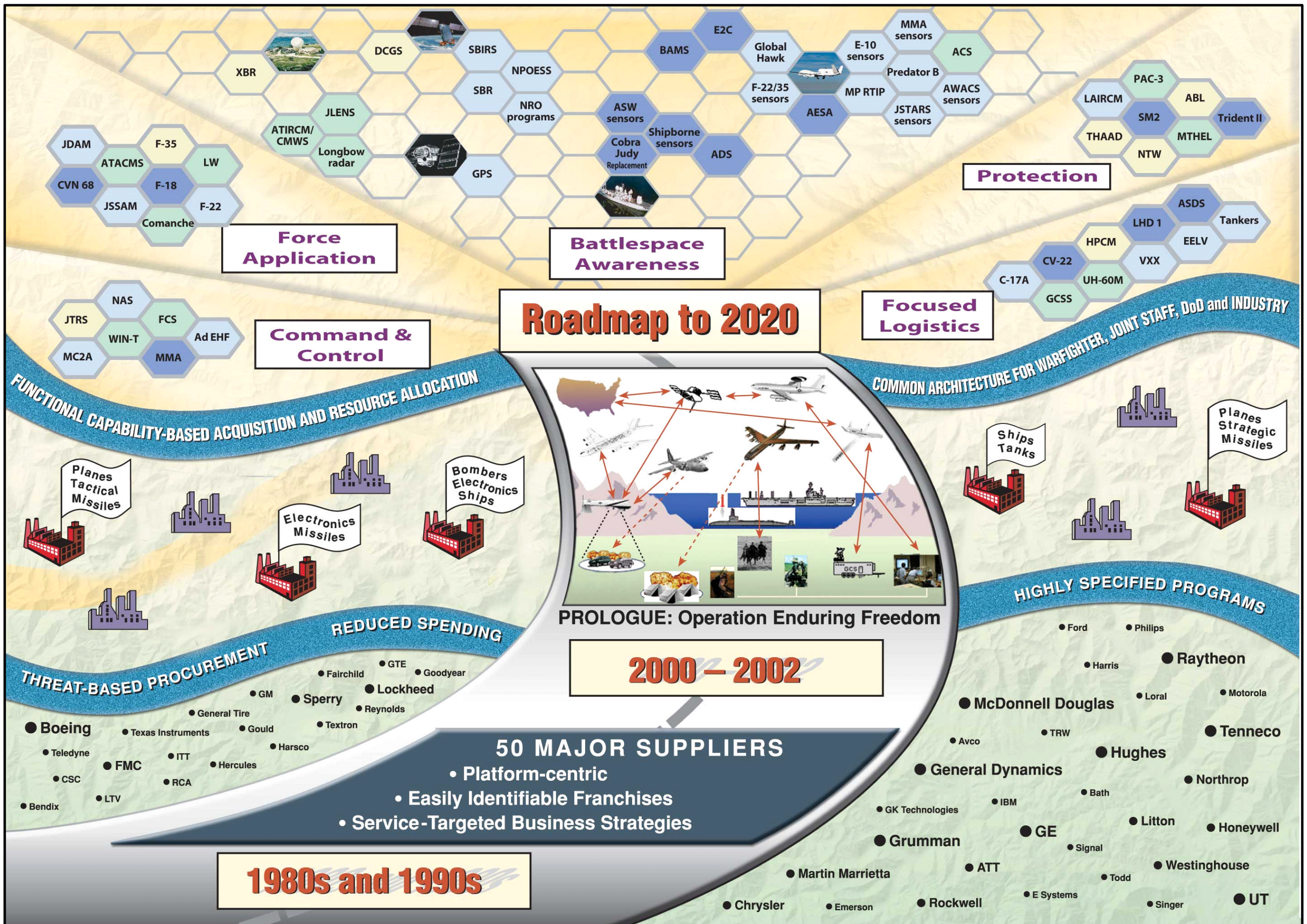

DEFENSE INDUSTRIAL BASE CAPABILITIES STUDY: BATTLESPACE AWARENESS

JANUARY 2004

A version of the cover graphic was used in *Transforming the Defense Industrial Base: A Roadmap* (ODUSD(IP), Feb 2003). As the center section of the chart shows, the defense industrial base of today is a distillate of its prior form. What were roughly 50 major defense suppliers in the 1980s have become five major, highly consolidated, cross-Service, cross-platform prime contractors. As such, for now, they are uniquely suited to provide system-of-systems approaches to defense requirements.

The earlier study concluded that the Secretary's transformation mandate required a different lens for viewing the defense enterprise: one organized around the most essential operational effects that the U.S. warfighter must be able to deliver to be successful. The Joint Staff has now reorganized around five new functional concepts. The top of the landscape shows these major Joint Staff functional concepts: Battlespace Awareness, Command and Control, Force Application, Protection, and Focused Logistics, with representative programs indicated for each. These five concepts along with related operating concepts are becoming the central theme for Department decision-making. We must stress, however, that these concepts are still evolving and include legacy programs, research and development (R&D) inititatives, as well as all new programs that provide the warfighting capability relative to each functional concept. The reader should not interpret this representative program "binning" as rigid or final. Also, programs can and do support capabilities in multiple functional concepts. We will continue to adjust our industrial base capability assessments to the evolving Joint Staff concepts as appropriate.

The Department's move to capabilities-based decision-making will fundamentally change the defense enterprise. How the Department looks at what it has and what it needs also will affect who participates in the defense industrial base—and likely will cause it to expand to include non-traditional emerging defense suppliers. Capabilities-based decision-making provides a common and comprehensive vernacular to the operators, the acquirers, and industry. Clearer communication and an integrated vision should continue to improve the efficiency of planning, decision-making, and execution.

Key to Color Coding:

= Army = Air Force
= Navy = DoD

This report and all appendices can be viewed online and downloaded at:

http://www.acq.osd.mil/ip

This report was produced for the Under Secretary of Defense (Acquisition, Technology, & Logistics) by the Deputy Under Secretary of Defense (Industrial Policy) from May-December 2003. Lt. Col. Chris Warack, USAF, led this effort. Stephen Thompson, Rosemary Carpenter, Dawn Vehmeier, Gary Powell, Mary Grafton, and other Industrial Policy staff also had major roles in the production of this report. Support was provided by Booz Allen Hamilton, Inc. (BAH), the Institute for Defense Analyses (IDA), and First Equity Development, Inc. Among others, special thanks are due to John Williams and Carmen Alatorre-Martin of BAH, and Jim Woolsey of IDA for their important contributions. The team would like to acknowledge the contributions of the six Red Teams, consisting of 30 individuals, who reviewed this report. Companies listed or mentioned in this report are representative; the list is not exhaustive. Inclusion or exclusion in the report does not imply future business opportunities with or endorsement by the Department. Inquiries regarding the report should be directed to Lt. Col. Chris Warack at (703) 697-0051 or (703) 602-4323.

DEFENSE INDUSTRIAL BASE CAPABILITIES STUDY: BATTLESPACE AWARENESS

OFFICE OF THE DEPUTY UNDER SECRETARY OF DEFENSE
(INDUSTRIAL POLICY)

JANUARY 2004

DEFENSE INDUSTRIAL BASE CAPABILITY STUDY (DIBCS) SERIES STUDY OBJECTIVES

Develop a capabilities-based industrial framework and analytical methodology as a foundation for programmatic and investment decision-making.

Identify technology critical to enabling the new Joint Staff functional warfighter capabilities. Establish a reference database of these key critical industrial base capabilities mapped to warfighting functional capabilities.

Conduct industrial base capability assessments on priority critical technologies to identify deficiencies.

Develop a systematic method to craft industrial base strategies to remedy industrial base deficiencies identified and encourage proactive, innovative management of the industrial base.

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Findings

Defense industrial base assessments must be linked to warfighting capabilities and assessed in a capabilities-based context. This report deploys a methodology used to link warfighting to industrial base capabilities.

An initial survey of the Battlespace Awareness Functional Concept identified 357 capabilities directly enabling American warfighting leadership in this area. To enable these capabilities, 270 technologies qualified as ones where the United States should be ahead of any potential adversary.

An assessment for industrial base sufficiency of the 31 more pressing applications of the 270 technologies found that, with few exceptions, available industrial base capabilities are sufficiently innovative and robust.

Policy levers and implementation concepts developed in this study to influence the industrial base—if embedded in DoD planning and acquisition policies, practices, and decisions—will help continue the development of well-crafted program acquisition strategies, as well as remedy any industrial base deficiencies identified.

Recommendations

1) ODUSD(IP) recommends that the Department implement the remedies in this report addressing the industrial base issues identified in the initial assessment of the Battlespace Awareness functional capability area.

2) Within the Department, ODUSD(IP) should be considered the clearinghouse for industrial base deficiencies. ODUSD(IP) will continue to assess Battlespace Awareness industrial base sufficiency using the capabilities framework, databases, and policy tools developed in this study. This framework will also be used for industrial base capabilities assessments for Command & Control, Force Application, Protection, and Focused Logistics.

3) The Department should establish architects for each of the functional architectures to be accountable for relevant implementation of the Joint Programming Guidance; to be lead integrators within each functional capability; to coordinate cross-architectural issues; and to coordinate issues across functional capabilities. Establishing responsibility for cross-functional industrial base considerations in this way will improve capability delivered to the warfighter and decision-making in the Department.

4) Acquisition strategies should plan for industrial base assessments and the systematic consideration of sources of innovation at major opportunities throughout the life of programs. Additional training on industrial base capabilities and considerations should be included in acquisition professional development.

FOREWORD

A DEFENSE INDUSTRIAL BASE FOR THE 21ST CENTURY

Twice in the last century the United States heeded the call of European and other nations to engage in major world conflicts. In both of these conflicts, the fledgling American industrial base added capacity and surged production to meet these unexpected demands. Recall that this happened when the defense industrial base was just being established—starting with Boeing, Lockheed, and Raytheon in the decade between 1915 and 1925.[1]

> *"… possibly the **single-most transforming thing** in our force will not be a weapon system, but a **set of interconnections** and a substantially enhanced capability because of that awareness."*
>
> *– Donald Rumsfeld, Secretary of Defense August 9, 2001*

Later in the last century, American sons and daughters "answered the call to defend a country they never knew and a people they never met"[2] in Korea—and subsequently in Vietnam, and then in Kuwait and Iraq for the first Gulf War. As a result of these conflicts, and several smaller ones, U.S. armed forces learned about operational and technical deficiencies, as well as about the difficulty of combating asymmetrical warfighting tactics. Notably, none of these conflicts required widespread surging of the defense industrial base.

This century is less than five years old, but we have refined these lessons learned in the first two engagements in the war against terrorism. In these engagements, we also have learned that the art of our adversaries' warfare will likely evolve so quickly that the size and capacity paradigms of the industrial base in the first two World Wars are unlikely to be effective. In these 21st Century engagements, state-of-the-art and legacy products of the defense industrial base were matched with multi-dimensional, unconventional, and asymmetric tactics to produce a truly come-as-you-are war with a brand-new, transformational script. U.S. forces adapted new systems just coming out of development, converted legacy systems to create new capabilities—all of which were focused to optimize battlefield impact. Going forward, the manufacturing base and program management structures supporting defense will have to be less entrenched, more flexible, and evolve more rapidly than at any time in the nation's history. They will also increasingly leverage a rapidly evolving commercial technology base. Thankfully, the science and academic communities, developers, and manufacturers are all equal to the challenge. In fact, as this century opened, it was the flexibility of U.S. production lines that led to great feats of technology adaptation and production increases focused mostly on some of these new technology adaptations.

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[1] Electric Boat, now part of General Dynamics, was founded in 1899 and listed on the New York Stock Exchange (NYSE) in 1926. Northrop Corporation was founded in the 1930s, as part of Douglas Aircraft, and listed on the NYSE 1952.

[2] Inscription on the Pool of Remembrance at the Korean War Veterans Memorial, Washington, D.C.

This new paradigm has also led the Joint Staff to redefine 21st century warfighting requirements along functional capabilities. This requires a redefinition and reassessment of the industrial base capabilities that are truly critical to the warfighter. It is hoped that the description of defense industrial base capabilities that are truly critical to the warfighter in this new paradigm will help to focus the manufacturing base on the challenges of 21st century warfare. After World War II, defense has generally leveraged only four percent or less of the American manufacturing industrial base. However, these manufacturers will always play one of the most critical roles in bringing to life the best of what American ingenuity can inspire.

> *"The defense industrial base is not a planned community. It is what happens when smart, innovative inventors, laboratories, entrepreneurs, and companies find their place in our landscape to deliver capabilities to the warfighter."*
>
> *- Suzanne Patrick, Deputy Under Secretary of Defense for Industrial Policy, Navy Gold Coast Conference, Ventura, California, October 7, 2003*

The Defense Industrial Base Capability Study (DIBCS) series develops a capabilities-based industrial framework as a foundation for Defense Department programmatic and investment decision-making. It develops a process to identify and assess the sufficiency of industrial base capabilities to supply critical enabling technologies. It also develops a systematic method to explore and develop remedies to industrial base deficiencies. It focuses on the innovative technical capabilities of the industrial base, not production capacity or workforce issues. It considers the best capabilities in both the domestic and foreign components of the industrial base to ensure that American warfighters have access to the capabilities they need. Finally, it focuses only on the American warfighters' needs and not the needs of other constituencies.

This study series is addressed to myriad participants in the defense enterprise. First, the components of the industrial base (academic institutions, inventors, government and civilian laboratories and agencies, developers, and manufacturers) will gain insight into the Department's new capabilities-based decision-making and will hopefully use it for their strategic planning and for prioritizing investments. The study should serve this function for the financial investment community as well.

Second, with these changes, the corporate culture of program offices and acquisition staffs must change to implement this capabilities-based paradigm effectively. Our case studies have valuable lessons learned on how to stimulate innovation from the broadest possible array of participants in the industrial base through all phases of a program and avoid unintentionally foreclosing innovation, cross-Service application, or revolutionary ways of doing business. These insights may enable program managers to better shape the industrial base to suit their needs—but more importantly, to satisfy the long-term needs of the Department and the nation. For it is the program managers who collectively control the flow of the Department's funding into the defense industrial base.

Third, senior leadership in the Department may find the framework and findings useful for their own planning and technology endeavors. Insights from this community will help evolve findings within the DIBCS framework and promote further understanding of the 21st century industrial base.

Finally, we believe that the methodology we have employed to assess industrial base capability could also be a useful self-examination tool: for companies to examine their own capabilities in this new functional capabilities context and for other countries or international security organizations to examine the suitability of their own industrial base structures to their own security requirements—and as a global offeror to the U.S. industrial base. The new common language for defense planning which the Joint Staff has provided in its functional capabilities architectures may over time be the biggest contribution of all to joint and coalition warfare in the 21st century.

Many of our Red Teams have reminded us that changed defense requirements and acquisition processes are the key enablers to assure the maximum utility of our endeavor. These changes are being implemented through the efforts of the Joint Staff and the Office of the Secretary of Defense. As these processes and the defense industrial base evolve, the involvement of all participants will be necessary to ensure that the industrial base continues to optimally serve the warfighter.

A Note on International Suppliers[3]

Generally, the Department wants to take full advantage of the benefits offered by access to the most innovative, efficient, and competitive suppliers—worldwide. It also wants to promote consistency and fairness in dealing with its allies and trading partners while assuring that the U.S. defense industrial base is sufficient to meet its most critical defense needs. Consequently, the Department is willing to use non-U.S. suppliers—consistent with national security requirements—when such use offers comparative advantages in performance, cost, schedule, or coalition warfighting. For this reason, the Department and many friendly governments have established reciprocal procurement agreements that waive their respective "buy national" laws and put each other's industries on par as potential suppliers. Nevertheless, under ideal circumstances the Department would prefer U.S. sources for those technologies and industrial capabilities supporting warfighting capabilities for which it has established leadership goals to *be ahead* or *be way ahead* of potential adversaries. However, the Department must be, and is, prepared to use non-U.S. suppliers to support critical warfighting goals when necessary and appropriate, and when the supplier and the nation in which it resides have demonstrated reliability in:

- Responding to DoD technology and product development requirements;
- Meeting DoD delivery requirements during peacetime and/or periods of conflict or international tension; and
- Precluding unauthorized transfer of technical information, technologies, or products within the nation or to third parties.

[3] Synthesis of Congressional testimony, policy handbooks, and discussion related to the National Defense Authorization Act for FY04.

RED TEAMS

Policy Implications

Mr. E.C. “Pete” Aldridge, former USD (Acquisition, Technology & Logistics)
Dr. Charles Holland, DUSD (Science & Technology)
Ms. Sue Payton, DUSD (Advanced Systems & Concepts)
Mr. Warren Citrin, former CEO, Solipsys
Mr. John O’Neill, President, Lockheed Martin Naval Electronics and Surveillance Systems—Undersea Systems

Functional Capability

Dr. Charles Holland, DUSD (Science & Technology)
Ms. Sue Payton, DUSD (Advanced Systems & Concepts)
Dr. Bruce Gwilliam, Defense Systems, OSD
Col. Gary Bender, Directorate for Intelligence, Joint Staff
Mr. Steven Derganc, Joint Requirements & Integration Directorate, U.S. Joint Forces Command

Business Process and Policy Implications

Mr. Andrew Marshall, Director, Office of Net Assessment, OSD
Dr. Anthony Tether, Director, DARPA
Dr. Robert Leheny, Deputy Director, DARPA
Mr. John Garstka, Office of Force Transformation, OSD
Mr. Victor Ciardello, Small & Disadvantaged Business Utilization, OSD
Mr. Robert Nemetz, Acquisition Resources & Analysis, OSD
Ms. Barbara Glotfelty, Defense Procurement & Acquisition Policy, OSD
Mr. Scott Comes, Program Analysis & Evaluation, OSD

Industry

Dr. Michael Andrews, Chief Technology Officer, L-3 Communications Holdings, Inc.
Mr. Millard Firebaugh, Vice President-Innovation, Electric Boat
Mr. Evan Polley, Principal, Dragon Advisors
Mr. Gerald Daniels, Vice Chairman & CEO, Engineered Support Systems, Inc.
Mr. A.J. “Beau” Beauregard, Director of Advanced Technology, Lockheed Martin Washington Operations

Congressional and Industry Associations

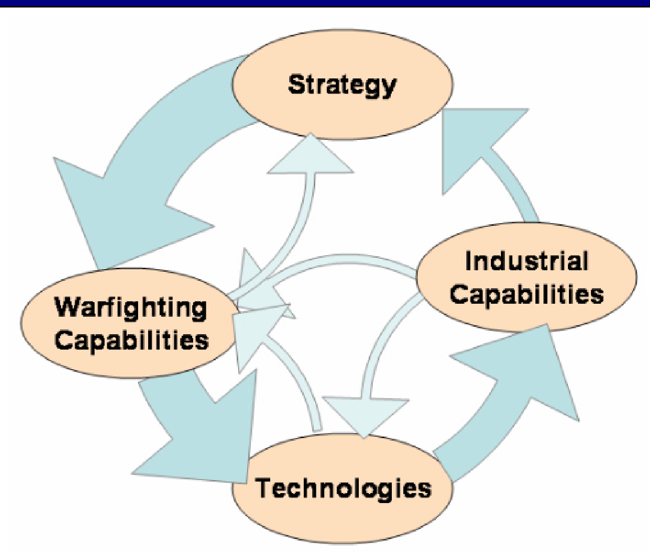
Mr. William Greenwalt, Professional Staff Member, U.S. Senate Committee on Armed Services
Mr. Jonathon Etherton, Vice President, Legislative Affairs, Aerospace Industries Association
Mr. Samuel Campagna, Director, Operations, National Defense Industrial Association
Mr. James Serafin, Vice President, Government Relations & Marketing, Government Electronics & Information Technology Association

Executive Summary

In February 2003, the Office of the Deputy Under Secretary of Defense for Industrial Policy, ODUSD(IP), produced *Transforming the Defense Industrial Base: A Roadmap.* This report identified the need for systematic evaluation of the ability of the defense industrial base to develop and provide functional, operational effects-based warfighting capabilities. The Defense Industrial Base Capabilities Study (DIBCS) series begins a systematic assessment of critical technologies and industrial capabilities needed in the 21st century defense industrial base to meet warfighter requirements as framed by the Joint Staff's Functional Concepts and Joint Operational Architecture. The DIBCS series ties directly to warfighter needs by linking industrial base capabilities to warfighter capabilities derived from the Functional Concepts. This report addresses the first of those functional concepts, Battlespace Awareness.

