely new and consists of TSAT, AEHF, WGS and MUOS, enabling assured, high capacity communications for mobile users and among airborne platforms only from TSAT.

JTRS will be operational and support mobile and other tactical users.

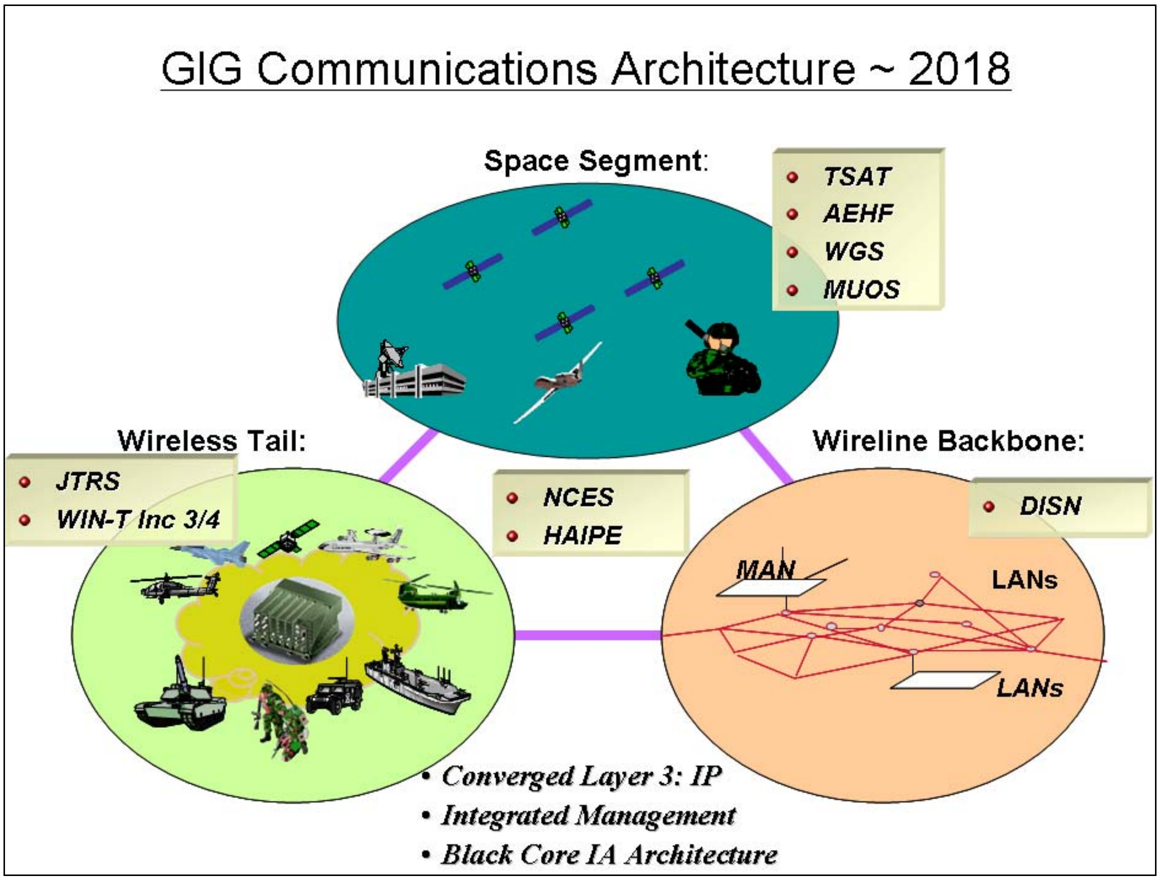

Figure E-4: GIG Communications Architecture ~ 2018

Satellite Communications

The ultimate end users of ISR information are military units in combat theaters which are rarely connected directly to the near-infinite capacity GIG fiber backbone (DISN) as are DoD and IC commands at fixed sites. Navy ships at sea, Army and Marine Corps forces, and to a lesser degree, Air Force units are therefore dependent on terrestrial line of sight communications via RF systems or, when dispersed, on satellite communications and high frequency radio. As the availability and demand for ISR information has grown over the years, satellite communications has become the pacing item in meeting the very large communications bandwidth needs of the military.

Desert Storm was the first large scale deployment of combat forces since Vietnam and it placed a large demand on communications resources existing at the time, for intra-theater support as well as reach-back to CONUS for intelligence, missile warning and logistical support. The period between Desert Storm and the terrorist attacks of September 11, 2001 was noteworthy for a number of varied deployments, including the Iraq no-fly zone operations, Somalia, and the Balkans. These too placed large and growing pressure on the communications assets available. The 9/11 attacks and the subsequent Global War on Terror accelerated the military and intelligence transformation already underway and resulted in further and more frequent deployments of highly mobile, lightly equipped forces that were increasingly dependent on communications reach-back for intelligence, command and control, and combat support. Finally, as the capabilities of unmanned aerial vehicles (UAV) increase and their use becomes ubiquitous, the need to control those vehicles, their sensors, and their weapons, as well as move large volumes of information collected by them, places an even greater strain on the already stressed satellite infrastructure. Figure E-5 illustrates how the demand for SATCOM has grown over the years.

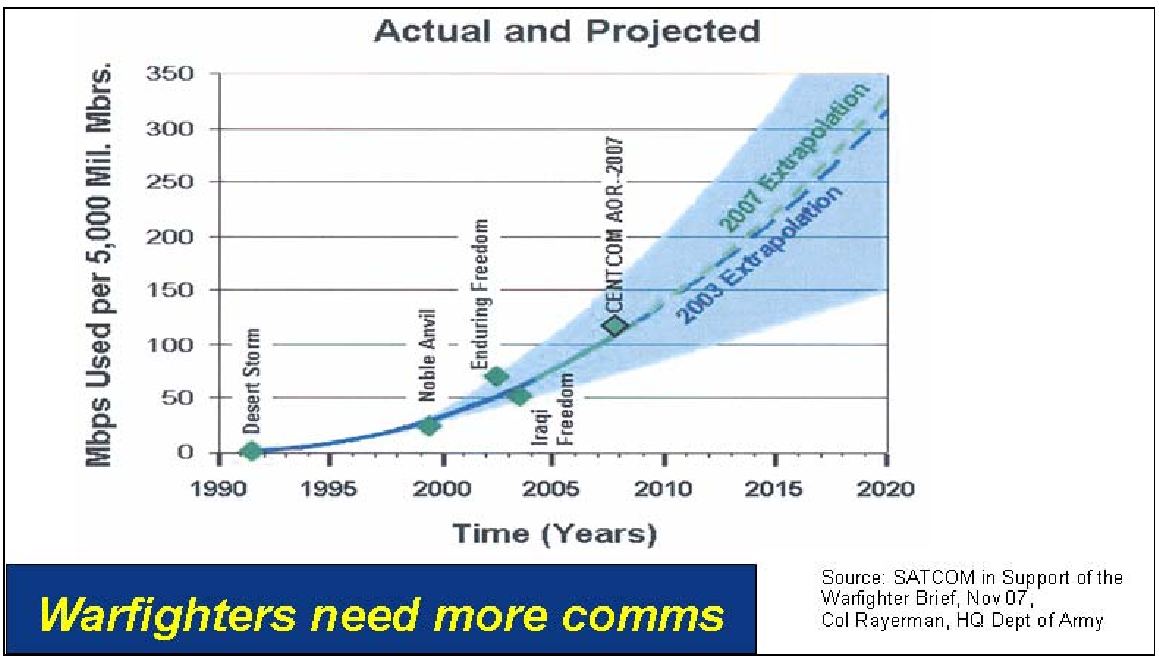

Figure E-5: Trend in SATCOM Demand

SATCOM transformation, as depicted in Figure E-6, can be viewed both as a product and an enabler. Early MILSATCOM developers credibly architected a system-of-systems which supported the multiple and widely varied missions, from strategic to tactical. Rapid advances in technology, propelled also by growing bandwidth demand and the need for flexibility, drove development of the AEHF, WGS, and MUOS systems. These systems were intended to support the same sets of missions for a greatly expanded user set, and with much greater bandwidth and agility than their legacy predecessors, although without protection from jamming except for AEHF. As the number of deployed units increases and the breadth of their missions widens, they continue to be lighter, more mobile and agile, and less able to support large communications packages, and therefore more dependent on reach-back to central locations for essentials like intelligence processing and exploitation. The continued explosive growth in the number, type and deployment of UAVs demands a networked, highly flexible environment. TSAT and the evolving TCA will fulfill that need.