The DIBCS methodology associates enabling technologies with warfighter capabilities and assesses the industrial capability to develop and produce those technologies. It defines leadership goals for warfighter capabilities (*neutral, equal, be ahead, be way ahead*) that establish the degree of innovation desired in the industrial base. A warfighting capability that is ubiquitous—mature and available to all—typically has a *neutral* leadership goal. Industrial capabilities linked to *neutral* warfighting capabilities require minimal innovation and can be sourced from the global marketplace. In contrast, a warfighting capability that brings key advantages has a *be way ahead* leadership goal. *Be way ahead* industrial capabilities must be highly innovative and often require effective competition among technologies and their suppliers to be sustained. America's commitment to its warfighters requires the Department of Defense to select the most competitive suppliers for these technologies from the global industrial base while maintaining security.

CAPABILITIES-BASED INFLUENCE CYCLE



Source: ODUSD(IP) and Booz Allen Hamilton

The DIBCS addresses *critical* technologies, those linked to *be ahead* and *be way ahead* warfighter capabilities, and particularly those with multiple applications. The methodology proactively assesses the available industrial capabilities, focusing on high standards of innovation and sufficiency.

Finally, the DIBCS recognizes that managing critical industrial capabilities may require policy implementations and suggests a consistent methodology to develop, sustain, and improve those capabilities.

The policy implementation construct which this study deploys is based on employing three policy "levers" to remedy instances in which required industrial capabilities are insufficient: (1) fund innovation; (2) optimize program management structures and acquisition strategies; and (3) employ external corrective measures (measures taken outside the confines of individual defense programs). These policy levers can be deployed through five major "portals" throughout the technology and weapon system lifecycle—insertion opportunities where managerial decisions have the most impact on developing and sustaining critical technologies and associated industrial capabilities: (1) science and technology; (2) laboratory to manufacturing transition; (3) weapon system design; (4) make-buy decisions; and (5) life cycle innovation for fielded systems. By highlighting industrial base deficiencies for critical technologies, and implementing appropriate policy initiatives and remedies, the Department is positioned to facilitate innovation that promotes joint, cross-Service warfighting.

THE ROLE OF BATTLESPACE AWARENESS

A new American approach to warfighting began to evolve in the aftermath of World War II. Over more than fifty years, doctrine evolved from Attrition Warfare to Maneuver Warfare to Network-Centric Warfare, enabled by numerous technological advances including satellite reconnaissance, the Global Positioning System (GPS), modern information technology, and precision weapons. For instance, the launches beginning in 1960 of the Galactic Radiation and Background (GRAB) and Corona satellites ushered in the satellite reconnaissance era that has evolved into numerous technical means to characterize enemy capabilities and to locate forces anywhere in the world. On the basis of the last century's doctrinal and technological evolutions, American 21st century warfare operates on the fundamental principle that U.S. forces will "see, understand, and act" faster than its adversaries. Battlespace Awareness provides the capabilities to "see" and many of the "understand" capabilities, as well.

This study begins with understanding the Battlespace Awareness functional capability area. Battlespace Awareness capabilities provide commanders and forces the ability to understand the environment in which they operate and the adversaries they face. The major Battlespace Awareness activities are observation and collection; orientation and assessment; knowledge management; modeling, simulation and forecasting; command and control of Battlespace Awareness assets; and interface with decision makers—all interconnected through a ubiquitous information network. Battlespace Awareness supplies the critical knowledge necessary to precisely apply force, to thwart or circumvent enemy efforts, and to bring the right support to the right place at the right time.

BATTLESPACE AWARENESS RECOMMENDATIONS

Understanding that Battlespace Awareness is a critical warfighting differentiator, the United States has for decades invested significant resources in this sector, reaping considerable benefits. As a consequence, the good news from our initial assessments in this study is that the industrial base capabilities for Battlespace Awareness are generally robust where the United States desires to *be ahead* or *be way ahead*. Only a few industrial capabilities fall short of the highest standard of sufficiency we desire to support those capabilities.

Our review identified 436 specific capabilities supporting Battlespace Awareness of which 357 were *be ahead* or *be way ahead* capabilities. Functional analysis of those capabilities led to 270 associated critical enabling technologies.[4] Of these, 31 of the most important applications of these technologies were initially assessed along with 41 of their component technologies for a total of 72 industrial capabilities assessed. The review shows that the United States meets its leadership goals in nearly all of the assessed technologies because of the focus on these capabilities described earlier, as well as persistent funding on joint and coalition operations in general. Most of the 72 industrial capabilities already exist or are under development by three or more domestic suppliers with added competition from the foreign component of the defense industrial base.

The first two recommendations outlined below result from the DIBCS methodology as applied to Battlespace Awareness. The third and fourth recommendations address process issues highlighted by numerous Red Teams and discussed throughout this report. They are intended to improve the requirements and acquisition processes essential to overall improvement of the defense industrial base.

RECOMMENDATION 1

For the three industrial capabilities needing additional attention to obtain or sustain the desired degree of U.S. capability leadership, this report recommends funding and other policy remedies for consideration by the acquisition community. The three industrial capabilities with recommended remedies are:

- Active Hyperspectral Imagers for chemical signature and surveillance;
- Active Electronically Scanned Array (AESA) Radar for wide-ranging applications on platforms in all mediums;
- Maser Clocks for precision timing devices in next generation systems.

The funding and policy remedies recommended are based on a policy construct consisting of *levers* for shaping the industrial base and *portals* through which the Department may most effectively deploy the levers. For other important warfighting enablers, such as radiation-hardened integrated circuits, we found that well-structured remedies to strengthen these industrial capabilities were already in place.

4 Information Technology industrial capabilities will be addressed in the next of the DIBCS series, *DIBCS: Command & Control*.

RECOMMENDATION 2

ODUSD (IP) should be considered the clearinghouse for identified industrial base deficiencies and will continue to assess Battlespace Awareness industrial base sufficiency. Some chronic industrial base issues such as batteries, fuel, and tracks for armored vehicles do not rise to the level of critical technology in the DIBCS methodology. Other issues such as the information technology industrial base and key manufacturing processes and materials will continue to arise and to be identified as they have in the past. Now, however, they will be placed into this capability-based context and policy-making construct for assessment and resolution as necessary.

> ***For Want of a Nail …***
>
> *While the DIBCS methodology focuses attention on critical industrial base capabilities, we also keep in mind that a system can fail from the lack of a structural or supporting component that does not directly enable the sought after warfighter capability. We must avoid the predicament of the King in the rhyme who loses his Kingdom because his farriers lacked the nails to replace a horseshoe.*
>
> *On the other hand, we cannot afford detailed assessments of every component. Instead we rely on the market but keep an eye out for developing problems. Program Managers can emphasize use of standard components and open system architectures to maximize the number of sources available to their programs through normal market forces. If any issue does arise, the DIBCS framework gives us the ability to link the component through the systems to warfighter capabilities and integrate impacts and remedies into Department decision-making.*

RECOMMENDATION 3

The Department should establish architects for all functional architectures to be accountable for relevant implementation of the new Joint Programming Guidance; to be lead integrators within each functional capability; to coordinate cross-architectural issues; and to coordinate issues across functional capabilities. Establishing responsibility for cross-functional industrial base considerations in this way will improve capability delivered to the warfighter and decision-making in the Department.

> *"It has to be somebody's job to manage the capability or technology area and optimize in the best interest of the capability or area. If management is assumed by a major system program manager, decisions are made to optimize for the major system, not the Department's overall interests."*
>
> *– Red Team Member*

RECOMMENDATION 4

Acquisition strategies should plan for industrial base assessments and the systematic consideration of sources of innovation at major opportunities throughout the life of programs. Additional training on industrial base capabilities and considerations should be included in acquisition professional development. Program managers are the tactical elements influencing the defense industrial base. Making iterative industrial base assessments part of major programs' life cycles will ensure that program managers consider the broader issues and opportunities of the industrial base and reflect them in their programs. The DIBCS framework is a useful tool for program managers to identify the critical industrial base capabilities supporting their program and linking them to the broader warfighting capabilities to which their program contributes.

Additional training will likely be required to encourage program management professionals to function as stewards of capability elements rather than as owners of specific programs.

THE LARGER DIBCS EFFORT

Battlespace Awareness is just the first of the industrial base assessments. Over the course of the next 18 months, four other functional capability areas will be examined. All DIBCS assessments will be informed by Joint Staff and other warfighting concepts that update and further define the warfighting capabilities required.[5]

DIBCS Report	Publication Date
Battlespace Awareness	January 2004
Command & Control	June 2004
Force Application	October 2004
Protection	December 2004
Focused Logistics	May 2005

[5] The latest draft of the Joint Staff's Battlespace Awareness Functional Concept includes two enabling capabilities related to rapidly infusing technology and recruiting, retaining, and training world-class personnel. These capabilities are not specifically treated using the assessment methodology in DIBCS.

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PART I

MEETING THE CHALLENGE

Transforming the Defense Industrial Base: A Roadmap identified the need for a systematic evaluation of the ability of the defense industrial base to develop and provide functional, operational effects-based warfighting capabilities. This is the first of five systematic assessments of the associated critical technology requirements and industrial capabilities to meet that challenge. This body of work is also intended to elevate industrial base concerns across the life cycle of programs.

ROADMAP TO THE FUTURE

> *"[The Department of Defense] shall work collaboratively to develop joint integrated architectures for capability areas as agreed to by the Joint Staff."*
>
> *– DoDI 5000.2*
> *May 12, 2003*

The Department's move towards capabilities-based decision-making will fundamentally change the defense enterprise. How the Department looks at what it has and what it needs will also affect who participates in the defense industrial base—and will likely broaden the base of defense suppliers.

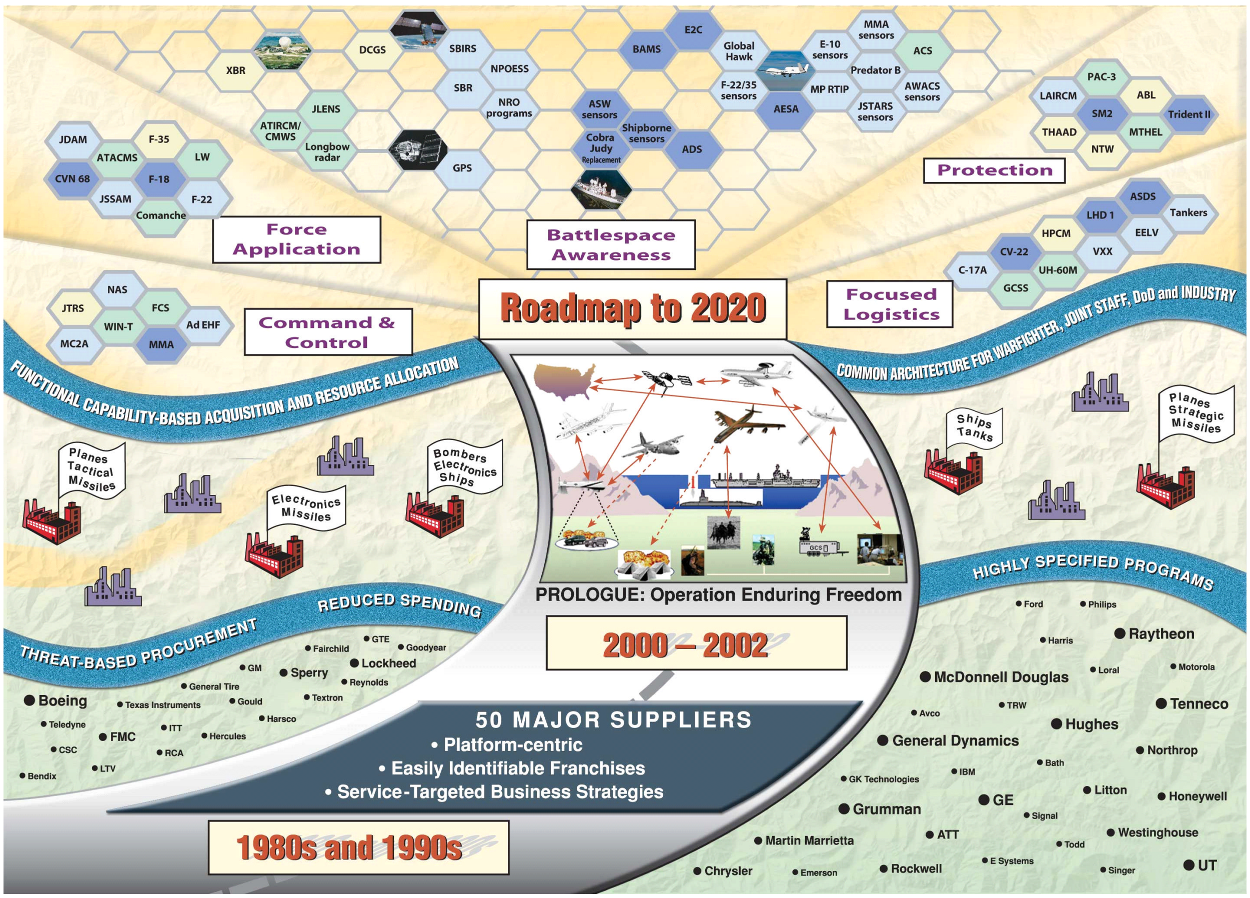
A version of the graphic on the next page was used in *Transforming the Defense Industrial Base: A Roadmap*. As the center sector of the chart shows, the defense industrial base of today is a distillate of its prior form. What were roughly 50 major defense suppliers in the 1980s have become five major, highly consolidated, cross-Service, cross-platform prime contractors. As such, for now, they are uniquely suited to provide system-of-systems approaches to defense requirements.

The middle of the map shows the backdrop against which the current Administration began making budgetary and weapons system acquisition decisions. This environment included three key features: a number of large programs still on the drawing board as long as 20 years after inception; a highly consolidated defense industrial base; and the realities of warfighting in the 21st century as punctuated by Operation Enduring Freedom and Operation Iraqi Freedom.

The earlier study concluded that the Secretary's transformation mandate required a different lens for viewing the defense enterprise: one that was organized around the most essential operational effects that the U.S. war fighter must be able to deliver to be successful. The Joint Staff recently reorganized its requirements process around five similar new functional concepts that are also relevant to the industrial base: Battlespace Awareness, Command and Control, Force Application, Protection, and Focused Logistics. These five concepts shown at the top of the map are becoming the central theme for Department decision-making and are further elaborated in the table on page 9 which defines the scope of the functional concepts and lists representative major programs within each one.

This new capabilities-based decision-making provides a common and comprehensive vernacular to the operators, the acquirers, and industry. This integrated vision should continue to improve the efficiency of resource and operational planning, and associated decision-making and program execution.

ROADMAP TO THE FUTURE



Source: Adapted from *Transforming the Defense Industrial Base: A Roadmap*, ODUSD(IP), February 2003

<u>THE DEFENSE INDUSTRIAL BASE CAPABILITIES STUDY METHODOLOGY</u>

With this new capabilities-based framework for decision-making in the acquisition and requirements process, the challenge for industrial policy is to evaluate the industrial base in this new framework and with the new vernacular. It is the explicit purpose of this series of studies to ensure that the industrial base can produce the systems and weapons required to implement the materiel solutions that enable the functional concepts developed by the Joint Staff.

Beginning with Battlespace Awareness, the DIBCS series will assess the sufficiency of the most critical segments of the industrial base in each functional capability area. The study uses a critical technology and industrial capability assessment methodology derived from the 2002 *Space R&D Industrial Base Study*. The methodology is consistent with the operational ethos embodied in our defense industrial base: that warfighter requirements, and the warfighter as the primary constituent, should determine its composition and products.

JOINT STAFF FUNCTIONAL CONCEPTS	
Battlespace Awareness Global Hawk, MP-RTIP, NAS, Predator UAV (MQ-9), NPOESS, SBIRS-High, Cobra Judy Replacement, E-2 Advanced Hawkeye[6]	Capabilities of commanders and all force elements to understand the environment in which they operate and the adversaries they face. Uses a variety of surveillance capabilities to gather information, a harmonized secure netcentric environment to manage this information, and a collection of capabilities to analyze, understand and predict.[7]
Command and Control GBS, AEHF, FBCB2, JTRS, SMART-T, WIN-T, MCS, NESP	Capabilities that exercise a commander's authority and direction over forces to accomplish a mission. Involves planning, directing, coordinating, and controlling forces and operations. Provides the means for a commander to recognize what is needed and ensure that appropriate actions are taken.
Force Application AMRAAM, DDG 51, GMLRS, JDAM, JSOW, CVN 21, MM III, SSGN	Capabilities to engage adversaries with lethal and non-lethal methods across the entire spectrum of conflict. Includes all battlefield movement and dual-role offensive and defensive combat capabilities in land, sea, air, space, and information domains.
Protection ATIRCM/CMWS, PAC-3, Chem Demil	Capabilities that defend forces and U.S. territory from harm. Includes missile defense and infrastructure protection and other capabilities to thwart force application by an adversary.
Focused Logistics LPD-17, C-130, CH-47, H-1 Upgrades, GCSS, T-AKE, T-45 Training System, C-17, C-5 RERP, FMTV, V-22, MH-60	Capabilities to deploy, redeploy, and sustain forces anywhere in or above the world for sustained, in-theater operations. Includes traditional mobility functions of airlift, sealift, and spacelift as well as short-haul (intra-theater and battlefield) transportation. Also includes logistics C2, training, equipping, feeding, supplying, maintaining and medical capabilities.
Source: Joint Staff Functional Concepts and ODUSD(IP)	

[6] Major programs are aligned with each functional concept to provide concrete illustration of that area's scope. Not all of the warfighter capabilities supplied by a program fall into a single sector, however. This capabilities-based analytic construct is fundamentally different from looking at programs or platforms. Acronyms are spelled out in the acronym list beginning on page 55. (Based on OUSD(AT&L)/ARA Memorandum, *Defense Acquisition Executive Summary (DAES) Review Process Transition: The Next Step*, October 15, 2003.)