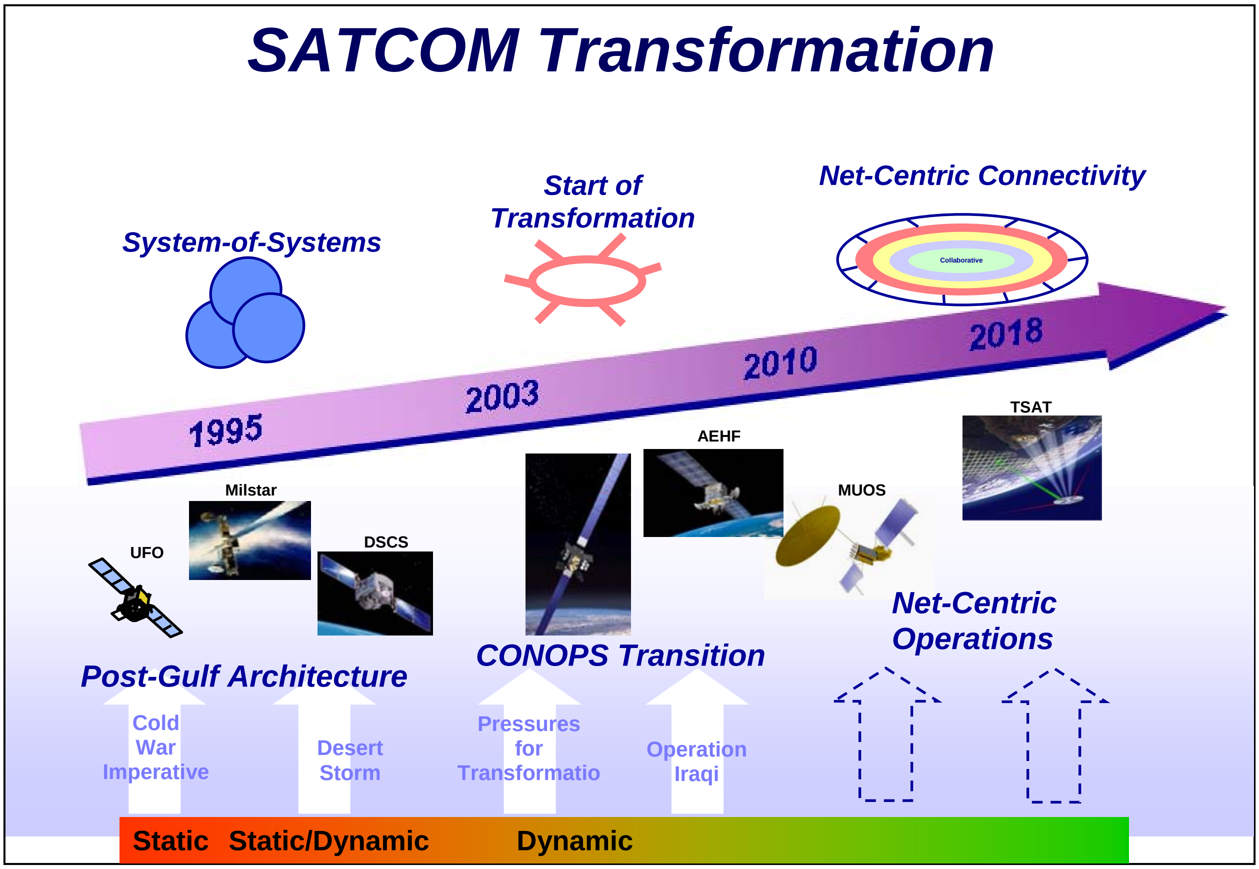

Figure E-6: SATCOM Transformation

There are currently three main categories of satellite communications: Narrowband or Ultra High Frequency (UHF), Wideband or Super High frequency (SHF), and Protected or Extra High Frequency (EHF). These bands and their associated characteristics and users are shown in Table E-1. Generally, UHF is employed for tactical voice and data, SHF for long-haul, high volume throughput, and EHF for strategic command and control where protection and anti-jam capabilities are critical. Further, as military operations and technology have evolved, another application of EHF is emerging. Using EHF, TSAT will provide protected wide-bandwidth capacity to mobile users and ISR relay, as well as serving as an IP network router.

MILSATCOM Today Band Characteristics and Use		
Systems	**Key Characteristics**	**Key Uses**
Narrowband (UHF)	▪ Broad coverage ▪ Small antennas – mobile ▪ Not Assured ▪ Inexpensive, mature technology	▪ Tactical voice and data networks ▪ Intel alert / dissemination ▪ Special forces
Wideband (SHF)	▪ Excellent throughput for large volumes of data ▪ Directional bands – portable ▪ Not Assured ▪ Mature technology	▪ Inter-theater long-haul ▪ Deployed force reachback to commands or U.S. ▪ Imagery dissemination
Protected (EHF)	▪ Available bandwidth supports frequency-hopping anti-jam ▪ Rapid recovery from nuclear scintillation (few seconds) ▪ Attenuated by rain/moisture ▪ Tight directional beams ▪ Recent emerging technology	▪ Nuclear warning ▪ Strategic command & control ▪ Tactical forces ▪ Netted user connections (conference call)

Table E-1: MILSATCOM Today

The U.S. Air Force Military Satellite Communications (MILSATCOM) Program Office is responsible for the systems engineering of the entire MILSATCOM architecture. It plans not only the acquisition of the various systems elements, but also sustainment and the transition from legacy to new generation systems.

Theater Tactical Communications

Combat theater users of communications for command and control and ISR range from the regional combatant commanders and their joint task force commanders down through Military Service component chains of command to individual soldiers, Marines, ships and aircraft. Tactical communications needs and capabilities vary by command level and degree of direct engagement with the enemy. While senior commanders may in some circumstances be able to set up and operate from static enclaves that facilitate installation of high capacity communications suites and ensure connectivity to the GIG backbone (DISN), lower level commands must be able to communicate with their seniors and coordinate with one another while under enemy fire and on the move.

Theater Tactical Communications

- Assured high capacity broadband communications are available In overseas theaters only at fixed land sites in permissive environments proximate to GIG nodes, including large Satcom teleports, or connected to them by secure fiber cable or wireline
- Communications to/from military units outside secure fixed headquarters enclaves are via RF LOS links, HF radio and Satcom, with airborne relay and cellular systems playing an increasing role, all vulnerable to disruption
- Tactical communications connectivity and capacity are contingent on a variety of factors, including:
  - Transmitter power, frequency and waveform
  - Antenna size, placement and stabilization
  - Atmospheric conditions and equipment reliability
  - Frequency spectrum constraints
  - Enemy intrusion and jamming
  - Terrain blockage
  - Degree of engagement with the enemy
  - Competing demands for communications services among units in theater
- While small units may not require large quantities of ISR data, their needs are focused, immediate and critical when engaged with the enemy, and must be assured
- Military service components in theater have differing missions, doctrine, specialized communications systems, and operational challenges
- Theater Combatant Commanders and their joint task force commanders coordinate communications among military service components, resolve interface and interoperability problems, and allocate often scare resources to meet overall mission needs

Figure E-7: Factors Affecting Theater Tactical Communications

As shown in Figure E-7 above, many factors affect the ability of such tactical units to transmit and receive command and control orders and crucial ISR information. In line with DoD policy, regional combatant commanders and the Military Services have over the years been moving toward a network-centric communications strategy. This approach takes advantage of the capability of the DISN, in the U.S. and overseas, to move large amounts of data rapidly. Increasingly as time passes, tactical units will have the ability to access ISR information that will meet their needs via IP-based requests to the network, rather than having to screen out non-essential information that now comes via broadcast methods or dedicated point to point circuits, and potentially missing out on information from unexpected sources.

All the military services are advancing toward the TCA's net-centric goals, but with each moving at its own pace. Impediments to more rapid implementation include: (1) funding demands of the wars in Iraq and Afghanistan; (2) the large quantity of legacy communications equipments that are not interoperable with other systems or lack the ability to operate in internet-like fashion; and (3) delays in key programs such as TSAT and JTRS which, when fielded, will mitigate many of today's shortcomings.

The study task force noted that, from the Military Services to regional combatant commanders, everyone is on board in recognizing the need to move from the circuit-based communications environment of the past to the net-centric IP-based Transformational Communications Architecture. However, the pace of change is uneven between the various entities and programs and technologies that could accelerate the transition are not well coordinated. Further, a principal factor making it more difficult to effect change has been the demands imposed by the wars in Iraq and Afghanistan where urgent needs of forces in Central Command must be met, but are filled in many cases with communications systems that are incompatible with others and are not amenable to incorporation into networks. Here, while it is understandable that the needs of forces in combat theaters must be satisfied expeditiously, in many circumstances little effort has been made to source equipments that would both fill the immediate need, but also fit into the net-centric communications environment of the future.

The list of challenges and critical communications needs shown in Figure E-8 below was derived from briefings by the Military Services and representatives of the Office of the Secretary of Defense, the Joint Staff and Central Command as well as discussions with individuals.

Critical Military Needs
Theater Tactical Communications

- Each Military Service component has its unique communications challenges:
  - **Army**
    - Communicating on the move
    - Providing ISR support to units below brigade level out at the “tactical edge”
    - Protection against jamming,
  - **Marine Corps**
    - Challenges and needs identical to those of the Army when on shore, plus . . . .
    - The added complexity inherent in a ship-to-objective assault against enemy opposition
  - **Navy**
    - Total dependence on Satcom, RF LOS links, HF radio, and increasingly, airborne relay
    - Bandwidth constraints induced by limited space available for antenna placement
    - Protection from enemy jamming and own ship RF interference
  - **Air Force**
    - Breaking down data link stovepipes – remedying the current inability to pass data between planes utilizing different data links, thus fostering ISR information sharing
    - Moving the dramatically higher quantities of data collected by its growing airborne ISR fleet
    - Making ISR information collected by non-traditional platforms, such as tactical fighters, available to others real-time
    - Protection from jamming
- **Five critical military communications needs:**
  - Improved ISR communications support for mobile land forces and ships. While small units may not require large quantities of ISR data, their needs are focused, immediate and critical when engaged with the enemy
  - Moving more aggressively to improve interoperability of communications systems both between the Services and intra-Service
  - Increasing communications throughput capacity – to handle and profit from burgeoning quantities of ISR data collected by manned and unmanned air systems
  - Protecting critical communications systems from enemy jamming and other interruptions
  - Systems and architectures that will facilitate integration of data collected from multiple ISR sensors

Figure E-8: Critical Military Needs: Theater Tactical Communications

The study task force believes very strongly that two key developments – TSAT and JTRS – will go a long way towards fulfilling the critical military communications needs cited and that these programs merit strong and continuing support from senior officials in the Pentagon, the intelligence agencies, and theater commanders worldwide.

Joint Tactical Radio System (JTRS)

JTRS is a family of interoperable, software-defined radios that extends net-centric warfare beyond the command center. JTRS offers:

- Wireless, self-managed networking capabilities for improved joint force effectiveness.
- Voice and low data rate networks for communications out to the tactical edge.
- A range of capabilities covering airborne, maritime, fixed site and ground domains.
- Small unit access to information via IP request to the network.
- Edge units the capability to input sensor data to the network for all to share.
- New networking waveforms as well as the capability to employ key legacy systems.
- Open systems architecture to facilitate upgrades through technology insertion.

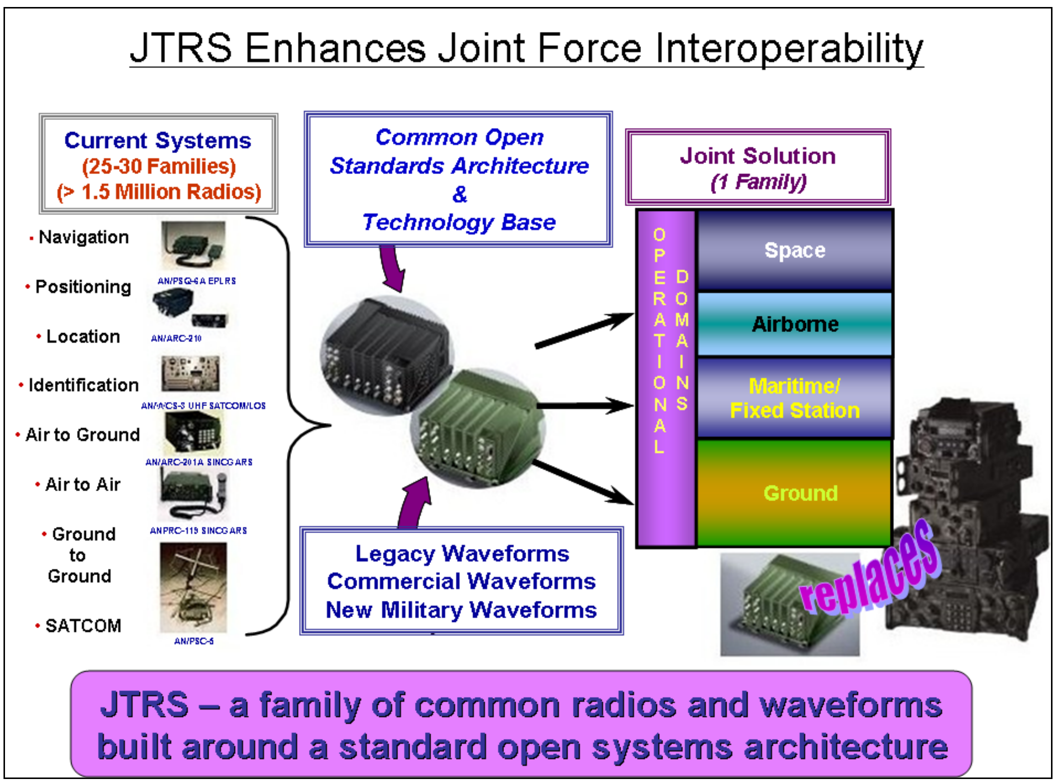

Figure E-9: Joint Tactical Radio System

As illustrated in Figure E-9, JTRS is a family of radios and waveforms built around a standard open systems architecture. JTRS delivers transformational communications capability – voice, video and data – to its primary customer, the warfighter at the "tactical edge." When coupled with TSAT, JTRS will provide assured, command and control and ISR communications for forces on the move. Without TSAT, JTRS will still provide voice and low bandwidth networking out to the tactical edge.