[7] Embodied in this thinking is the decomposition of platforms into their enabling capabilities and assessing technologies in the functional capability area where their capabilities are most enabling. So, for instance, major sensor suites associated with tactical aircraft and Navy combatants provide capability for Battlespace Awareness. The associated missiles and fire control assets, however, are allocated to Force Application. This decomposition of platforms into capabilities is at the heart of netcentric warfare and the new functional paradigm.

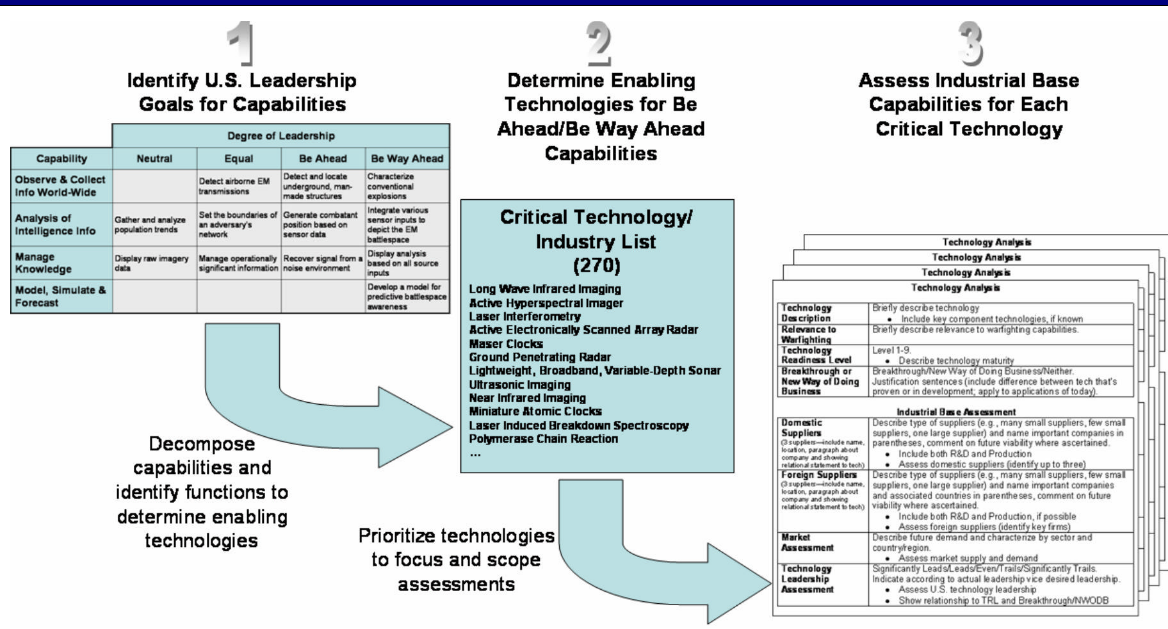
This methodology categorizes warfighter capabilities according to the advantage they give the United States over its adversaries. As described in the table to the right, extra attention is focused on those warfighter capabilities where the United States should lead any potential adversary. Less attention is focused where leadership is not possible or not particularly advantageous. Ideally, the Department would wish to have a significant lead in every warfighter capability. Practically, however, the Department cannot do so and should distinguish those capabilities where leadership gives the warfighter the greatest advantage. The philosophy is to concentrate DoD attention and scarce resources on the areas that make the biggest difference in 21st century joint military operations: those warfighting capabilities for which the Department has *be ahead* and *be way ahead* leadership goals.

Leadership Goals	
Neutral	Position relative to potential adversaries is immaterial.
Equal	Desire capability at least as good as potential adversaries; systems are likely in a common technological generation.
Be Ahead	Desire a significant capability difference over potential adversaries; systems should likely lead by a technology generation or order of magnitude better performance in key attributes.
Be Way Ahead	Desire a very significant capability difference over potential adversaries; systems should likely lead by multiple technology generations or orders of magnitude in performance.

Source: Booz Allen Hamilton and ODUSD(IP)

Therefore, we focus on the warfighter capabilities where we want to achieve and maintain the greatest lead, and then identify the key technologies that enable those capabilities. The studies assess the most critical of those technologies for industrial base sufficiency. When an industrial base deficiency is identified, it is examined in more depth and remedies are recommended using the portals and levers available to the Department to correct an immediate deficiency or to avoid a future one. In the chart below and elaborated on the next page are these steps: identification of capability

Defense Industrial Base Capabilities Study Methodology



Source: Booz Allen Hamilton and ODUSD(IP) leadership goals, determining enabling technologies where leadership is desired; and, industrial base assessment of the critical technologies.[8]

1. Identify U.S. Leadership Goals for Capabilities. Since a detailed understanding of capabilities and associated architectures will continue to evolve within the Department, these industrial base studies use a research and analysis team of subject matter experts to identify detailed warfighter capabilities derived from each of the Joint Staff's functional concepts for our purposes. These experts are guided by a DIBCS Senior Advisory Group (SAG) composed of retired senior military and civilian DoD leaders and selected industry experts. The team, under the direction of the DIBCS SAG, then selects the leadership goal for each identified capability based on the advantage it provides the United States in executing joint operations in the 21st century.[9] The specific capabilities and associated leadership goals will be incrementally refined as details continue to emerge from development of the Joint Staff's functional concepts and the associated integrated architectures.

DIBC SENIOR ADVISORY GROUP
WITH FORMER RELEVANT POSITIONS AND EXPERTISE NOTED*

Gen. (ret) Thomas S. Moorman, Jr. [(a)]
Vice Chief of Staff, USAF
Commander, AF Space Command

VADM (ret) Lyle G. Bien [(b)]
Deputy Commander in Chief, USSPACECOM
Commander, Naval Space Command

Mr. Cosmo DiMaggio III [(c)]
Industry Expert, Technology Research

Mr. Neil T. Gillespie [(a)]
Industry Expert, Navy & Marine Systems

Christopher Ling [(a)]
Industry Expert, C4I Systems

RADM (ret) Robert M. Nutwell [(a)]
Deputy Asst Secretary of Defense for C3I
Deputy Director, Space and Information Warfare, Command and Control, Chief of Naval Operations

Ms. Renata F. Price [(a)]
Science Advisor, Deputy Chief of Staff, Research, Development and Acquisition,, Army Materiel Command

Dr. Edward L. (Ted) Warner [(a)]
Asst Secretary of Defense for Strategy and Requirements
Asst Secretary of Defense for Strategy and Threat Reduction

* All Department and Military affiliations are former positions; SAG composition varies by functional area.
(a) Currently with Booz Allen Hamilton
(b) Independent Consultant
(c) Currently with the Tauri Group

2. Determine Enabling Technologies for *Be Ahead/Be Way Ahead* Capabilities. The next step in the study is identification of the key enabling technologies for those capabilities with leadership goals rated *be ahead* or *be way ahead*. The DIBCS SAG oversees a team of military technology experts to identify and prioritize these technologies, using a variety of sources such as the *Joint Warfighting Science and Technology Plan*. The priority of a technology is determined by the number of different critical warfighting capabilities where it applies and the degree to which it enables individual capabilities.

3. Assess Industrial Base Capabilities for Each Critical Technology. Finally, the study examines the industrial capabilities necessary to supply these critical technologies in priority order. This generally involves identifying the major domestic and foreign suppliers and examining them for sufficiency and suitability.

When applying this methodology to Battlespace Awareness, time and resources have been focused on a limited number of priority technologies examined in detail. The remaining technologies are documented and can be addressed to the same level of

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8 The policy construct of portals and levers is developed in this study beginning on page 21.
9 See Appendix A for DIBCS Battlespace Awareness capability framework.

detail as resources permit. The purpose of the initial assessment is to form a broad understanding of sufficiency and risk in the most critical elements of each functional capability area's industrial base. If this assessment identifies a concern, the study notes the deficiency and potential remedies for further investigation.

Part of this assessment is how domestic industrial capabilities compare with foreign capabilities. To provide the best capability possible to the warfighter, the United States will look for best value throughout the global industrial base. If the Department uses the foreign industrial base, however, it must manage certain risks that this could entail. Three risks are: security of supply, technology security, and congruency of strategic interests. Security of supply relates to having access to defense products from the industrial base when the Department needs them. Technology security relates to controlling access to industrial base capabilities by potential adversaries. Congruency of strategic interest describes the alignment of corporate interests and strategic planning with national interests and objectives. In assessing whether particular foreign sources represent acceptable risk, the Department must look at numerous factors including the criticality of the technology involved, the status of foreign relations with the other countries involved, and the availability of the technology on the open market**.**

JUST THE BEGINNING

We believe that this capabilities-based framework will help decision-makers understand and address any industrial base deficiencies. The first round of studies should be completed in 2005. Completing the initial look at each functional area, however, is just the beginning. The baseline will continue to evolve as the Joint Staff implements its functional concepts and as the Department simultaneously continues to assess the industrial base supplying those corresponding capabilities.

It also is in the Department's interest to encourage the alignment of industrial strategic direction with the Department's strategic direction. The studies should help companies large and small—and indeed the whole of our defense industrial enterprise—have more direct insight into the critical industrial base capabilities required by the 21st century warfighter. This insight should better inform investment decisions and strategic planning as well.

The DIBCS series develops a logical, capabilities-based approach to identifying and understanding industrial base sufficiency. It fits naturally into the evolving acquisition and requirements processes while providing a firm basis for identifying industrial base deficiencies and proposing remedies for implementation.

PART II

CRITICAL INDUSTRIAL BASE CAPABILITIES IN BATTLESPACE AWARENESS

Establishing leadership goals for U.S. warfighting capabilities, and understanding the defense programs that will deploy them, are crucial to defining technology and industrial capabilities requirements. This study applies the DIBCS methodology to the Battlespace Awareness functional capability area, establishing leadership goals for Battlespace Awareness capabilities. Using this warfighter capabilities-based analysis, the study identifies critical technologies and assesses the priority subset of associated industrial base capabilities.

REFINING THE BATTLESPACE AWARENESS FUNCTIONAL CAPABILITY AREA

This study begins with understanding the Battlespace Awareness functional capability area. Battlespace Awareness capabilities provide commanders and forces the ability to understand the environment in which they operate and the adversaries they face. The major Battlespace Awareness activities, as described in the Executive Summary, are observation and collection; orientation and assessment; knowledge management; modeling, simulation and forecasting; command and control of Battlespace Awareness assets; and interface with decision makers—all interconnected through a ubiquitous information network. Battlespace Awareness supplies the critical knowledge necessary to precisely apply force, to thwart or circumvent enemy efforts, and to bring the right support to the right place at the right time.[10]

BATTLESPACE AWARENESS FUNCTIONAL CONCEPT CAPABILITIES	
Operational	• Observe and Collect Information World-Wide • Analysis of Intelligence Information • Model, Simulate & Forecast • Manage Knowledge • Command and Control of Battlespace Awareness Assets
Enabling	• Integrate Battlespace Awareness Network • Rapidly Infuse Technology • Recruit, Retain, & Train World-Class Battlespace Awareness Personnel

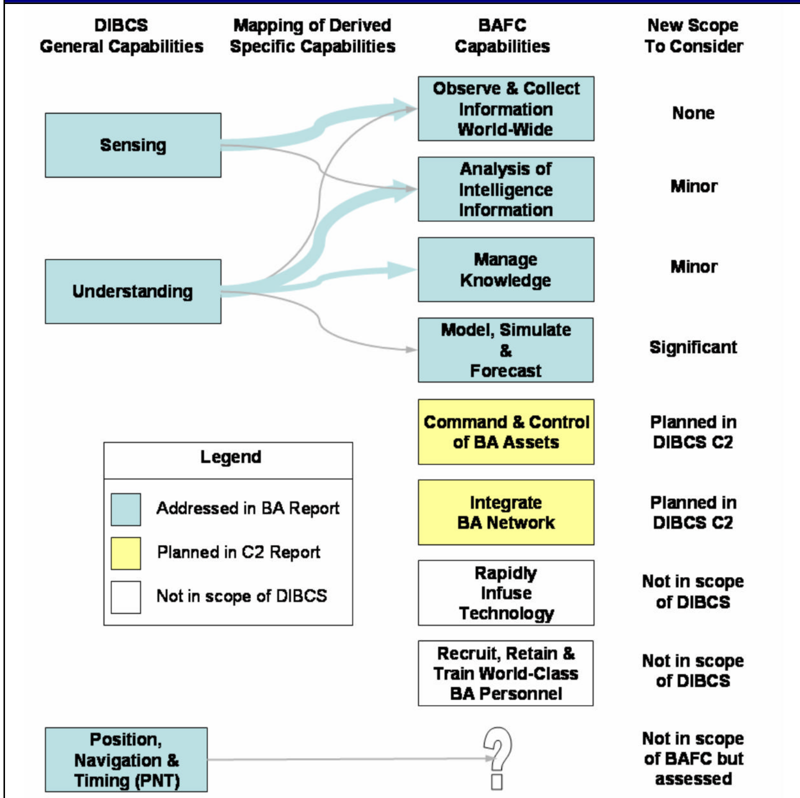
The process of identifying specific key warfighter capabilities and establishing leadership goals will continue to evolve. The Joint Staff, representing the warfighter, has the lead for defining these capabilities. The scope of this study derives from the Joint Staff's Battlespace Awareness Functional Concept (BAFC) which is still in development. The BAFC is currently focused on a portfolio of eight broad capabilities: five operational capabilities and three enabling capabilities, as listed to the right.

The DIBCS methodology decomposes broad operational capabilities into a collection of more specific capabilities and establishes a first set of leadership goals. When this study began, however, the draft BAFC was unavailable. Therefore, the subject matter experts developed an interim set of generic capability

[10] Joint Staff, *Battlespace Awareness Functional Concept*, draft, October 31, 2003.

areas to analyze and decompose: *Sensing; Understanding;* and, *Position, Navigation, and Timing (PNT)*.[11] These generic capability areas aligned well with early versions of the draft BAFC. As this report was being finalized, however, the draft BAFC evolved substantially and advanced the scope of Battlespace Awareness beyond the initial analysis. While we correctly anticipated the majority of the Battlespace Awareness scope, some of this additional scope will be addressed in the DIBCS Command and Control report and some will be addressed in the continued evolution of the DIBCS baseline for Battlespace Awareness. The graphic to the right shows how the first set of DIBCS capability areas mapped to the latest draft BAFC capabilities and allocates them to the scope of the DIBCS series. While the *Sensing* and *Understanding* capabilities easily fit the BAFC framework, the *PNT* capabilities did not clearly fit into any of the Battlespace Awareness functional capability areas as defined by the Joint Staff.[12] However, given our view of the importance of *PNT* to locating and identifying the elements of the battlespace, we completed our assessment of these capabilities—knowing they may be added to this functional capability area later, or to another area as the Joint Staff evolves its concepts.

EVOLUTION OF BATTLESPACE AWARENESS CAPABILITY AREAS



Source: ODUSD(IP)

Besides adding scope to the five BAFC operational capabilities, the Joint Staff also added three enabling capabilities to the functional concept. The first of these, "Integrate Battlespace Awareness Network," will be examined in the DIBCS Command and Control effort as part of the larger issue of networks. The other two enabling capabilities, "Rapidly Infuse Technology" and "Recruit, Retain, and Train World-Class Battlespace Awareness Personnel," are general capabilities relevant to the Battlespace Awareness industrial base—and indeed, to the industrial base supporting the other four functional concepts as well. As these enabling capabilities are not directly product-related, DIBCS is not treating them in the detail applied to the other capabilities.

[11] For clarity, functional capabilities, leadership goals, and policy tools developed in this study are italicized; Joint Staff operational capabilities are in quotes.

[12] Another explanation is that the *PNT* capabilities support all of the other functional concepts but have not qualified as a major capability area in any specific one.

After planning the original scope of the Battlespace Awareness capabilities assessment, the subject matter experts, under the guidance of the DIBCS Senior Advisory Group, then identified 436 specific warfighting capabilities within the five general capabilities as shown in the table below. The next step was to establish the leadership goal that the United States should strive to maintain for each capability. As the BAFC began to take shape, these specific capabilities were adapted to the new framework as described earlier.

BATTLESPACE AWARENESS OPERATIONAL CAPABILITIES SUMMARY CHART

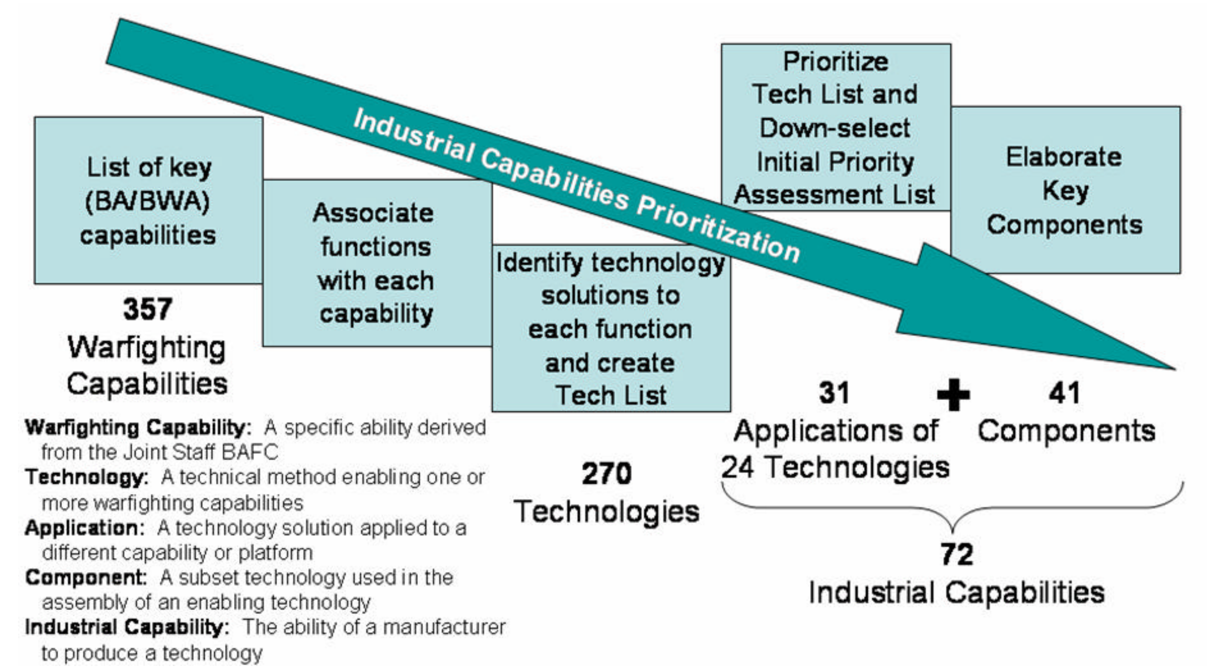
Capability Area	Specific Capabilities by Leadership Goal			
	Neutral	Equal	Be Ahead	Be Way Ahead
Observe and Collect Information World-Wide	1	50	100	98
Analysis of Intelligence Information	1	16	48	51
Manage Knowledge	1	8	14	25
Model, Simulate, & Forecast	0	0	0	9
Command & Control of Battlespace Awareness Assets	*Included in DIBCS: Command & Control*			
Integrate Battlespace Awareness Network				
PNT	*0*	*2*	*7*	*5*
436 TOTAL	**3**	**76**	**169**	**188**

Source: Booz Allen Hamilton and ODUSD(IP)

Since Battlespace Awareness has underpinned 20th and 21st century U.S. warfighting doctrine, the Battlespace Awareness capabilities are tilted toward the *be ahead* and *be way ahead* leadership goals. Of these 436 specific capabilities, 357 were assessed as *be ahead* or *be way ahead* warfighting capabilities. For example, in "Observe and Collect Information Worldwide," we determined that it was adequate to have *equal* capability relative to commercial resolutions for imaging surface ships and surfaced submarines, but determined that we needed to *be ahead* in locating and characterizing electro-magnetic transmissions and *be way ahead* in simultaneously detecting, locating, tracking, and identifying moving objects throughout a theater-wide area. Similarly, we believe a *neutral* posture is acceptable for certain "Manage Knowledge" capabilities such as displaying raw imagery data, but felt we must *be way ahead* in quantifying and disseminating change detection information, providing near real-time imagery information of the battlefield, and twenty-three other specific capabilities. The table above summarizes the number of specific capabilities attributed to each of the four DIBCS leadership goals.