Importantly, JTRS is the only DoD program of record that provides networking capability for small units. Shown in Figure E-10 is a simplified representation of the future battlefield after JTRS has been fielded and communications satellites now under development are deployed. Depicted is how JTRS radios with networking waveforms (SRW and WNW) will afford land forces units below battalion level the capability to request and receive ISR data when engaged with the enemy and on the move. Further, the individual soldier or Marine can input, up the chain, ISR sensor data collected out at the tactical edge. There are, of course, capacity and data rate limitations for these companies, platoons, squads and individuals, but this nevertheless represents a dramatic, order of magnitude improvement in communications capability for formerly communications-deprived small units of the Army and Marine Corps.

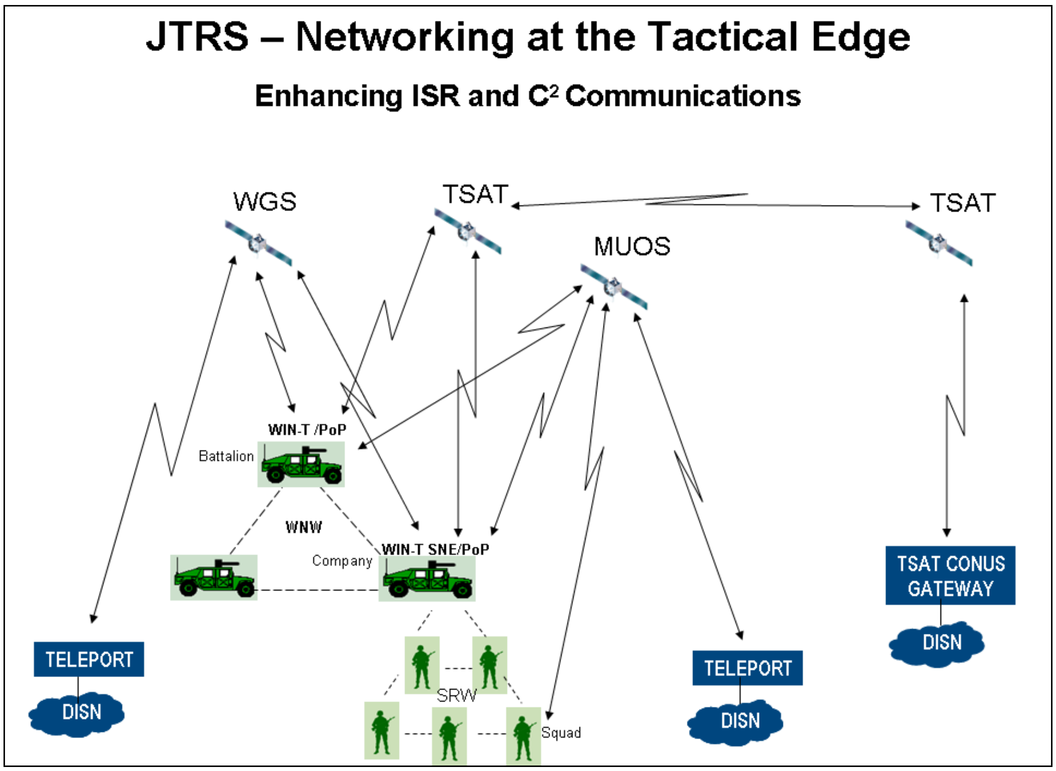

Figure E-10: JTRS and the Future Battlefield

Not shown in the above figure are the communications linking these lower level command elements to brigade, division, corps, Military Service component commander, and the joint force commander. But just as JTRS greatly enhances communications for the units shown above, senior Army and Marine Corps commanders, as well as Air Force and Navy commands and coalition partners, will benefit significantly from the ability of land force units at the "edge" to both profit from, and contribute to, ISR data available in combat theaters.

Status of JTRS Program

The JTRS Program is on schedule and within cost per the recently re-baselined acquisition program. Technical risks have been identified, including uncertainties associated with

Information Assurance certification for all the domain radios shown in Figure E-10 as well as associated software, but the time since the rebaseline is too short to assess confidence in the new program. JTRS Increment 1 is fully funded to match delivery capability, while Increment 2 has not yet been staffed and is a year or more from JROC consideration.

The requirements by the Military Services for quantities of radios by form factor are not yet stable. The stated numbers required have declined since inception of the JTRS program and are a reflection of continued procurement of legacy radios and some uncertainty over the Services' evolving architectures.

While the JTRS program is executing well, it is threatened by the unabated, continued procurement of legacy radios. This practice suppresses the real requirement for JTRS capability and radios, and could result in higher unit costs.

A notable exception to these problems is the separate MIDS/JTRS program, which is entering low-rate production after a successful development. Link-16/MIDS is the most important type of legacy radio to connect to the GIG in the net-centric force, and it seems to be on time.

What is Needed

The Department should reinstate the Radio Acquisition Policy and rigorously enforce its waiver policy which was held in abeyance and temporarily replaced in May 2005 by a far more lenient notification process.

Re-imposition of the Radio Acquisition Policy will:

- Allow procurement of legacy radios only by approved exception.
- Eliminate duplicative radio and waveform development and capture the savings.
- Earlier capture of emerging capability needs and their incorporation into JTRS.
- Maximize the return on investment in JTRS.
- Result in better scoping and accelerating the pace of fielding JTRS into the force.
- Facilitate more rapid satisfaction of JCS/J6-validated urgent operational requirements.