Next, the study identified and assessed the industrial sufficiency for critical technologies enabling the *be ahead* and *be way ahead* warfighter capabilities. The large number of *be ahead* and *be way ahead* capabilities, however, outstripped the resources available for immediate research. Under the guidance of the DIBCS SAG, the process illustrated on the next page was used for the initial prioritization of critical technologies for detailed industrial base analysis.

BATTLESPACE AWARENESS TECHNOLOGY PRIORITIZATION PROCESS



Source: Booz Allen Hamilton and ODUSD(IP)

This study identified a total of 270 technologies enabling the 357 *be ahead* and *be way ahead* warfighter capabilities.[13] The enabling technologies and warfighting capabilities are elaborated in Appendices A and B, respectively. These technologies can be categorized into 17 broad industrial areas as shown to the right. Within these broad industrial areas, our assessment identified a total of 260 companies involved in the 72 industrial capabilities investigated. This list is summarized in Appendix C. It does not list every company in these industries, but illustrates the overall strength of the domestic industrial base. It also indicates how valuable the foreign component is to the defense industrial base.

BROAD INDUSTRIAL AREAS FOR BATTLESPACE AWARENESS
Acoustic Sensing
Chemical, Biological, Radiological and Nuclear Event Sensing
Combination Sensing
Environmental Sensing
Electro-Optical Sensing
Hyperspectral Sensing
Information Technology
Infrared Sensing
Laser Sensors
Magnetic Sensing
Microwave Sensing
Other Imaging
Radar
Radio Frequency Sensing
Sonar
Tagging
Timing and Geopositioning Devices
Source: Booz Allen Hamilton

The Department is committed to supply the best technology possible to the warfighter, whether foreign or domestic—and hundreds of companies from around the world provide critical Battlespace Awareness capabilities to the U.S. warfighter.

[13] As earlier indicated, information technology is an important industrial area for both Battlespace Awareness and Command and Control. Identification of critical technologies in this area was deferred to the next DIBCS report on Command and Control for a more complete assessment.

CRITICAL INDUSTRIAL AND TECHNOLOGY DEFICIENCIES AND ISSUES

A systematic assessment of the Battlespace Awareness capability area identified the critical technologies and industrial capabilities that make militarily-superior warfighting possible in this functional capability area. Of the 270 critical technologies identified, initial assessments covered 31 applications of 24 priority technologies. Twenty-one assessed technologies and their applications and components were assessed to be sufficient as shown on the next page. Issues were identified in the remaining three technologies: one, a deficiency, and two areas of concern summarized in the chart below.

BATTLESPACE AWARENESS INDUSTRIAL BASE ISSUES

Technology	Industrial Base Sufficiency Analysis			Rationale (for associated remedies, see page 44)
	Domestic Sources	Foreign Sources		
Active Hyperspectral Imager	4	3		U.S. capability trails potential adversaries' capabilities due to foreign technology advancements in civil applications.
Active Electronically Scanned Array (AESA) Radar	2 major	5		Number of major domestic suppliers of AESA radars is probably still sufficient. However, degree of U.S. leadership is threatened by significant overseas competition.
Maser Clocks	2	3		Maser clocks provide better precision and reliability than cesium atomic clocks and are standard in foreign GPS-like systems. U.S. capability is at best equal, and small market demand limits supplier base.

With the exception of the deficiencies and concerns identified, the initial assessment of the 72 industrial capabilities (31 applications and 41 components) shows that the industrial base supporting these Battlespace Awareness technologies is fairly robust as measured in the number and strength of competitors supplying the capability in question. Hence, the United States satisfies its leadership goals in most of the critical technologies initially assessed and has the industrial capabilities needed for critical components.[14] A discussion of the three issues identified for remedies follow.

Active Hyperspectral Imager. Hyperspectral imagery uses a sensor to make measurements in different bands of the electromagnetic spectrum across the sensor's field of view. Like the human eye's use of color to distinguish objects, the relative differences in the energy contained in each band characterize the materials or substances that are reflecting the energy. In active imaging, a controlled energy source

[14] The primary objective of this study is the identification of the array of capabilities and technologies in Battlespace Awareness and a process for assessing them and addressing deficiencies. Resources limited the number of critical technologies assessed to 24 of the most pressing, but issues in the remaining technologies will be assessed. The ODUSD(IP) staff will continue to evolve the baseline established in this study, updating the capability framework and critical technology lists, performing additional assessments of critical technologies, and identifying any additional industrial base issues for consideration by Department decision-makers.

is used to illuminate the scene, making the measurements even more precise. This is an emerging technology enabling the specific capability to detect, locate, and track chemical, biological, radiological, and nuclear events. This specific capability is key to the BAFC "Observe and Collect Information World-Wide" capability. A sensor implementing this technology would be able to look into the battlespace and enable the warfighter to see exactly where specific chemical substances are in the air or on the surface. Warfighters could use this information to protect themselves or to instruct other forces to avoid contaminated areas. There are several small companies engaged in competing implementations of this technology: differential absorption light detection and ranging (LIDAR) (DIAL) and laser induced fluorescence (LIF) development.

21 BATTLESPACE AWARENESS TECHNOLOGIES WITH SUFFICIENT INDUSTRIAL BASE CAPABILITIES
Passive Acoustic, Seismic, and Electromagnetic (PASEM) and Effluent Sensing Techniques
Laser Induced Breakdown Spectroscopy
Polymerase Chain Reaction
Hyperspectral Imager
Long Wave Infrared Imaging
Near Infrared Imaging
Staring Dual Band Infrared Arrays
Laser Interferometry
LIDAR seekers with Autonomous Target Acquisition
RF Emitter-related Sensors
Inertial Navigation System with Micro Electromechanical Systems (MEMS)
Interferometric Fiber Optic Gyroscope
Foliage Penetrating Synthetic Aperture Radar
Ground Penetrating Radar
Lightweight, Broadband, Variable-Depth Sonar
Synthetic Aperture Sonar
Atomic Clocks
Laser Cooled Atomic Clocks
Miniature Atomic Clocks
Ultrasonic Imaging
Ultraviolet Imaging

However, according to open sources, these technologies are advancing and proliferating more rapidly overseas for civil environmental monitoring applications than they are advancing in the U.S. defense industrial base. This failure to *be way ahead* cedes an advantage to potential adversaries in understanding the battlespace situation regarding the ever more threatening area of chemical weapons use.

Active Electronically Scanned Array (AESA) Radar. AESA radars use an array of transmitters and receivers to aim the radar's beam by controlling timing differences among each element of the array. This removes the need for mechanical components and allows the radar to be aimed at nearly the speed of light. Furthermore, AESA radars are more flexible since the array can be easily configured electronically among multiple modes of operation from one moment to the next, and may even operate in multiple configurations simultaneously.

Airborne AESA radar may be used to target and track an enemy aircraft and it may also be used to create synthetic aperture radar images of ground targets for delivering precision-guided munitions. Ground and sea-based AESA radars may be used to track aircraft for air traffic control or anti-aircraft missions, and may detect and track missiles for targeting missile-defense systems. Space-based and air-based AESA radars may be used for detecting and tracking moving objects in the air and on the ground. These specific capabilities are all part of the JCS "Observe and Collect Information World-Wide" capability.

The two major domestic suppliers of AESA radars, Northrop-Grumman and Raytheon, have met the Department's needs and should continue to do so in the future. Lockheed-Martin is a significant supplier but limited to ship-based AESA radars. Other suppliers in the industrial base satisfy niche requirements. Given the market size for advanced AESA radars, the industrial base is sufficient. With the small number of suppliers, however, it is very important to pay extra attention to efforts that encourage innovation. Continued innovation is vital to keep the U.S. warfighter *way ahead* of potential adversaries and to avoid complacency.

<u>Maser Clocks</u>. Global Positioning System (GPS) position, navigation, and timing capabilities have revolutionized many warfighter capabilities. GPS technology ultimately is based on having closely synchronized, precise clocks on multiple satellites so that a receiver can carefully measure the difference in time it takes signals from different satellites to reach it. This allows the receiver to calculate its position and the current time. Since its inception, GPS has used atomic clocks that generate a precise, stable timing signal based on the regular oscillations of cesium or rubidium atoms within a carefully controlled environment. A maser clock provides a stable, precise time measurement using the oscillations of coherent microwaves, similar to the way that an atomic clock uses atomic oscillations. In the laboratory, however, a maser clock can generate better signals than atomic clocks by orders of magnitude and can be manufactured without mechanical parts, increasing reliability.

Capabilities to precisely measure or continuously monitor the location of forces and objects around the world have revolutionized modern warfare for the United States and its allies. These capabilities provide a single consistent framework for locating our own forces (blue force tracking), designating targets, and guiding forces and weapons to targets or other objectives. This common framework for position, navigation, and timing enables all other capabilities in battlespace awareness by defining the battlespace and the relationships of everything in it.

The revolution in U.S. warfighting enabled by GPS has not gone unnoticed by the rest of the world. While the early Russian Global Orbiting Navigation Satellite System had significantly less capability than GPS, there are new systems under development around the world that may challenge U.S. leadership in position, navigation and timing capabilities. Given the small defense market for atomic and maser clocks and the lack of significant commercial applications, these industrial capabilities require special attention. Foreign GPS-like systems are adopting the emerging hydrogen maser technology with its better precision and reliability over the cesium and rubidium atomic clocks in current GPS systems.

Maser clocks are not the only technology that can satisfy the warfighter's need for position, navigation, and timing capabilities; as such, competing technologies to help drive innovation should also be considered. For example, research is also underway on laser cooling for conventional atomic clocks or an entirely different approach to timing using miniature atomic clocks. As they mature, one of these technologies may or may not enable a better overall set of capabilities than maser clocks. Regardless, one of these competing technologies is likely to be the one enabling the future leading capabilities for precise position, navigation, and timing. These alternatives should be nurtured and migration plans should be developed to innovate existing and future systems.

By closely monitoring Battlespace Awareness *be ahead* and *be way ahead* warfighting capabilities, and associated critical technologies and industrial capabilities, the Department is positioned to take action to ensure that technologies and industrial capabilities will be sufficient to meet current and future defense requirements. While relying primarily on market forces, the Department has several tools available to help shape and guide innovation in the defense industrial base. These are further discussed in the next section of this report.

PART III

MAJOR INNOVATION PORTALS AND POLICY LEVERS IN THE INDUSTRIAL PROCESS

Once an assessment of industrial base sufficiency is completed, the Department must work with its program managers and industry to resolve any deficiencies. Furthermore, the Department must encourage the development of innovative industrial capabilities to prevent deficiencies in the first place. ODUSD(IP) has developed a policy construct to incentivize innovation in industrial base capabilities and to remedy deficiencies. This policy construct promotes a systematic approach to address industrial base development and avoid deficiencies.

Maintaining the U.S. warfighting advantage requires continuous innovation of critical warfighting capabilities. Key among many factors driving innovation is competition among ideas and the application of those ideas. Ideally, the Department would like more competition for the most critical warfighting capabilities, those facilitating asymmetric advantages. Ideally, as well, the Department would seek to lower risks by choosing and developing domestic suppliers to provide those technologies where the United States wants to have warfighting capabilities superior to those of potential adversaries. Clearly, however, we would not deprive the warfighter when a foreign source has the best solution. By the same token, the Department also seeks to ensure that key technology is protected through export controls and other interagency measures. However, as the criticality of the warfighting capability lessens, the need for competitive U.S. sources to drive innovation of that capability also lessens.

PORTALS AND LEVERS FOR POLICY IMPLEMENTATION

Management of critical industrial capabilities requires policy implementations. There are three major policy levers that can be used to remedy instances in which required industrial capabilities are insufficient: (1) fund innovation; (2) optimize program management structures and acquisition strategies; and (3) apply external corrective measures where warranted.

These levers are best employed through the five openings or portals into the acquisition process where we believe the most effective influence on the industrial base can be achieved. These key opportunities to innovate the industrial base are: (1) science and technology (S&T); (2) the transition from laboratory to manufacturing; (3) weapon system design; (4) make/buy decisions; and (5) life cycle innovation.

The Department's challenge is to identify, monitor, and act to ensure that the critical technologies and industrial capabilities required to develop and field warfighting capabilities are sufficient in number and have the level of innovation necessary to meet projected DoD requirements. In addition, our assessment that technologies were critical enough to assess on a priority basis was based on the multiple application of these technologies. As a consequence, these recommended actions might also foster applying critical technologies across multi-service joint applications. By highlighting industrial base deficiencies for critical technologies and implementing appropriate policy initiatives and remedies, the Department will continue to foster the innovative industrial base that is the basis of our warfighting advantage.

HOW PORTALS AND LEVERS WORK

Our analysis has led us to focus on the five primary portals through which the Department can assure sufficiency of sources and innovation—and potentially also tap into particularly innovative technology to pollinate it among other applications. Acquisition policy guidance encourages Department acquisition professionals to appropriately deploy policy levers through these portals as a normal practice throughout the industrial processes that define a program. However, such guidance sometimes is overcome by other programmatic priorities. Particularly in cases where required industrial capabilities are insufficient or have cross-platform utiltiy, remedial action may help optimize outcomes.

Early in responding to an emerging warfighting requirement, critical industrial capabilities may be resident in too few potential suppliers to generate confidence in timely success. For example, when developing or applying a new technology or developing a missing key system or systems enabler, sources may be limited to the incumbent suppliers of the previous generation of that technology, such as in the development of Global Hawk, which is discussed later in this section. The available sources may also not be able to address multiple applications of a given technology. The Department should be prepared to act in such situations.

Later, in concept development or weapon system development and design, the number of potential suppliers may be insufficient to generate innovation or price competition due to industry consolidation, teaming arrangements, waning interest, or other factors. The Navy's Future Destroyer (DDX) program is a good example of an instance in which the Department acted in such a situation to ensure the availability of an innovative, competitive industrial base.[15]

For mature systems or in mature industries, contractors may choose to source commonly available components from the global industrial base for reasons of best performance and cost. Additionally, older systems may be so far removed from the state-of-the-art that domestic suppliers deliberately discontinue producing necessary subsystems and components. While the Department is less concerned as a whole about such situations, it will act to ensure that it continues to have reliable sources for the materiel it needs to meet its national security responsibilities.

In our construct, management decisions and options can be examined systematically using the array of portals and levers, as discussed in this section. Portals generally

[15] The DDX program is discussed in detail on p. 37.

correspond to program phases. In the case of applying remedies, the phase of the program determines which portals apply. The *science and technology* portal should be open nearly continuously for the more critical technologies since we should evolve these technologies until they reach their scientific limitations. Optimally, the *make/buy decisions* and the *life cycle innovation* portals are also open nearly continuously once a system is fielded so that technology refresh can be accomplished as necessary. The *transition from lab to manufacturing* and the *weapon systems design* portals represent more limited windows of opportunity. In this construct as illustrated below, once the portal(s) have been determined, the three levers (*fund innovation*, *optimize program management/acquisition strategy*, and *employ external measures*) are systematically considered for how to best influence the desired outcome. The remedy or remedies can then be mapped on the board. This is the construct we will discuss further in the pages that follow: first portals and then levers.

MAJOR INNOVATION PORTALS AND POLICY LEVERS IN THE INDUSTRIAL PROCESS

Levers \ Portals	Science & Technology	Lab to Manufacturing	Weapon System Design	Make/Buy Decisions	Life Cycle Innovation
Fund Innovation					
Optimize Program Management/ Acquisition Strategy					
Employ External Measures					

Source: ODUSD (IP)

To illustrate the portals and levers, this report uses a number of examples. These examples include opportunities taken to use a lever effectively and opportunities lost. While the examples come from a variety of programs, the discussion here is focused on industrial base impacts of the action taken or not taken and are not intended to reflect on the overall status or outcome of the program.

Innovation Portals

This study's focus on innovation is driven by the need to *be ahead* or *be way ahead* in critical technologies. As depicted in the graphic above, there are five major portals of opportunity where managerial decisions determine the likelihood that critical technologies and associated industrial capabilities are developed and sustained expeditiously and cost-effectively:

- *Science & Technology*. Programmatic and funding decisions by both the government and industry involving technology development significantly impact the likelihood that there will be sufficient industrial capabilities to incorporate critical technologies in defense systems. A capabilities-based approach like the DIBCS methodology can serve as a guide for shaping these decisions by stimulating investment in critical industrial base capabilities.

- *Laboratory to Manufacturing Transition*. Manufacturing approaches that optimize either for manufacture by the developer or for only one warfighting application often transition new technologies from the laboratory to production with unintended limitations. For critical enabling technologies like those identified earlier, the Department should encourage manufacturing processes that encourage competitive solutions and enable their transition to other applications. Industrial base concerns must, of course, be balanced against delays that preclude the timely delivery of new operational capabilities to the warfighter.

- *Weapon System Design*. Design practices (for example, the effective use of standard software and hardware interfaces) can encourage innovation. On the other hand, government or prime contractor specifications that are too prescriptive can undermine innovation. This often is the case in subsystems or components that optimize designs around single-supplier products, applications, or technologies. This kind of behavior leads to sub-optimized designs and sole sources. The Department's policy on the use of an open systems approach promotes the use of products from multiple suppliers and allows next generation modules to be inserted to upgrade capabilities throughout the life cycle of the weapon system. A key attribute of evolutionary acquisition and spiral development is planning and managing technology insertion to foster opportunities for new warfighting applications from original—and new—manufacturing sources.

- *Make/Buy Decisions*. Contractor make or buy decisions are the front lines of competition and innovation. For critical technologies, the policy levers should be used within this portal to encourage contractors not to favor in-house capabilities or long-term teammate products over more innovative solutions available elsewhere. When warranted, the Department will engage actively to shape make/buy decisions. This is not a new policy but requires advanced planning in the acquisition strategy.[16] Unwarranted favoritism, especially if systemic, discourages innovative suppliers. Warfighters lose when contractors try to

[16] Government involvement in make/buy decisions is illustrated in explicit subsystem acquisition strategies like the E-10A (see p. 33), Space Based Radar, as well as the consent decrees associated with the Northrop-Grumman/TRW case (see p. 38). Less extreme measures such as make/buy plans and award fee criteria can be applied routinely.

satisfy critical capability requirements without choosing the most innovative, best-value suppliers.

- *Life Cycle Innovation*. Under evolutionary acquisition strategies, even more so than in the past, fielded defense systems will continue to undergo further development to improve warfighting capabilities. These innovative improvements offer new opportunities to import emerging technological and industrial capabilities that maintain or expand warfighting superiority. Thus, they should draw from the broadest possible spectrum of the overall industrial base. As a consequence, cost-effective commercial practices and standards and open architectures become particularly important.

Traditionally, these portals have been the provinces of a discrete set of industrial base participants aligned to specific phases within the industrial process as shown below.

TRADITIONAL INNOVATION PORTALS AND INDUSTRIAL PROCESS PARTICIPANTS

Program Phases	Science & Technology	Lab to Manufacturing	Weapon System Design	Make/Buy Decisions	Life Cycle Innovation
Participants	Inventors, Academia, Government Labs and R&D Centers, Domestic And Foreign Industry	Service Labs, Program Offices, Industry, Commercial and Government Centers of Excellence (e.g., NCMS, Fraunhofer Institute)	Industry/ Government Program Office	Industry	Industry/ Government Program Office

Source: ODUSD (IP)

For example, inventors, academia, laboratories, government and industry research and development centers, and industry generally all act in the *science and technology* portal. However, as programs proceed through *weapon system design*, *make/buy decisions*, and *life cycle innovation* portals, the breadth of participants generally narrows to include only industry and government program personnel. This practice is akin to premature down-selection, foreclosing access to the broader defense industrial base and reducing innovation potential. Our first example of the *life cycle innovation* portal (and *acquisition strategy* lever) also is an example of broad industrial base participation to solve a critical need.

ARCI EXAMPLE

- Rapid insertion of technology to enhance system performance, including commercial technology
- Use of maximum breadth of industrial base provides for frequent competitions
- Annual portal for technology refresh and innovation prevents Navy from being captive to a single contractor

The Navy applied the *acquisition strategy* lever to induce innovation and competition in submarines as part of *life cycle innovation* in response to advances in world submarine acoustic technology in the mid-1990s. In 1996, the Navy adopted a revolutionary plan to maintain superiority by applying state-of-the-art signal processing in state-of-the-practice COTS hardware and software. The Acoustic Rapid Commercial off-the-shelf (COTS) Insertion (ARCI) program restored the Navy's submarine acoustic superiority and provided an innovative approach to continued improvement.

In ARCI, the Navy uses standard hardware and software interfaces, and a capabilities-based (versus requirements-based) model to integrate skills from the Navy, academia, and small and large businesses. It developed a rigorous process which rapidly inserts advanced capability into the fleet on a regular basis. By partitioning the sonar system into processing strings, the Navy was able to leverage the strengths of the developers and enable a sequential and incremental capability insertion plan. ARCI prime contractor Lockheed Martin provides system integration and system management. Digital Systems Resources, now part of General Dynamics, developed the towed array. The Applied Research Laboratory at the University of Texas developed the high frequency active array; and John Hopkins University's Applied Physics Laboratory served as the advanced technology test program lead. Members of the advanced development community (Navy laboratories, academia, and industry) continue to provide the new ideas, algorithms, and implementations.

The use of standard hardware and software interfaces is fundamental to ARCI's ability to continue innovation throughout the system life cycle. Selecting standard interfaces commonly used throughout industry removes a significant barrier to supplier participation. Nearly any information technology supplier is familiar with internet protocols as well as common hardware architectures, operating systems, and application program interfaces. It is the adaptation of commonly used standards like these to defense requirements that enables participation by the broadest base of suppliers, including emerging defense suppliers. Standard hardware and software interfaces enable a maximum level of innovation for development and continued improvement of critical warfighter capabilities.

While the ARCI example focuses on the *life cycle innovation* portal, we believe that continuous use of these portals provide the best opportunities to influence the current and future sufficiency of the industrial base. Effective collaboration among all industrial base participants through all program phases makes it possible to access and deploy the best available knowledge and ingenuity. It also makes more certain the Department's ability to identify and employ the appropriate policy levers discussed below to induce and sustain innovation across the breadth of the defense enterprise.

Policy Levers

Three major policy levers offer tools with which the Department can develop, sustain, or expand innovation, drawing on the entirety of the industrial base, no matter the phase of the program. Ideally, DoD managers and contractors deploy these levers routinely through the appropriate portals discussed above to develop robust technological solutions to defense problems, insert those technologies, sustain critical industrial capabilities, and leverage those which may have applications elsewhere in the defense enterprise. For those cases where the Department determines that critical technological and industrial capabilities are deficient, it should carefully define the concern and use the appropriate lever to remedy the deficiency. For example, in the ARCI example just cited, the *life cycle innovation* portal was used with the *fund innovation* and *optimize acquisition strategy* levers, as shown in the graphic to the right.

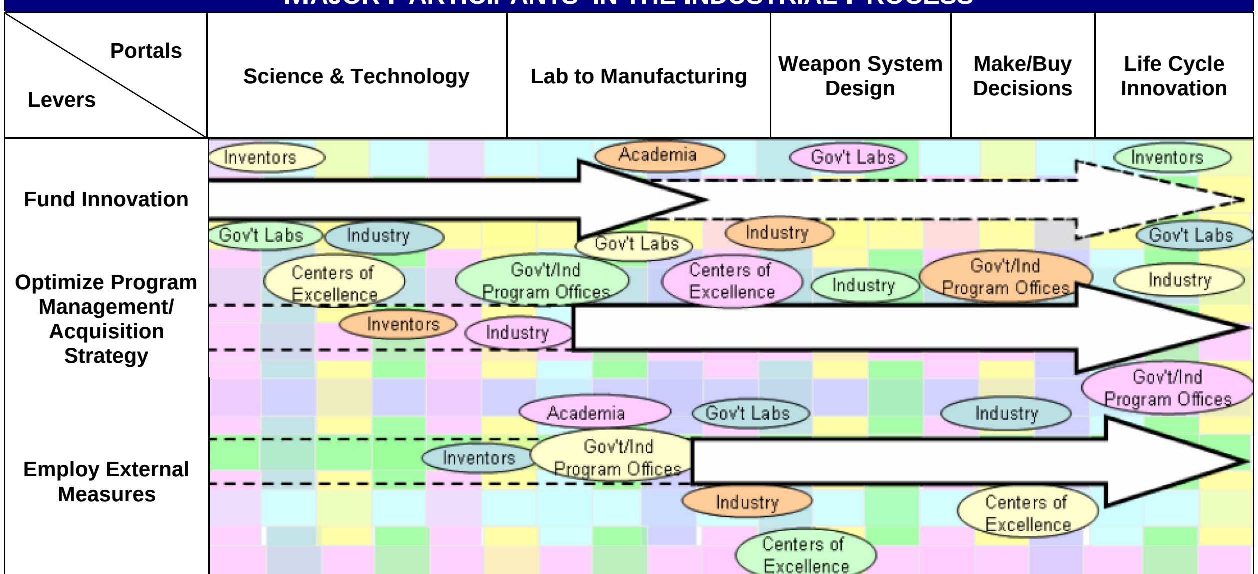
PORTALS AND LEVERS APPLIED TO THE ARCI EXAMPLE

Levers \ Portals	Science & Technology	Lab to Manufacturing	Weapon System Design	Make/Buy Decisions	Life Cycle Innovation
Fund Innovation					
Optimize Program Management/ Acquisition Strategy					
Employ External Measures					

Source: ODUSD (IP)

The three levers we will now discuss are (1) *funding innovation*, (2) *optimizing program management and acquisition strategy*, and (3) *employing external measures* as necessary. Ideally, acquisition managers make use of all participants—laboratories, academia, industry, etc.—through all phases of a program's life cycle to nurture innovation in multiple sources for the purpose of acquiring leading-edge technologies at an affordable price, as shown in the graphic below. A discussion of each of the levers and associated examples follows in the next section.

MAJOR PARTICIPANTS IN THE INDUSTRIAL PROCESS



Source: ODUSD (IP)

Fund Innovation

Direct funding of innovation by the government in its science and technology (S&T) accounts and by industry in independent research and development (IRAD) accounts is paramount. During government and industry laboratory development—and the transition from the laboratory to manufacturing and later—funding alternative technologies, as well as multiple

> *"Creating market conditions attractive to business will bring you all the capacity and innovation you can use."*
> *– Red Team Member*

applications and suppliers, broadens the industrial base. It also improves what is available to the warfighter, often at less cost.[17] Inadequate funding for innovation can have severe consequences—hence the significance of the Department's efforts to boost science and technology funding as a critical first step to develop multiple innovative sources and technology applications.

> *"Competitive early development is expensive and thus avoided, but sole source efforts often cost twice original estimate anyway. We lose technologically, and don't gain programmatically."*
> *– Red Team Member*

The role of contracting officers, program managers, and other acquisition professionals in translating the intent of S&T funding to induce maximum innovation is critical. Too often, the intent to develop multi-application, joint capabilities from specific critical technologies is unintentionally undermined by contracting actions made without strategic vision—or by programmatic decisions excessively focused on one program and its requirements. As evolutionary, broader, and more flexible acquisition tenets become increasingly important, it will be the challenge of the acquisition universities and other Department curricula to place more emphasis on the innovative paradigms so critical to 21st century warfighting. The functional area architects recommended in this study should also prove an asset to this process by constantly monitoring and comparing each other's portfolios of different capabilities and associated programs for maximum overall effectiveness. Examples that follow discuss use of the three major policy levers to source innovative technology applications.

UAV EXAMPLE

- Acquisition strategy created a single source
- Resulted in increased cost and schedule
- Represented a lost opportunity

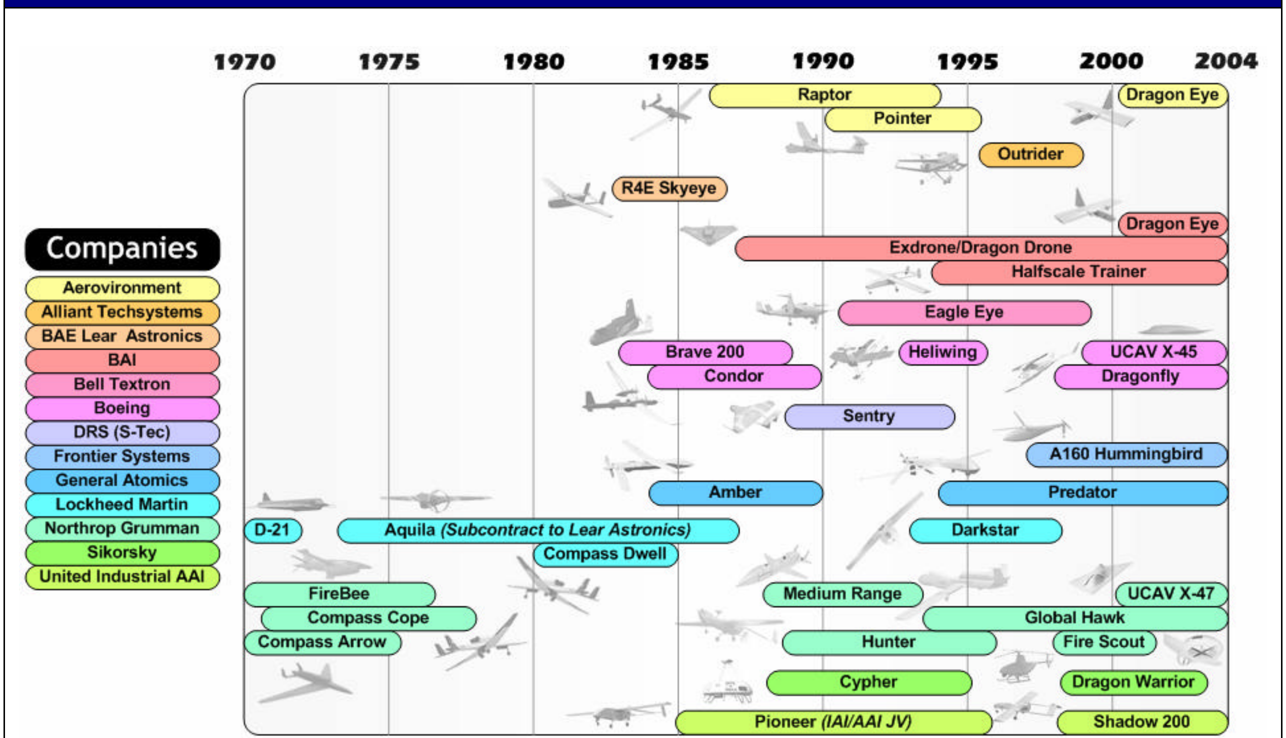
The history of UAV development has not benefited from the hallmarks of successful aircraft development: ample funding and number of suppliers. Nor has the Department succeeded in fully migrating this extraordinary manned aircraft technology base to future unmanned applications. Consistent funding and multiple competitions enabled fighter aircraft, whose integrated sensor suites are key components of Battlespace Awareness, to become one of the most dominant warfighting capabilities of the U.S. forces from the period following World War II to the present. The United States now has a capability that assures such complete air dominance that potential adversaries generally don't dare challenge it. The Department achieved such dominance through consistent long-term funding for system innovation and through multiple competitions. In the first few decades after World War II, more than a dozen firms competed to develop and produce military aircraft. Subsequently, some firms left the business and others merged, resulting in eight remaining firms in 1990.[18] The Department nurtured

[17] In addition to classic S&T funding, other sources of innovation funding include the Defense Acquisition Challenge Program, Quick Reaction Fund, Defense Technology Transition Initiative, Advanced Concept Technology Demonstrations (ACTDs), Title III Program, Small Business Innovation Research programs, Small Business Technology Transfer programs, and Manufacturing Technology programs. See Appendix D for a brief overview of these programs.
[18] Birkler, John, et. al. *Competition and Innovation in the U.S. Fixed-Wing Military Aircraft Industry*, Rand Corporation, 2003.

innovation in military aircraft by engaging an ample number of suppliers in aircraft manufacturing over a period of more than 45 years.

Although UAVs are now almost universally identified as a critical technology, the history of their development has been marked by uneven funding due to lack of support by the Services, frequent program cancellations, and few competitions for large production contracts. As a result, no company has had the continuous activity that fosters evolutionary innovation—and the Department's progress in obtaining systems has been marked by fits and starts, impeding the development and diffusion of critical knowledge within the industrial base. The chart below illustrates the uneven nature of UAV development. Many companies over more than three decades have participated in this area—but none have had a long, continuous pattern of involvement in unmanned programs. In addition, many of these companies have exited or been subsumed in the process.

UAV DISJOINTED DEVELOPMENT PATTERN[19]



Source: Institute for Defense Analyses

The nature of UAV technology is such that a robust industrial base capability would be characterized as having innovative technologies with myriad applications; multiple suppliers because of low entry costs; and maximum use of commercial-off-the-shelf components or systems. The consequence of the Department's UAV procurement pattern is few deployed UAVs and a still-nascent capability in spite of the relatively long

[19] Affiliations in this chart reflect the companies as they exist today and not the heritage companies that may have initiated or contributed to the program.

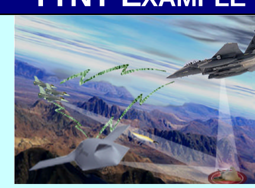
history of basic technology development. We can only guess where—and over how many applications—unmanned system innovation may have taken the Department had the history been different.

Consider, for example, the development of the Global Hawk UAV, now in high demand because of its demonstrated value in Operations Enduring Freedom and Iraqi Freedom. This is a case where the lever of funding innovation during weapon system design was intended to help maintain a competitive and innovative industrial capability. However, funding constraints led to a change in strategy and the opportunity was not realized. Global Hawk began as an Advanced Concept Technology Demonstration (ACTD) program leveraging Ryan's unmanned technology expertise going back several decades. It was selected in May 1995 from among five competing concepts. DARPA, the Global Hawk program manager, originally planned to fund two contractor teams through initial flight testing. However, budget cuts just prior to selection forced the Department to choose only a single contractor team.

If, on the other hand, the Department had funded multiple competing teams through initial flight test at a $160 million estimated cost for two, it would have significantly reduced: (1) performance risk because of competitive flight tests; (2) schedule risk arising from single source procurement; (3) super-optimization of one mission application and contractor approach; and (4) future acquisition costs by making available multiple sources for future competitions. This development program represented an early opportunity—not seized—to expand market demand and broaden the supplier base for a critical warfighting capability. The Department is now funding billions of dollars for UAV developments which could have blossomed earlier and at less cost—had the pressure to save $160 million not been so great in 1995.

Conversely, the Tactical Targeting Network Technology (TTNT) program demonstrates application of the *fund innovation* lever through the *weapon system design* portal to develop a robust and innovative supplier base. TTNT, also managed by DARPA, aims to provide the communications infrastructure to support tactical targeting from airborne platforms as part of the Joint Tactical Radio System. In early 2001, DARPA funded four large contractors to work on design requirements and four small contractors to focus on specific component technologies. In June 2002, DARPA chose one systems contractor and three small contractors to further mature TTNT technology and produce articles for testing—thereby continuing to fund multiple approaches. The Department ensured it retained ownership of TTNT intellectual property to facilitate the development of competition for subsequent phases of the program's life cycle.

TTNT EXAMPLE



- Acquisition strategy created innovative environment
- Source selection and management structure institutionalized this environment

From the beginning, the DARPA program manager funded a broader industrial base by soliciting industry responses for two sets of requirements: (1) total system requirements for which larger companies were better suited; and (2) component requirements that small companies with emerging technologies could best satisfy. DARPA funded an industrial base for this program of four system and four component suppliers in the preliminary design phase, reduced it to one system and three component suppliers a year later for the maturation of TTNT technology; and in the future production phase, will be able to attract more suppliers because of the Department's predominant ownership of the intellectual property, thereby allowing for expansion of the defense industrial base—if required.