Taking these recommended actions will maximize JTRS' return on investment, strengthen internal DoD budget defenses and will better assure Congress' continuing support for the program. Most importantly, arresting proliferation of legacy radio procurements and duplicative developments will enhance joint force interoperability and warfighter combat effectiveness.

Transformational Satellite System (TSAT)

TSAT offers assured, high throughput strategic and tactical global connectivity for both ISR and command and control, offering critical communications services not previously available. TSAT provides the following capabilities:

- Near real-time connectivity of all GIG assets.
- Assured, higher capacity SATCOM for ships and on-the-move land forces.
- Worldwide persistent connectivity of high and low resolution ISR assets.
- Survivable communications for strategic forces and homeland defense.

TSAT also facilitates networked, interoperable air, ground and space ISR systems, not like the stovepipes of today, and provides 10,000 times the capacity of the current Milstar II in both protected packets and circuits. TSAT's advanced antennas, waveforms, laser crosslinks and routers allow for more bandwidth, accesses and speed to mobile users. In addition, through frequency hopping and small coverage beams, TSAT provides anti-jam capability to both strategic and tactical users.

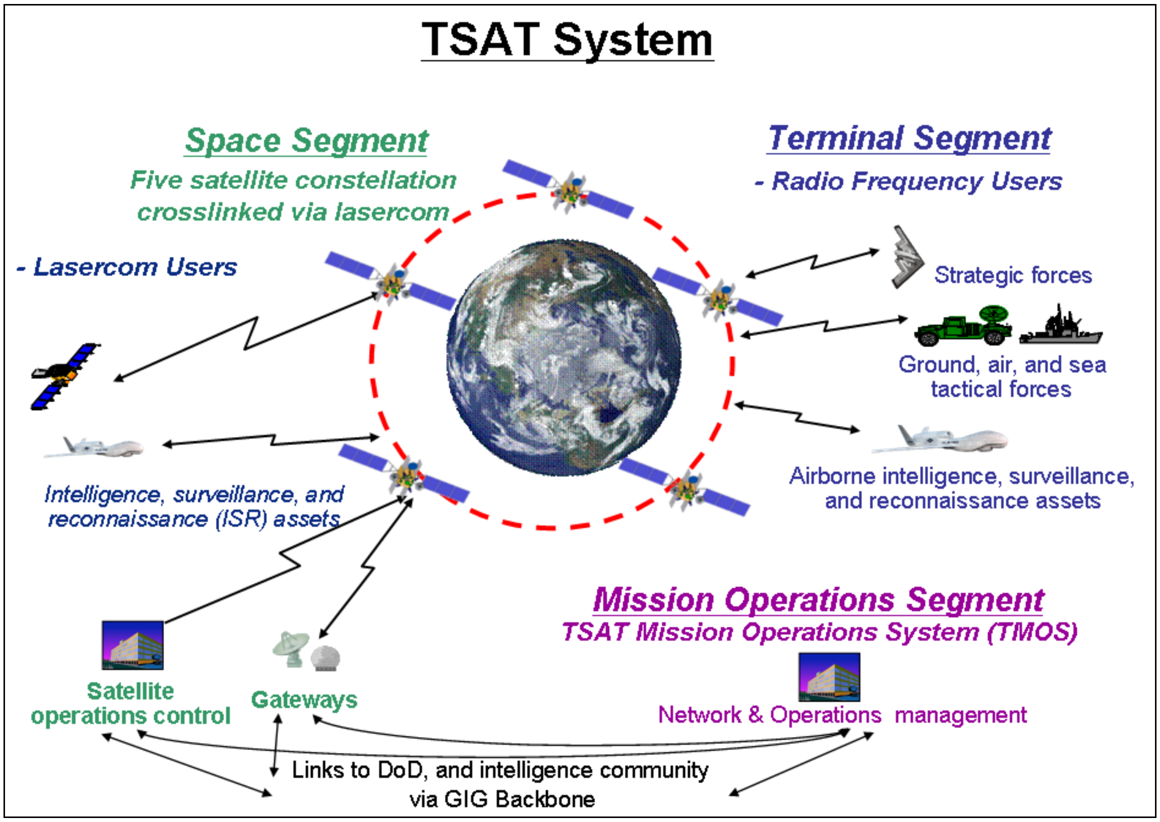

Figure E-11: The TSAT System

The TSAT System is illustrated in Figure E-11 and is comprised of three segments – space, the TSAT Mission Operations System (TMOS), and terminals. The TSAT program office acquires only space and TMOS segments. The terminals are acquired by the individual Military Services, each of which has its own terminal program. Nonetheless, terminals are considered part of the overall TSAT system as they must meet certain requirements in order for the system as a whole to function. For example, a terminal must transmit with enough power to ensure that its data rates match those of the specified satellite design.

The TSAT space segment consists of five crosslinked satellites plus a spare. All five have routers and can provide IP networking services to users. They have lasercomm crosslinks, which can also provide ISR services for airborne platforms and space sensors. And all five provide Ka-band services for ISR users.

The TMOS performs mission planning for the TSAT system. Users can access the mission planning system via a web-based interface, and the system can respond with new service agreements within minutes. TMOS provides network and operational management for TSAT, monitoring the system, and adjusting for faults, cyber attacks, performance tuning, and new operations policies.

As an element of GIG communications, the TSAT system connects to deployed network systems such as Warfighter Information Network-Tactical (WIN-T) and Automated Digital Networking System (ADNS), and to the terrestrial DISN. The TSAT CONUS Gateway provides a high data rate downlink with direct connection to the DISN.

The TSAT's Internet Protocol (IP) routing will connect thousands of users through networks rather than limited point-to-point connections. IP packet-based switching requires fewer communication resources and provides greater flexibility. Additionally, TSAT will enable high data rate connections to Space and Airborne Intelligence, Surveillance, and Reconnaissance (SISR, AISR) platforms.