Optimize Program Management and Acquisition Strategy

Over the years, the Department and its prime contractors have developed and employed a myriad of program management structures and acquisition strategies primarily to optimize program cost, schedule, and performance—sometimes not considering the full impact of such structures and strategies on the industrial base. However, as the following examples illustrate, organizational structures and acquisition strategies can have a significant impact on the Department's ability to acquire multiple innovative sources to maintain technology leadership. Acquisition programs are at the front lines of shaping the defense industrial base. Tactics at the program-level must be consistent with the Department's strategies to develop sufficient industrial base capabilities, incentivize industry to be innovative, and to seek multi-application solutions.

> *"Robust competition to meet challenging performance goals is the most consistent source of innovation."*
> *- Red Team Member*

Government and industry program management structures, as well as acquisition strategies, can provide positive or negative impacts on the numbers of suppliers and sources of innovation. For example, government management structures can encourage the development of multiple suppliers. On the other hand, as discussed below, if they allow too narrow a focus on Service-specific applications with the prime contractor and its sub-contractors, they can work to discourage other contractors from contributing competing innovative technologies. Likewise, industry management structures can positively impact innovation. For example, partnering with competitors for contracts in specific program areas where there are few contract awards and limited funding can produce innovative synergies. In some instances, however, partnering can result in monopolistic behavior that works to exclude competitors and squelch innovation. Finally, acquisition strategies may impact innovation either positively or negatively. A strategy where the Department funds multiple sources in early technology development, for example, nourishes the growth of multiple, innovative sources. A strategy where contractors have too much responsibility for program development and inadequate government oversight may foster dependence on current suppliers to the exclusion of other sources of innovative solutions.

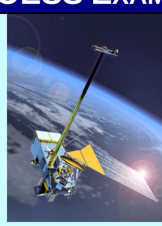
Traditional program cost, schedule and performance goals also can defeat program managers trying to apply strategies necessary to obtain the innovative technology the Department requires. The dynamic nature of program development and budget decisions can force changes in acquisition strategies to the detriment of broader industrial base considerations.

SBIRS EXAMPLE

- Government program office structure proved to be inefficient in controlling cost, schedule and performance
- Required restructuring of government and contractor management teams
- Restructured contract to bring performance and technology into line

A case of program management structure masking industrial base problems is illustrated in Space-Based Infrared System-High (SBIRS-High). Here is a case where the *optimize program management structure and acquisition strategy* lever was not employed during weapon system design. The program office was structured to provide minimum management oversight of the contract using a total systems performance responsibility (TSPR) clause. Major problems of cost, schedule, and performance in SBIRS-High surfaced in late 2001 in part due to the inability of industry to produce key capabilities because of problems related to lack of maturity in the system design.[20] These problems forced both government and contractor program offices to be restructured. The Department's review of the program at that time identified government program office structural issues, government and contractor program management turnover, and the TSPR acquisition strategy collectively as major contributors to the program's problems. The recovery plan is attempting to correct these issues with a restructured contract and management team. This experience reminds the Department of the risks of inadequate program oversight. Lack of attention to the impact of management structure and acquisition strategy on program performance set the stage for program failure, and this program continues to struggle to recover.

NPOESS EXAMPLE



- Program merger resulted in consolidation of competitive opportunities
- Acquisition strategy maintained robust competitive environment for innovative industrial capabilities

The combination of the military Defense Meteorological Support Program (DMSP) and the civil Polar-orbiting Operational Environmental Satellites (POES) saved significant money but risked reducing the opportunities for competition in a very innovative set of industrial capabilities. To address these risks, the integrated program office (IPO) for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) addressed this impact to the industrial base through application of the *acquisition strategy* and *fund innovation* levers through the *weapon system design* portal. The merger did not change the number of satellites to be procured but did reduce the number of distinct satellite design opportunities from two to one. The resulting program was estimated to produce sizable cost savings of over $1.6 billion through 2018 by reducing redundancies in U.S. meteorological satellite systems. To avoid reducing the innovation in the industrial base along with the costs, the IPO employed acquisition strategies to create a robust competitive environment by directing competitive subcontracts in the key sensor technologies. Losers of the sensor design competitions were allowed to team with the winners to leverage their best collaborative design and production capabilities, and stay engaged in one of the few major space-based remote sensing programs.

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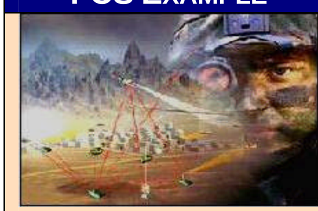
[20] Other causes cited during Nunn-McCurdy breach deliberations included lack of effective requirements and system engineering, and a breakdown in execution management within both Government and contractor teams.

Using the *management structure/acquisition strategy* lever to ensure multiple innovative sources will be even more challenging for future programs. As network-centric warfare demands synergies among defense systems, we are reminded that management structures and acquisition strategies must adapt to ensure the industrial base is properly incentivized to innovate key technologies—across multiple applications or missions. The E-10A Multi-Sensor Command and Control Aircraft program is an example of how the needs to replace several platforms can be met with a distinctive organization and acquisition strategy. The E-10A program employs a cluster of program offices within a lead program office, reinforcing common technologies and systems among the cluster's elements. The program's acquisition strategy is a hybrid as well. It has sole source system integration and platform contractors where the benefits of innovation and competition have already been garnered. However, where innovative technologies can provide critical capabilities, such as in the Battle Management Command and Control System, competition is preserved.

E-10A EXAMPLE

- Innovative management structure
- Competition-based acquisition strategy
- Results in an innovative industrial base for future competitions

FCS EXAMPLE



- Innovative management structure has potential to generate competitive industrial base environment
- Lack of government oversight and over-reliance on industry as an LSI may have unintended negative consequences

The Future Combat System (FCS) offers an example of an innovative management structure and acquisition strategy approach designed for an extremely complex and massive network-centric program critical to the Department's 21st century warfighting needs. It is using the *management structures/acquisition strategy* lever through the *weapon system design* portal to gain access to system-of-systems and network-centric capabilities found in the larger prime contractors and system engineering houses while retaining full access to the rest of the industrial base to provide critical capabilities in the systems and components that make up FCS. The Army has selected a strategy that establishes a contractor lead system integrator (LSI)—the Boeing/SAIC team—that works closely with the government program office. SAIC and Boeing play a major role in establishing program standards and selecting component contractors. They manage the identification, selection, and procurement of the major FCS systems and subsystems, with the explicit challenge and mandate not to self-deal.

However, while it is too early to know for sure, the FCS LSI approach may not provide the government the necessary in-depth understanding of that program's impact on the industrial base, particularly for the application of innovative technologies developed in FCS for non-Army applications. Based on its experience with TSPR, the Department has expressed unease with such heavy reliance on a contractor team for key program decisions, especially faced with high Department program office turnover rates. Thus, it is critical that the Department maintain insight into the LSI contractor processes and procedures of this program to ensure that they satisfy industrial base outcomes. In

FCS, the contract requirement that the Army Acquisition Executive review all decisions in the *make or buy* portal should help to mitigate this risk.

As these examples have illustrated, deploying the portals and levers on the construct we have developed differs for each situation. Developing a new technology or addressing an industrial base deficiency will require a solution crafted specifically for that deficiency. In making decisions, from resource allocation to acquisition strategies, the Department must ensure that the industrial base and strategies to ensure its sufficiency be considered—particularly in cases involving critical and multi-application technologies.

> *"The ability of acquisition managers to do this effectively depends on whether they continue to manage individual programs, which forces a parochial view, or a capability or technology area, which would cause them to optimize for that broader capability or technology area—a structural issue."*
>
> *– Red Team Member*

The future will demand great finesse in the application of the *program management/acquisition strategy* lever if the Department is to synergize available industrial base capabilities across broad applications. It is for this reason that we recommend establishing the functional area architect and conducting industrial base assessments for critical capabilities throughout the program life cycle. With the functional architects in all acquisition board meetings to monitor acquisition strategies and elevate industrial base concerns, these reviews will become more effective in maximizing innovation to the benefit of warfighting capabilities—and the defense industrial base.

Changing warfare strategies must erode the familiar platform-centric patterns the Department has long used to structure its thinking, but will only do so in the measure that acquisition professionals view themselves as stewards of warfighting capabilities and not owners of stovepipe platforms. The rest of the Department is adapting to these changes in order to create acquisition processes that recognize the power of synergizing capabilities across Services and platforms. Even our historical platform-based milestone approval process is now undergoing revision to focus on gaps and overlaps in capabilities provided by systems, rather than on the discrete systems themselves. Acquisition strategies are already beginning to bear the imprint of the portals and levers construct to challenge program managers to develop plans for innovation and innovative uses of their technologies—throughout program life cycles.

Employ External Measures

Previously we discussed two levers available to program managers to develop multiple sources of innovative technologies that can potentially be used to enhance multiple warfighting capabilities: *funding innovation* and *optimizing program management structures and acquisition strategies*. While these tools traditionally may be used to solve cost and technical quality problems, another important purpose is to ensure the development and sustainment of critical and innovative industrial base capabilities.

Now we will discuss measures external to the normal life cycle development of a program that the Department employs on an ongoing basis but also can employ when the first two levers do not secure sufficient innovation for critical capabilities. This third lever includes collaborating with other agencies to apply regulatory remedies in order to prevent undesired foreclosure of competition or innovation.

The graphic below depicts the seven "external" corrective measures available to the Department to remedy or prevent undesired effects on the industrial base. Three of them are external to individual programs, but internal to the Department. While the four on the right side of the chart are external to the Department, the Department has significant influence as to how these tools are employed.

EXTERNAL MEASURES			
DoD		Interagency	
Measure	**Purpose**	**Measure**	**Purpose**
Stage competitions to add sources	Induce innovation. Major risk reduction for too few/failing source(s) or lack of performance	Hart-Scott-Rodino Remedies	Maintain sufficient number of competitive sources
		Exon-Florio Remedies	Maintain technology leadership and security of supply but allow foreign direct investment
Restructure Management Approach	Eliminate excessive self-dealing or narrow focus on specific issues or applications	Balanced Export Controls	Keep military technology from adversaries but allow competition in global markets
Block Teaming Agreement	Discourage fusion of innovation into single source; prevent cartel-like behavior	Foreign Cooperative Agreements	Help develop and access foreign sources where appropriate
Source: ODUSD (IP)			

Funding permitting, the Department can stage competitions to add sources in order to induce innovation and improved performance, while reducing risk. When innovation is desired, competitions must avoid contract clauses and acquisition strategies that encourage risk-averse behavior and drive out innovation. The Department also can restructure its management approaches, as was done in the case of the SBIRS-High program discussed earlier, to preclude excessive in-house sourcing or premature narrowing of technology focus. As will be discussed in the case of DD21/DDX, the Department can block teaming arrangements in order to prevent combinations that would result in single sources and thereby restrict the competitive pressures that drive innovation. The Department can, and does, use these tools to ensure program management decisions do not lead to unintended consequences.

The Department also uses interagency processes to influence competition and innovation while protecting national security. Using the deliberative process established by the Hart-Scott-Rodino Antitrust Improvement Act, the Department works with the Department of Justice (DoJ) and Federal Trade Commission (FTC) to block proposed business combinations when necessary to preserve competition or for other reasons of national security. The Exon-Florio Amendment to the Omnibus Trade and Competitiveness Act authorizes the President to suspend or block foreign acquisitions, mergers, or takeovers of firms located in the United States when they pose credible threats to national security by transferring key industrial capabilities. The Department participates in an interagency committee, chaired by the Department of the Treasury to exercise the Department's leadership prerogative. Similarly, the Department of Defense works with the Department of State on export controls. Export controls should be structured to keep key, critical military technology from our adversaries, yet allow domestic firms to compete in international markets to preserve their global competitiveness.[21] Foreign Cooperative Agreements are agreements between the Department of Defense and foreign governments that allow the Department to develop and access foreign technologies and products that offer unique warfighting benefits.

DoD Measures

The Department has various corrective measures it can apply in order to preserve a robust, innovative industrial base when such action is necessary. First of all, it can take measures to induce innovation by staging competitions to add sources. Over the years, the Department sometimes has been forced to induce innovation within high risk programs or programs that have shown a decline in performance. Techniques range from developing alternative sources, such as in the case of the Navy's ARCI program, to developing technology insertion processes such as practiced today with spiral development planning. The goal always has been to find the best technology and ideas so that program offices can source the broadest array of solutions available.

Another measure the Department sometimes employs is to restructure its management approach. As was discussed earlier, when the SBIRS-High program was experiencing significant problems in late 2001, the Department took action to restructure management oversight to ensure the maturation of innovative technologies inherent in the program, among other corrective measures. The formation of joint program offices within the Department is often used to create a management structure to accelerate the development of innovation and the preservation of competitive sources. Examples of this are the Missile Defense Agency and the recent stand-up of the Joint Unmanned Combat Air Systems program office at DARPA.

A third measure that the Department occasionally employs is to block teaming arrangements. Teaming relationships sometimes can effectively reduce the number of suppliers in a given market, especially if the two firms teaming are dominant in a particular market sector. On some occasions, it becomes necessary for the Department to interject itself to avoid, or even break up, teaming arrangements between companies in order to sustain competitive conditions and nurture innovation.

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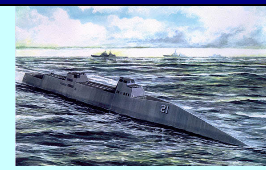
[21] Northrop Grumman's development of the APG-68(V)9 radar for sale to the United Arab Emirates and Singapore helped bring forward technologies and mitigate risk on 4th generation radars for both the F-22 and JSF programs. The foreign investment helped to lower non-recurring engineering costs and to transfer technology and manufacturing advances to production. This demonstrates how international market benefits the Department.

One notable example of the Department wielding the *employ external measures* lever occurred in 1998, when the two existing Navy combatant shipbuilders, Ingalls and Bath Iron Works, and the Navy's only large ship combat system supplier/integrator, Lockheed-Martin, announced they would team to bid for the Navy's new DD21 surface combatant ship design and construction program. To motivate continued improvement in key industrial capabilities, the Navy developed and implemented a revised acquisition strategy prohibiting Ingalls/Bath Iron Works and Lockheed-Martin from participating as a team. Thus, for the DDX competition, the two shipyards formed separate teams, promoting the development of distinctive capabilities and alternative sources in a critical industrial sector.

DDX EXAMPLE



- Industry teaming threatened access to innovation
- Acquisition strategy revised to ensure competitive sources

Interagency Measures

There are also measures the Department can employ in collaboration with government regulatory bodies outside the Department. The Hart-Scott-Rodino (H-S-R) legislation provides the basis for the Department's review of the impact of proposed acquisitions or mergers on innovation and competition in the industrial base. Working closely with anti-trust authorities, the DoJ and the FTC, the Department is able to block mergers or, if necessary, secure judgments that force restrictions on the acquiring firm in order to preserve competition in key technologies for critical capabilities. Finally, the Department, in conjunction with the Department of Treasury and the Department of State, can prevent the transfer of critical technologies through Exon-Florio remedies and export control laws, respectively. On the other hand, DoD can also negotiate Foreign Cooperative Agreements to fund and access critical technologies, especially where the source for a critical capability is foreign.

H-S-R Adjudication

The Department's role in Hart-Scott-Rodino (H-S-R) assessments is to look at the implications of a transaction on future competition and innovation. This prospective look is particularly critical as revisiting a merger after the fact is only permitted if the offending issue was not foreseeable at the time of the review.

Raytheon's recent acquisition of Solypsis highlights a situation in which the Department proactively worked with the DoJ to preserve competition in technologies critical to its network-centric warfighting plans. The Cooperative Engagement Capability (CEC) will integrate battle force combat systems and sensors into a single, force-wide, distributed combat system in order to counter increasingly capable and less detectable cruise and tactical ballistic missiles.

RAYTHEON – SOLIPSYS EXAMPLE

Raytheon | SOLIPSYS

- Proposed merger of two sensor netting companies
- Transaction allowed with agreement to offer capability to competitors
- Remedy preserved competition for future while enhancing the development of advanced capabilities

Recently, as the CEC Block II competition moved forward, Raytheon decided to acquire Solipsys, a firm with the only other sensor netting product thought to be technically mature enough to represent a viable alternative to the unique CEC hardware and software design: the Tactical Component Network (TCN). Recognizing the implications of this transaction, the Department used the *employ external measures* lever and, with the DoJ, insisted that Raytheon sign a letter of agreement to offer the Solipsys TCN as a merchant supplier to other contractors for future solicitations. By exercising this lever, the Department preserved the possibility of competition for future defense applications. As the example illustrates, the Department works with the antitrust regulatory agencies on a forward-looking basis to ensure a healthy, competitive industrial base for critical capabilities and applications.

LOCKHEED - NORTHROP EXAMPLE

- Proposed merger of two AEW radar providers and platform integrators
- Transaction denied
- Preserved competition in AESA market

The Department also recommended antitrust regulatory actions to preserve innovation and competition in airborne active electronically scanned array (AESA) radar technologies critical to battlespace awareness. One of the defining moments for the airborne AESA industry occurred as a result of Lockheed Martin's attempt to buy Northrop Grumman in 1997. The Department and the DoJ reviewed the merger and filed suit to block it in March 1998, citing potential horizontal and vertical integration issues regarding airborne early warning (AEW) radar along with the loss of competition and innovation in a number of critical systems and components. At the time of the merger, Lockheed and Northrop Grumman were the only two U.S. AEW radar providers. Only two companies (Raytheon and Northrop Grumman) had experience integrating AESA fire control radars in fighter aircraft. After the merger, Lockheed Martin would have had significant vertical AEW and AESA capabilities and could have foreclosed opportunities to potential radar competitors or denied radars to other aircraft competitors. By blocking the merger, the Department and the DoJ preserved competition in the airborne AESA industry, paving the way for its innovation and application to myriad non-airborne applications.

NORTHROP – TRW EXAMPLE

NORTHROP GRUMMAN | TRW

- Proposed merger of satellite prime and subsystem provider
- Transaction allowed with consent decree providing for systems prime impartiality and requirement to provide payloads to competitors
- Department's Compliance Officer to oversee make/buy and merchant supplier provisions
- Remedies preserve competition; competitors not foreclosed from legacy TRW payloads and components

With Northrop Grumman's acquisition of TRW, the Department also took measures to ensure multiple competitive sources in the critical reconnaissance satellite systems sector. After thorough analyses of the effects of the proposed acquisition, the Department communicated its concerns to the DoJ which in turn negotiated a consent decree, forcing Northrop Grumman to select payloads on a competitive and non-discriminatory basis and to provide legacy TRW technology to other competitors.

Although discussed earlier as a measure the Department can use internally, blocking teaming relationships also is an action that the Department sometimes takes in conjunction with the

> *"By requiring Northrop to make its sophisticated satellite payloads available to competitors, along with other provisions, this consent decree enables the U.S. government—the only customer of reconnaissance satellites—to continue to benefit from competitive prices, higher quality, and continued innovation."*
>
> *– R. Hewitt Pate, Acting Assistant Attorney General, Antitrust Division, DoJ, December 11, 2002*

DoJ when such teamings have the potential to adversely affect competition and thus negatively impact innovation.