TSAT Today

According to the program office, all seven of TSAT's critical technologies are mature, a judgment validated by an independent technology readiness assessment in June 2007. The program was approved to contract award to enter the development phase, which is expected in late 2008.

In December 2006, the DoD issued a program decision memorandum that reduced the TSAT budget by $323M for FY2008. According to DoD officials, this budget reduction was due to concerns about an overly optimistic TMOS software development schedule and the long term synchronization of TSAT with the terrestrial portion of the GIG, including terminals and teleports. As a result, all TSAT launches have been delayed by at least one year[11]. The latest launch date estimate is 2018 based on current funding levels, but could be accelerated to 2017 if funding is increased.

If TSAT is cancelled or significantly delayed further, the military and intelligence communities will be faced with a limited set of potential actions. They must dramatically reduce their expectations about the number of deployed units and UAVs supportable by the communications assets available, and they must also be prepared to both aggressively fund continued development of the TMOS ground system and continue to fund procurement of, and improvements to, legacy and other program-of-record systems, however no assured wide-band communications will be available from any programs except TSAT.

Alternatives to TSAT are limited and include less capable "work-arounds" to full TSAT capability that offer IP networking capability, but without high throughput data rates and protection from jamming. Only 15% of AISR communications can be supported by commercial SATCOM, and only TSAT can fully meet future AISR communications needs.

TSAT is Essential

Just as the military and intelligence communities have transformed the way they operate, TSAT will transform the way they communicate. As shown in figure E-12, TSAT will provide a dramatic increase in capacity and capability over existing and interim satellite communications resources. Depending on circumstances, military forces often operate from unimproved and disadvantaged locations world-wide, are highly mobile, and depend heavily on reach-back for

[11] Source: GAO-08-467SP Assessment of Major Weapon Programs.

near-real time intelligence, imagery, and logistical information as well as inter-unit cooperation and support. The greatly expanded use of UAVs for intelligence, surveillance, and reconnaissance and for direct target engagement has placed extraordinary demands on the current SATCOM system. TSAT will mitigate those demands and further operational flexibility.

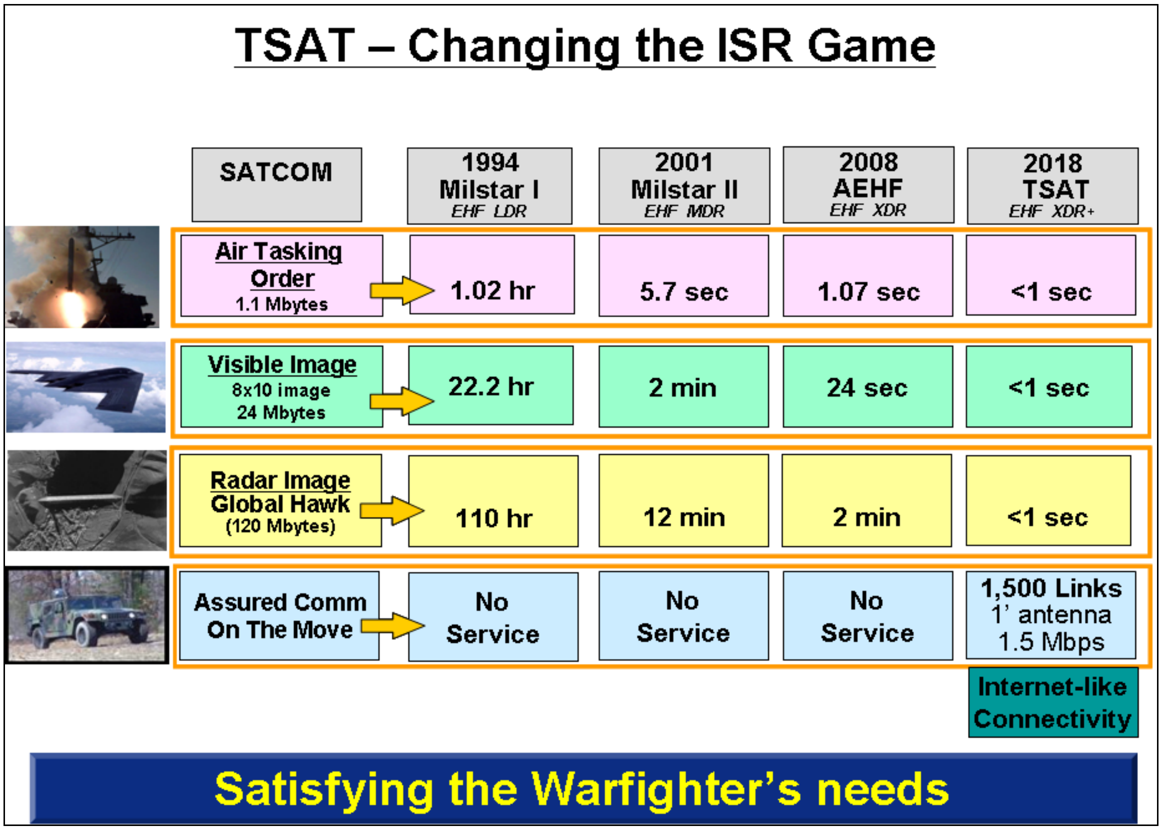

Figure E-12: TSAT Will Dramatically Increase Satellite Communications Capability Enabling ISR Advances

The TSAT system is essential to enhancing military and intelligence operations. Without TSAT, mobile land forces and Navy ships will lack sufficient assured ISR communications capacity, and the Military and IC will be unable to move and fully benefit from the large and growing quantity of data generated by new airborne and space ISR systems. TSAT exemplifies the promise of the TCA's enhanced capabilities and is a critical element of the transformation in military and intelligence operations.

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APPENDIX F: IMPROVING SENSOR TASKING

For access to Appendix F contact the Defense Science Board office at 703-571-0081 or DSBOffice@osd.mil.

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APPENDIX G: SENSORS GAPS AND SHORTFALLS

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APPENDIX H: ACRONYMS & GLOSSARY OF TERMS

A

ADNS	Automated Digital Networking System
AEHF	Advanced Extremely High Frequency satellite
AGITK	Advanced Geospatial Intelligence Toolkit
AISR	Airborne Intelligence, Surveillance, Reconnaissance
AOR	Area of Responsibility
A/S	Assistant Secretary
ASD	Assistant Secretary of Defense
ASD(CIP)	Assistant Secretary of Defense, Critical Infrastructure Protection
ASD(NII)	Assistant Secretary of Defense, Networks and Information Integration.
ASD(SO/LIC)	Assistant Secretary of Defense, Special Operations/Low Intensity Conflict

B

BA	Battlespace Awareness
BA CPM	Battlespace Awareness Capability Portfolio Manager

C

CBRNE	Chemical Biological Radiological Nuclear Explosive
CERT	Commuter Emergency Response Team
CIA	Central Intelligence Agency
CIO	Chief Information Officer
CIP	Critical Infrastructure Program
COIC	Counter-IED Operations Information Center
COCOM	Combatant Command
COI	Communities of Interest
CONOPS	Concept of Operations
CONUS	Continental United States
CPM	Capability Portfolio Manager
CTC	Counter Terrorism Center

D

DARPA	Defense Advanced Research Projects Agency
DCGS	Distributed Common Ground System
DCIP	Defense Critical Infrastructure Program
DDRE	Director of Defense Research and Engineering
DEPSECDEF	Deputy Secretary of Defense
DFAR	Defense Federal Acquisition Regulation
DHS	Department of Homeland Security
DIA	Defense Intelligence Agency
DIB	DCGS Integration Backbone
DISA	Defense Information Systems Agency
DISN	Defense Information System Network
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
DNI	Director of National Intelligence
DSB	Defense Science Board
DSS	Defense Security Service
DTRA	Defense Threat Reduction Agency

E

EHF	Extra High Frequency
EO	Electro-Optical
EO/IR	Electro-Optical/Infrared

F

FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
FEMA	Federal Emergency Management Agency
FOIA	Freedom of Information Act
FOPEN	Foliage Penetrating

G

GAO	Government Accountability Office
GCC	Government Coordinating Council
GEOINT	Geospatial Intelligence
GIG-BE	Global Information Grid – Bandwidth Expansion
GIS	Geospatial Information Systems
GMTI	Ground Moving Target Indicators
GOCO	Government Owned, Contractor Operated
GPS	Global Positioning System

H

HD	Homeland Defense
HD/CIP	Homeland Defense/Critical Infrastructure Protection
HS	Homeland Security
HSI	Hyperspectral Imaging
HUMINT	Human Intelligence
HURT	DARPA Heterogeneous Urban RSTA Team

I

IC	Intelligence Community
ICM	Integration Collection Management
IED	Improvised Explosive Device
IP	Internet Protocol
ISB	Intelligence Science Board
ISR	Intelligence, Surveillance, Reconnaissance

J

JFCC	Joint Functional Component Command
JSTARS	Joint Surveillance Target Attack Radar System
JTRS	Joint Tactical Radio System

K

KML	Keyhole Markup Language

L

LADAR	Laser Radar
LAN	Local Area Network
LEO	Low Earth Orbit
LSRS	Littoral Surveillance Radar System

M

MAN	Metropolitan Area Network
MDV	Minimum Detectable Velocity
MILSATCOM	Military Satellite Communications
MIMO	Multiple Input, Multiple Output
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MUOS	Mobile User Objective System

N

NASA	National Aeronautics and Space Administration
NCES	Net-Centric Enterprise Services
NEF	National Exploitation Factors
NetOps	Network Operations
NGA	National Geospatial-Intelligence Agency
NIST	National Institute of Standards and Technology
NORTHCOM	U.S. Northern Command
NRO	National Reconnaissance Office
NSA	National Security Agency

O

OASD(HD)	Office of the Assistant Secretary of Defense for Homeland Defense
OGC	Open Geospatial Consortium
OSD	Office of the Secretary of Defense

OUSD(AT&L)	Office of the Under Secretary of Defense for Acquisition, Technology and Logistics
OUSD(I)	Office of the Under Secretary of Defense for Intelligence

P

PCII	Protection of Critical Infrastructure Information

R

RAMCAP	Risk Analysis and Management for Critical Asset Protection
R&D	Research and Development
RDT&E	Research, Development, Test and Evaluation
RF	Radio Frequency
RSTA	Reconnaissance, Surveillance and Target Acquisition

S

SAR	Synthetic Aperture Radar
SCC	Sector Coordinating Council
SHF	Super High Frequency
SISR	Space Intelligence, Surveillance, Reconnaissance
STRATCOM	U.S. Strategic Command

T

TCA	Transformational Communications Architecture
TMOS	TSAT Mission Operations System
TPED	Task, Process, Exploit, Disseminate
TPPU	Task-Post-Process (in parallel)-Use
TSAT	Transformational Satellite System
TSWG	Technical Support Working Group

U

UAV	Unmanned Aerial Vehicle
UFO	Ultra-High Frequency Follow-on Satellite
UGS	Unattended Ground-based Sensors

UHF	Ultra High Frequency
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
UN	United Nations
U.S.	United States
USGS	U.S. Geological Survey

V

VTOL	Vertical Take-off and Landing

W

WGS	Wideband Gap Filler satellite
WIN-T	Warfighter Information Network-Tactical
WMD	Weapons of Mass Destruction

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