The teaming relationship between DRS Technologies and Raytheon for electro-optical systems using second generation forward looking infrared technology is illustrative of a situation that required the attention of the Department and the DoJ. The Department decided to allow teaming on current contracts since the benefits of competition had already been garnered, given the phase of development of the related acquisition programs. However, the Department indicated that teaming for future programs (e.g., the Advanced Amphibious Assault Vehicle) would be unacceptable because of the negative effect on competition. The regulatory review resulted in both firms modifying their teaming agreement accordingly.

DRS - RAYTHEON EXAMPLE

- Proposed team of the only two second generation FLIR suppliers
- Teaming allowed for existing contracts; not for future competitions
- Modification of teaming agreement retains competition for future while realizing savings on current contracts

When corporate mergers or teaming agreements significantly reduce the competitive pressures which drive innovation, the Department must be prepared to use regulatory powers. In such situations, H-S-R adjudications provide the Department a means to maintain competition and induce innovation for industrial and technological capabilities critical to the warfighter.

Exon-Florio Remedies, Export Control, and Foreign Cooperative Agreements.

The Exon-Florio Amendment to the Omnibus Trade and Competitiveness Act of 1988 amended the Defense Production Act to authorize the President to suspend or block foreign acquisitions, mergers, or takeovers of U.S. firms when credible threats to national security cannot be resolved through other provisions of law. The President has delegated management of the Exon-Florio Amendment to the interagency Committee on Foreign Investment in the United States (CFIUS), chaired by the Department of the Treasury. Within the CFIUS, the Department of Defense determines if the company or business unit being acquired possesses critical defense technology under development or is otherwise important to the defense industrial and technology base.[22]

Critical technologies and capabilities highlighted by the DIBCS will be important decision aids for the Department in this process. In cases where the Department believes the technologies and capabilities are leading-edge and unavailable to potential adversaries, it may choose not to allow companies with these capabilities to be acquired by foreign companies, or it may develop remedies to reduce the risks of unauthorized

[22] For further information on the HSR and CFIUS processes, refer to the ODUSD(IP) *Business Combinations Deskbook* posted at http://www.acq.osd.mil/ip.

technology transfer. In this manner, the Department actively works to safeguard critical defense technologies.

The Department also can advocate export control restrictions to the Department of State when U.S. companies desire to export critical technologies or capabilities abroad. Conversely, where a sole source of a critical capability may be foreign, it may be advisable to engage in cooperative agreements with the company's government to ensure adequate funding to shape the endeavor.

CATALYST II EXAMPLE

- Combined U.K. and U.S. EW systems with U.K. software
- Saved $5-8 million and 2-3 years development time and increased commonality with major ally

In the case of the Catalyst II program, the Department sought more robust electronic warfare (EW) capabilities through the integration of a United Kingdom system, Soothsayer, with a U.S. system, Prophet. Each is an EW system focusing on upgrades to electronic support, electronic attack, and precision location systems. For this new application, the United States also acquired SAGE software from the United Kingdom with a state-of-the-art capability to detect, classify, and locate modern battlefield communications signals. The combined Catalyst II program saved between $5-8 million and two to three years of development time.

In summary, the portals and levers approach is a valuable tool to enhance the health of the defense industrial base. Portals encourage systematic examination of management decisions throughout the technology and program life cycles. Levers provide the means to ensure the innovation and investment that will keep the United States ahead of foreign competition for critical industrial base capabilities. Along with the levers available to programs, external measures within the Department and with the cooperation of regulatory agencies are available to retain innovation and remedy deficiencies. The Department must lead by example in applying new functional capability-based thinking, management practices, and behavior.

PART IV

POLICY REMEDIES FOR CRITICAL BATTLESPACE AWARENESS INDUSTRIAL BASE ISSUES

The Department has a rich history of programmatic lessons learned that it can apply to support the development, fielding, and continued improvement of Battlespace Awareness *be ahead* and *be way ahead* warfighting capabilities. The initial assessment of the critical industrial capabilities in the Battlespace Awareness functional capability area identified three issues that can benefit from this history. Examination of the remaining critical industrial capabilities undoubtedly will uncover additional issues. Appropriate remedies for those issues also will be considered.

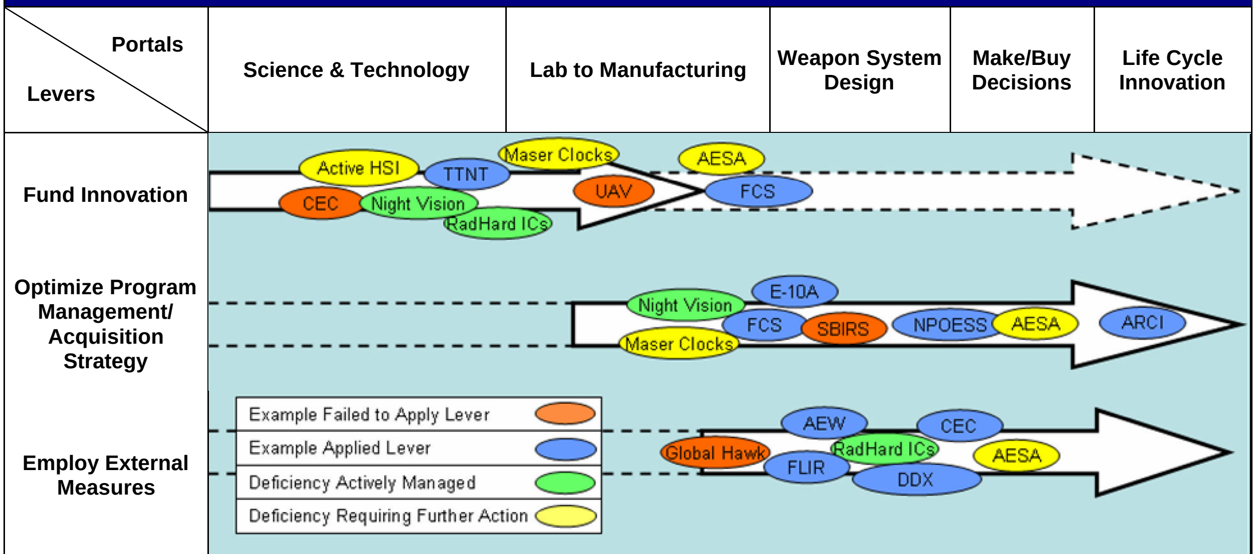
LESSONS LEARNED

We have discussed several lessons learned from applying major innovation portals and policy levers in the industrial process. In DARPA's TTNT program, the Department funded innovation and chose acquisition strategies early in technology development that provided multiple sources of innovation for future program needs. In the SBIRS-High program, the Department realigned program management structures more suitably to effect desired program outcomes. We also have noted instances where the Department applied external measures to proposed consolidations such as Northrop-TRW and Raytheon-Solypsis. In such instances, the Department took actions to retain the competitive pressures necessary for innovation by ensuring continued access by system integrators to competing technologies. We have also discussed the importance of the global industrial base to our endeavors, citing foreign cooperative programs such as the Singapore APG-68(v) radar enhancements to the F-16 and the integration of the U.K Soothsayer technology and SAGE software with the U.S. Prophet EW system.

We have discussed other case studies where the Department has not applied the levers available to it—and has limited innovation. While Global Hawk represents a great advancement in warfighting capability, the early development of that program was marked by inconsistent funding of innovative competitors, resulting in a thin industrial supplier base for critical UAV technologies. In the communications payload industry, vertical integration may be reducing competitive pressures and foreclosing opportunities to adapt the most innovative technologies providing the greatest warfighting capabilities.

The chart on the following page illustrates the examples discussed along with the industrial base deficiencies identified in this study of the Battlespace Awareness sector. Each example is plotted on the diagram arraying portals and levers. Some examples are plotted multiple times where a strategy uses several pieces on the game board. The chart shows where policy levers were applied (blue background) and where the Department missed opportunities to apply levers (red background). Deficiencies in critical industrial base capabilities for Battlespace Awareness capabilities identified through the initial assessment in this report are highlighted with a yellow background. Potential actions to remedy those situations will be discussed on page 44. Remedies for some deficiencies (green background) already are underway.

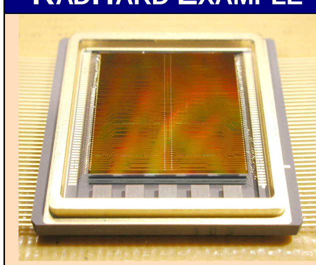
BATTLESPACE AWARENESS INNOVATION PORTALS AND POLICY LEVERS



Source: ODUSD (IP)

For example, radiation hardened electronics remains a critical technology for the myriad space systems that provide many of the most critical battlespace awareness capabilities. Radiation hardened electronics are manufactured to withstand the increased radiation levels present in space and the strategic environment where components manufactured with standard technologies would produce incorrect results or fail. Unfortunately, the market for these components is limited almost entirely to the Department of Defense and NASA and the capital investment and process development costs are very high. While innovation in commercial electronics is rapid, no commercial business case supports the required investment to innovate radiation hardened electronics. In recognition of this, the Department has established a Radiation Hardened Oversight Council to manage continued innovation in this critical technology. Most notably, the Department has created a $167 million Title III program[23] to capitalize two competing manufacturing processes that leverage innovation from the commercial electronics industry to meet critical defense requirements.

RADHARD EXAMPLE



- Market too small to support business case for commercial capability
- Department has used Title III of the Defense Production Act to capitalize two facilities to supply this industrial base capability

[23] Title III of the Defense Production Act provides a vehicle to establish, modernize, or expand domestic production capability and capacity for technology items, components, and industrial resources that are essential for national defense. For further information, see description in Appendix D.

NIGHT VISION EXAMPLE

- Acquisition strategy with multiple best value technology contracts saving money on better products
- Low demand limits supplier base

The Army's experience with night vision sensor technology illustrates the benefits of early funding for innovation and competition. It also demonstrates how highly-specialized products lead to high entry barriers and to reduced competition as demand decreases and technologies mature. Image intensification technology provides both soldiers and aviators enhanced night vision capabilities—a key Battlespace Awareness enabler. Night vision goggles are a helmet-mounted image intensification system used by individual soldiers for night operations. The aviator's night vision imaging system, also helmet-mounted, provides imagery sufficient to complete nighttime missions from full moonlight to starlight conditions.

The Army began funding laboratory development efforts in 1960. A first generation "Starlight Scope" surfaced during the Vietnam War. By the mid-1980s, the Army had developed five firms capable of competing to produce night vision intensification products. In 1985, the Army established PM Night Vision to leverage technology improvement using a best value contracting policy via a five-year omnibus contract. It was awarded to two winning teams comprising five companies on a 60 – 40 percent basis. The result has been lower cost and more capable products. Third generation image intensification products cost about 60 percent less than first generation products. During the last five years, as Army demand has decreased and the technology has matured, two U.S. firms remain (ITT Night Vision and Northrop Grumman). Given the highly-specialized nature of the product and the significant capital investment required, future DoD competitions for other Services and applications likely will attract bids only from these two suppliers, although capabilities exist among several non-U.S. suppliers.

BATTLESPACE AWARENESS INDUSTRIAL BASE REMEDIES

As we commented earlier in this study, the large majority of industrial base capabilities assessed for this report were sufficient, as listed below.

BATTLESPACE AWARENESS TECHNOLOGIES WITH SUFFICIENT INDUSTRIAL BASE CAPABILITIES	
Passive Acoustic, Seismic, and Electromagnetic (PASEM) and Effluent Sensing Techniques	Inertial Navigation System with Micro Electromechanical Systems (MEMS)
Laser Induced Breakdown Spectroscopy	Interferometric Fiber Optic Gyroscope
Polymerase Chain Reaction	Foliage Penetrating Synthetic Aperture Radar
Hyperspectral Imager	Ground Penetrating Radar
Long Wave Infrared Imaging	Lightweight, Broadband, Variable-Depth Sonar
Near Infrared Imaging	Synthetic Aperture Sonar
Staring Dual Band Infrared Arrays	Atomic Clocks
Laser Interferometry	Laser Cooled Atomic Clocks
LIDAR seekers with Autonomous Target Acquisition	Miniature Atomic Clocks
RF Emitter-related Sensors	Ultrasonic Imaging
	Ultraviolet Imaging

Our analysis of the industrial base for critical Battlespace Awareness warfighting capabilities identified three issues requiring action, as summarized on the chart below. The recommended remedies and associated explanations are provided for consideration within the Department. The recommendations use the portals and levers construct developed in this study.

BATTLESPACE AWARENESS INDUSTRIAL BASE ISSUES							
Technologies	**Industrial Base Sufficiency Analysis**				**Policy Levers**		
	Phase	**Domestic Sources**	**Foreign Sources**		**Fund Innovation**	**Optimize PM Structure & Acq Strategy**	**External Corrective Measures**
Active Hyperspectral Imager	R&D	4	3		Invest in R&D technology using S&T portal	N/A	N/A
Active Electronically Scanned Array (AESA) Radar	Prod	2 major	5		Promote investment in S&T for technologies that enable new applications	In near term programs, maximize competitive opportunities for weapon system design	Block teaming agreements for future competitions that do not increase innovation during weapon system design
Maser Clocks	R&D	2	3		Invest in R&D and demo of technology using S&T portal	Provide competitive opportunities for this technology in weapon system design	N/A

Source: Booz Allen Hamilton and ODUSD (IP)

Active Hyperspectral Imager. To remedy the lack of leadership in the U.S. industrial base relative to the industrial capabilities available to potential adversaries, the United States should invest more heavily in this technology. Specifically, the Department should consider a strong program to develop the chemical signature and surveillance capabilities of this technology tied to a demonstration of relevant warfighter capabilities. Compliance with the Kyoto accords is driving overseas developments in these technologies. This circumstance places greater pressure on U.S. industrial base research and development (R&D) to develop militarily-significant new *be way ahead* capabilities.

Active Electronically Scanned Array (AESA) Radar. AESA radar manufacturing is a mature industrial capability with two strong domestic suppliers and several foreign and smaller domestic suppliers. The proven benefits of high performance radar make this technology highly desirable by militaries around the world. This demand places continuous pressure on U.S. leadership in the technology. Therefore, continued investment in R&D by industry and by the Department is critical. This investment should focus on performance improvements, better manufacturing techniques, and broad applications for AESA radars and their critical components.

Competition also plays a substantial role in continued innovation and U.S. leadership in this technology. The Department should carefully manage competitions for AESA radars in the future, either as part of the overall system or as a separate subsystem competition. Key near-term competitions are planned for the Space-Based Radar (SBR), DDX, and Future Guided-Missile Cruiser (CGX) programs. These relatively valuable and large quantity programs are ideal opportunities to use competition to foster innovation and maintain U.S. leadership. The Department should also use its leverage to block any teaming agreements that impede competition in these programs.

Maser Clocks. Current plans for the GPS program emphasize the evolution of existing atomic clock technology that has been in use for several decades. The United States should take note of developments overseas and ensure that the best technology remains available within the U.S. defense industrial base by investing in maser clock R&D. Furthermore, the Department should structure future competition for GPS systems to allow for competition among innovative timing technologies and thus incentivize industrial investment and attention to technologies that enable continued U.S. leadership in this important warfighter capability.

The Department should continue to closely monitor the Battlespace Awareness *be ahead* and *be way ahead* warfighting capabilities, and associated critical technologies and industrial capabilities, and be prepared to deploy appropriate policy levers to maximize innovation and competition within the industrial base when critical industrial base deficiencies are identified. The methodology developed for the DIBCS Battlespace Awareness and the associated portals and levers provides the Department with the necessary tools. Applying these tools with diligence will greatly increase our confidence that the critical industrial base capabilities are available when needed to maintain the U.S. warfighting superiority over any potential adversary.

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AFTERWORD

Our February 2003 report, *Transforming the Defense Industrial Base: A Roadmap*, reflected a revolutionary warfighting doctrine then germinating within the Department. The term “effects-based operations” may have given way to the five new functional concepts defined by the Joint Staff and around which they are reorganizing. The intent, however, remains the same: to focus the Department’s resources on the most essential operating effects that the U.S. warfighter must deliver in order to win.

The Defense Industrial Base Capabilities Study (DIBCS) series, of which *Battlespace Awareness* is the first, advances this intent. It articulates a structured top-down analysis and policy framework/methodology with which decision makers can harness the full power of competition to address critical warfighting capabilities, unleashing innovation in academia, industry, and the Government.

This study on Battlespace Awareness recommends first that the Department address the three issues of concern identified in the initial assessment of this particular functional capability. Second, it recommends that this office be considered the clearinghouse for assessing industrial base deficiency and commits this office to continue to assess Battlespace Awareness industrial sufficiency—and, indeed, sufficiency of the other four functional capability areas.

Our assessment found the industrial base supporting Battlespace Awareness to be fundamentally strong; well over 200 companies provide essential industrial capability building blocks. These companies range in size from firms with half a dozen employees and millions of dollars in revenues to firms with tens of thousands of employees and billions of dollars in revenues. It is difficult to be concerned about excessive consolidation of the U.S. defense industrial base when faced with this range of offerings—and the international participants in Battlespace Awareness span the globe.

Two other recommendations emerged through the work undergirding this study, which have broader policy implications: that functional architects be established who will, among other roles, serve as conduits for innovation within and among functional capability areas, and that the Department require that acquisition strategies of programs address industrial base assessments and the systematic consideration of sources of innovation.

In fact, the eight months over which this report has been produced have provided ample opportunities to test and begin defining the functional architect and the acquisition policy construct developed in this report. We believe that functional architects will be considered important facilitators as the Department recasts its requirements and acquisition processes. Acquisition strategies are already beginning to bear the imprint of our portals and levers construct to challenge program managers to develop plans for innovation and innovative uses of their technologies—throughout program life cycles. Finally, discussions are underway with the Department’s acquisition centers of learning to embed these new capability paradigms into course curricula. But it will be up to the Department leadership to structure programs that effectively meet the warfighters’ 21st Century capability requirements.

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ACRONYMS

AAA	Anti-Aircraft Artillery
ACTD	Advanced Concept Technology Demonstration
AEHF	Advanced Extremely High Frequency
AESA	Active Electronically Scanned Array
AEW	Airborne Early Warning
AMRAAM	Advanced Medium Range Air-to-Air Missile
ARCI	Acoustic Rapid COTS Insertion
ATIRCM/CMWS	Advanced Threat Infrared Countermeasure/Common Missile Warning System
BA	Battlespace Awareness
BAFC	Battlespace Awareness Functional Concept
BAH	Booz Allen Hamilton, Inc.
C-5 RERP	C-5 Reliability Enhancement and Re-Engining Program
CBRNE	Chemical, Biological, Radiological, and Nuclear Events
CEC	Cooperative Engagement Capability
CFIUS	Committee on Foreign Investment in the United States
CGX	Future Guided-Missile Cruiser
COTS	Commercial Off-the-Shelf
CVN	Nuclear-powered Aircraft Carrier
DARPA	Defense Advanced Research Projects Agency
DDG	Guided Missile Destroyer
DDX	Future Destroyer
DE	Directed Energy
DIAL	Differential Absorption LIDAR
DIBCS	Defense Industrial Base Capability Study
DMSP	Defense Meteorological Support Program
DoJ	Department of Justice
DTED	Digital Terrain Elevation Data
DUSD	Deputy Under Secretary of Defense
EM	Electromagnetic
EMP	Electromagnetic Pulse
EO	Electro-Optical
ESA	Electronically Scanned Array
EW	Electronic Warfare
FBCB2	Force XXI Battle Command Battalion/Brigade and Below
FCS	Future Combat System
FMTV	Family of Medium Tactical Vehicles
FTC	Federal Trade Commission
GCSS	Global Combat Support System
GBS	Global Broadcast System
GMLRS	Guided Multiple Launch Rocket System
GPS	Global Positioning System
GRAB	Galactic Radiation and Background
H-S-R	Hart-Scott-Rodino
HVAC	Heating, Ventilation & Air Conditioning

IDA	Institute for Defense Analyses
IPO	Integrated Program Office
IR	Infrared
IRAD	Independent Research and Development
ISAR	Inverse Synthetic Aperture Radar
JDAM	Joint Direct Attack Munition
JSOW	Joint Standoff Weapon
JTRS	Joint Tactical Radio System
LIDAR	Light Detection and Ranging
LIF	Laser Induced Fluorescence
LPD	Amphibious Transport Dock
LPI/LPD	Low Probability of Intercept/Low Probability of Detection
LSI	Lead System Integrator
MCS	Maneuver Control System
MEMS	Microelectromechanical Systems
MM III	Minuteman III
MMIC	Monolithic Microwave Integrated Circuit
MP-RTIP	Multi-Purpose Radar Technology Insertion Program
NAS	National Airspace System
NCMS	National Center for Manufacturing Sciences
NESP	Navy EHF SATCOM Program
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NYSE	New York Stock Exchange
OSD	Office of the Secretary of Defense
PAC 3	Patriot Advanced Capability-Phase 3
PASEM	Passive Acoustic, Seismic, and Electromagnetic
PCR	Polymerase Chain Reaction
PNT	Position, Navigation, and Timing
POES	Polar-orbiting Operational Environmental Satellites
R&D	Research and Development
S&T	Science and Technology
SAG	Senior Advisory Group
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar
SBIRS-High	Space-Based Infrared System - High
SMART-T	Secure Mobile Anti-Jam Reliable Tactical Terminal
SSGN	Nuclear-Powered Cruise Missile Submarine
T-AKE	Auxiliary Cargo (K) and Ammunition (E) Ship
TCN	Tactical Component Network
TSPR	Total Systems Performance Responsibility
TTNT	Tactical Targeting Network Technology
UAV	Unmanned Aerial Vehicle
USD	Under Secretary of Defense
UV	Ultraviolet
WIN-T	Warfighter Information Network-Tactical

APPENDIX A

DIBCS BATTLESPACE AWARENESS CAPABILITY FRAMEWORK

Observe & Collect Information World-Wide

This is the ability to detect, identify, characterize, and track items, activities, and events worldwide of interest to the decision-makers and policy-makers that rely on military BA. Observe and collect covers the range of detection, identification, characterization, and tracking from items such as WMD and WMD precursors through political events of military significance. This capability includes persistent observation, reconnaissance, and information collection from both open and clandestine sources. [BAFC, 31 October 2003]

Observe & Collect Information World-Wide Neutral
• Calculate the noise in a system

Observe & Collect Information World-Wide Equal
• Image surface structures and infrastructure to commercial resolution • Detect surface electromagnetic (EM) transmissions from fixed sources • Image ground, mobile, man-made objects, and tactical infrastructure to commercial resolution • Detect surface EM transmissions from mobile sources • Image ships and surfaced submarines to commercial resolution • Detect, locate, and identify ship and surfaced submarine mooring locations • Detect ship and surfaced submarine EM transmissions • Detect, locate and identify dual-use chemical, biological, radiological, and nuclear facilities • Detect, locate, and measure wave height • Image terrain to level 2 digital terrain elevation data (DTED) standards • Detect, locate, and characterize fires and volcanic eruptions • Measure soil moisture content in a focused area • Detect and measure soil type and composition in a focused area • Detect snow coverage in a focused area • Detect ice coverage in a focused area • Measure ground temperature in a focused area • Detect, locate, and characterize vegetation/foliage density and type in a focused area • Detect, locate, and identify very large objects resting on the ocean bottom (habitats, ships, submarines, etc) • Detect, locate, and characterize undersea floating objects • Detect, locate, and characterize ocean currents • Detect, locate, and characterize ocean temperature • Detect, locate, and characterize ocean salinity • Detect and locate undersea oceanic and polar ice

Observe & Collect Information World-Wide Equal
• Detect, locate, and characterize ocean bottom topography within 3 - 6m resolution • Detect and measure ocean bottom type, composition, coverage, and plant life • Simultaneously identify and categorize multiple seismic activities • Detect background magnetic characteristics • Detect and measure subterranean type, composition, density, and coverage • Detect and locate missiles and projectiles in-flight (mortar, AAA, SAM, ballistic missiles, etc) • Detect airborne EM transmissions • Detect, locate, and measure cloud type, density, coverage, and thickness • Detect, locate, and measure wind • Detect, locate, and measure precipitation type, density, and coverage • Detect, locate, and measure temperature • Detect and measure atmospheric pressure • Detect, locate, and measure humidity • Characterize the ionosphere • Detect electrostatic characteristics in the atmosphere • Detect, locate, and characterize obscurants and particulate to include density, coverage, composition, and persistence • In non-real-time, detect, locate, and track man-made orbiting objects, as well as their maneuvers, separations, rendezvous, and dockings • Collect magnetosphere characteristics • Detect solar activity • Map/profile network architecture and support infrastructure to characterize the network, identify associated equipment and features, and determine their purpose or function • Measure network activity • Determine information types used on networks • Characterize and eliminate noise • Assess initial seismic recordings for magnitude of the disturbance • Analyze data to identify the moving target • Determine a projectile launch and track • Conduct tests and initial assessments on collected soil, air and water samples

Observe & Collect Information World-Wide Be Ahead
• Image structures and infrastructure through foliage, camouflage, and obscurants to commercial resolution • Characterize structures and infrastructure composition (wood, mud, reinforced concrete, asphalt, etc) • Detect and measure population densities within structures • Direct tagging of fixed surface objects with known location

Observe & Collect Information World-Wide Be Ahead
• Detect and locate man-made acoustic signals • Locate and characterize surface EM transmissions from fixed sources • Image ground, mobile, man-made objects, and tactical infrastructure through foliage, camouflage, and obscurants to commercial resolution • Detect equipment manning • Detect and locate tactical infrastructure changes • Detect, locate, and identify prepared tactical relocation sites • Detect, locate, and track moving vehicles • Detect, locate, and track low observable objects • Direct tagging of mobile ground objects with known location • Detect and locate man-made acoustic signals • Locate and characterize surface EM transmissions from mobile sources • Image ships and surfaced submarines through camouflage and obscurants to commercial resolution • Detect manning of ships and surfaced submarines • Detect and locate ship and surfaced submarine infrastructure • Detect, locate, and track moving ships, boats, and other floatation devices • Detect, locate, and track low observable ships and surfaced submarines • Detect ship and surfaced submarine decoys and countermeasures • Direct tagging of ships and surfaced submarines with known location • Detect and locate ship and surfaced submarine acoustic signals • Locate and characterize ship and surfaced submarine EM transmissions • Detect and locate conventional explosions • Detect and locate directed energy events on the surface • Detect and locate a missile launch • Detect and locate a projectile launch • Detect and locate surface nuclear detonations • Detect and locate surface electromagnetic pulse (EMP) events • Detect and locate chemical, biological, radiological, and nuclear weapons facilities (R&D, production, storage, and elimination) • Identify, locate, and track areas of chemical, biological, radiological, and nuclear contamination • Image terrain through foliage, camouflage, and obscurants to level 3 DTED standards • Measure snow depth in a focused area • Measure ice thickness in a focused area • Detect and locate underground, man-made structures and infrastructure • Detect and locate man-made underground activity (burrowing, drilling, and purpose) • Detect and locate mine fields • Direct tagging of man-made, underground ingress/egress, and heating, ventilation & air conditioning (HVAC) points with known location

Observe & Collect Information World-Wide Be Ahead
• Detect, locate, and identify large objects on the ocean bottom (airplanes, mini-submersibles, etc) • Detect and locate suspended objects (mines, markers, hydrophones, etc) • Direct tagging of fixed subsurface objects with known location • Detect, locate, and track undersea crafts • Detect, locate, and track undersea low observable objects • Detect and characterize subsurface acoustic signals • Direct tagging of mobile subsurface objects with known location • Detect and locate an undersea missile or torpedo launch • Detect and locate underground explosions or blasting • Detect and locate underwater explosions • Detect and locate underground nuclear detonations • Detect and locate underground chemical, biological, radiological, and nuclear weapons facilities (R&D, production, storage, and elimination) • Identify, locate, and track areas of underground chemical, biological, radiological, and nuclear contamination • Characterize undersea oceanic and polar ice • Detect, locate, and characterize ocean bottom topography with 1 - 3m resolution • Detect, locate, track, and characterize marine life • Measure and characterize subsurface background noise • Pinpoint precise location and time of seismic activity • Detect, locate, and track moving targets from take-off to landing • Detect, locate, and track hovering targets from take-off to landing • Detect, locate, and track moving, airborne low observable objects • Detect, locate, and track stationary, airborne low observable objects • Track and characterize missiles and projectiles in-flight • Direct tagging of air objects with known location • Detect and locate man-made acoustic signals • Locate and characterize airborne EM transmissions • Detect and locate conventional explosions in the air • Detect and locate airborne directed energy events • Detect and locate atmospheric nuclear detonations • Detect and locate airborne EMP events • Identify, locate and track areas of airborne chemical, biological, radiological, and nuclear contamination • Detect, locate, and identify cloud type, density, coverage, and thickness trends • Detect, locate, and identify wind trends • Detect, locate, and identify precipitation type, density, and coverage trends • Detect, locate, and identify temperature changes • Detect, locate, and identify atmospheric pressure changes • Detect, locate, and identify humidity changes • Identify ionospheric changes

Observe & Collect Information World-Wide
Be Ahead

- Identify obscurant, particulate movement and dissipation
- Determine the type, function, and size of man-made orbiting objects
- Detect, identify, locate and track re-entering man-made orbiting objects
- Detect and characterize laser cross links and up/down links
- Detect, locate, and characterize space EM transmissions
- Detect and locate conventional explosions in space
- Detect and locate directed energy events in space
- Detect and locate exoatmospheric nuclear detonations
- Identify nuclear weapons or payloads in or deployed to space
- Detect electrostatic effects (including ionization)
- Characterize solar activity
- Detect, locate, and track earth-crossing natural objects
- Characterize network capacity, sophistication, type, operating systems of nodes, function, reconstitution capabilities, and choke points identifying weaknesses, dependencies, and inefficiencies
- Characterize network activity
- Detect and identify network protection devices
- Exploit the information on networks
- Detect /map database structures
- Identify unique characteristics of a broadcast signal
- Identify unique characteristics of a direct link or non-broadcast signal
- Recover signal from a medium noise environment
- Calculate positional data for source of seismic readings
- Breakdown soil, air, and water samples into chemical compounds
- Recognize and identify threats

Observe & Collect Information World-Wide
Be Way Ahead

- Provide focused area 3-D image of structures and infrastructure through foliage, camouflage, and obscurants to a resolution that supports targeting of precision guided munitions
- Provide focused area 3-D image of structures and infrastructure through foliage, camouflage and obscurants to support detection, location, and function of underground man-made openings (entrances and ventilation ducts)
- Detect and identify changes in surface structures and infrastructure
- Determine surface structures' internal and external layout (offices, storage, elevators, utilities, networks, HVAC, auxiliary power plant)
- Detect and track personnel movement within structures
- Indirect tagging of fixed surface objects with unknown location
- Characterize and exploit man-made acoustic signals
- Precisely locate and exploit surface EM transmissions from fixed sources

Observe & Collect Information World-Wide Be Way Ahead

- Detect, locate and characterize surface low-probability of intercept/low-probability of detection (LPI/LPD) EM transmissions from fixed sources
- Focused area 3-D image of ground, mobile, man-made objects, and tactical infrastructure through foliage, camouflage, and obscurants to a resolution that supports targeting of precision guided munitions
- Detect and characterize operational mode of man-made surface objects
- Characterize tactical infrastructure changes
- Detect, locate, track, and identify moving vehicles over a theater-wide area simultaneously
- Detect, locate, and track foot soldiers on the move
- Detect, locate, and track very low and extremely low observable objects
- Differentiate between decoys and countermeasure and real objects effects
- Indirect tagging of mobile surface objects with unknown location
- Characterize and exploit man-made acoustic signals
- Precisely locate and exploit surface EM transmissions from mobile sources
- Detect, locate, and characterize surface LPI/LPD EM transmissions from mobile sources
- Provide focused area 3-D image of ships and surfaced submarines through camouflage and obscurants to a resolution that supports targeting of precision guided munitions
- Detect and characterize operational mode of ships and surfaced submarines
- Characterize ship and surfaced submarine infrastructure changes
- Detect, locate, track, and identify moving objects at sea over a theater-wide area simultaneously
- Detect, locate, and track swimmers on the move
- Detect, locate, and track very low and extremely low observable ships and surfaced submarines
- Indirect tagging of ships and surfaced submarines with unknown location
- Characterize and exploit ship and surfaced submarine acoustic signals
- Precisely locate and exploit ship and surfaced submarine EM transmissions
- Detect, locate, and characterize ship and surfaced submarine LPI/LPD EM transmissions
- Characterize conventional explosions on the surface
- Characterize directed energy events on the surface
- Characterize and identify a missile launch
- Characterize and identify a projectile launch
- Characterize surface nuclear detonations
- Characterize surface EMP events
- Characterize chemical, biological, radiological, and nuclear weapons facilities (R&D, production, storage, and elimination)
- Detect, identify, and locate effluents related to chemical, biological, radiological, and nuclear weapons R&D, testing, production, use, and elimination

Observe & Collect Information World-Wide Be Way Ahead
• Detect, identify, and locate biomarkers related to chemical, biological, radiological and nuclear weapons R&D, testing, production, use, and elimination • Rapidly detect and identify changes in chemical, biological, radiological, and nuclear effluents, biomarkers, facilities, etc • Characterize chemical, biological, radiological, and nuclear agents for proper response • Focused area 3-D image of terrain through foliage, camouflage, and obscurants to level 5 DTED standards • Focused area 3-D image of terrain through foliage, camouflage, and obscurants to support detection, location, and function of underground natural openings (caves) • Characterize underground, man-made structures and infrastructure composition (concrete, reinforced concrete, size, purpose, etc) • Determine underground, man-made structure layout (living quarters, labs, HVAC, utilities, storage, ingress/egress, etc) • Characterize man-made underground activity (burrowing, drilling, and purpose) • Detect and locate individual land mines • Indirect tagging of underground, man-made facilities with unknown location • Detect, locate, and identify small objects on the ocean bottom (people, mines, cables, etc) • Characterize subsurface suspended objects (mines, markers, hydrophones, etc) • Indirect tagging of fixed subsurface objects with unknown location • Detect, locate, and track undersea swimmers • Detect, locate, and track undersea very low and extremely low observable objects • Extract and process actionable information from man-made acoustical signals • Indirect tagging of mobile subsurface objects with unknown location • Characterize and identify an undersea launch of missiles or torpedoes • Characterize underground explosions and blasting • Characterize underwater explosions • Characterize underground nuclear detonations • Characterize underground chemical, biological, radiological, and nuclear weapons facilities (R&D, production, storage, and elimination) • Detect, identify, and locate effluents related to underground chemical, biological, radiological and nuclear weapons R&D, testing, production, use, and elimination • Detect, identify, and locate biomarkers related to underground chemical, biological, radiological and nuclear weapons R&D, testing, production, use, and elimination • Rapidly detect and identify changes in chemical, biological, radiological, and nuclear effluents, biomarkers, facilities, etc • Characterize chemical, biological, radiological, and nuclear agents for proper response

Observe & Collect Information World-Wide Be Way Ahead

- Analyze and disseminate underground chemical, biological, radiological, and nuclear agent detection, identification, location, and warning information
- Detect, locate, and characterize ocean bottom topography with less than 1 meter resolution
- Characterize natural seismic activity
- Identify and characterize airborne moving targets
- Identify hovering targets
- Detect, locate, and track moving, airborne very low and extremely low observable objects
- Detect, locate, and track stationary, airborne very low and extremely low observable objects
- Predict in-flight missile and projectile launch/origination and impact/termination point locations (mortar launch and impact, ballistic missile launch and impact, SAM launch and explosion, AAA firing, etc)
- Indirect tagging of air objects with unknown location
- Characterize and exploit man-made acoustic signals from airborne sources
- Precisely locate and exploit all airborne EM transmissions
- Detect, locate, and characterize airborne LPI/LPD EM transmissions
- Characterize conventional atmospheric explosions
- Characterize airborne directed energy events
- Characterize atmospheric nuclear detonations
- Characterize airborne EMP events
- Characterize chemical, biological, radiological, and nuclear agents for proper response
- Analyze and disseminate airborne chemical agent detection, identification, location, and warning information
- Detect, identify, and locate air effluents related to chemical, biological, radiological, and nuclear weapons R&D, testing, production, use, and elimination
- Determine the health and operational status of man-made orbiting objects
- Real-time detect, locate, and track man-made orbiting objects
- Intercept and exploit laser cross links and up/down links
- Exploit EM transmissions from orbiting objects
- Characterize exoatmospheric conventional explosions
- Characterize exoatmospheric directed energy events
- Characterize exoatmospheric nuclear detonations
- Characterize nuclear weapons or payloads in or deployed to space
- Identify critical network nodes and links, network infrastructure choke points, and network centers of gravity
- Identify purpose of specific network activity
- Probe a network unnoticed or undetected
- Retrieve selected information only
- Exploit databases

Observe & Collect Information World-Wide Be Way Ahead
• Provide near real-time imagery information of the battlefield • Probe a network without leaving a signature

Analysis of Intelligence Information

This is the ability to use open and protected methods to discern: patterns, opportunities, and vulnerabilities, and characterize information in order to facilitate superior decision-making. This capability is a combination of both ability to conduct detailed, in-depth analysis of very specific phenomenology and the ability to fuse information from a wide variety of sources in order to create valuable insights and actionable, relevant information. This includes increasing blue understanding of the capabilities, intentions, and plans of global actors to allow leaders to employ appropriate focused action. This area also includes support to broader blue capabilities such as information operations. [BAFC, 31 October 2003]

Analysis of Intelligence Information Neutral
• Gather and analyze population trends from open sources

Analysis of Intelligence Information Equal
• Analyze any open transmitted broadcast to identify signal characteristics • Analyze any direct, dedicated link or non-broadcast transmission • Analyze a panchromatic image of an area of interest • Analyze the thermal signature of an object • Interpret measured distance, speed, rotation and chemical properties of an object • Characterize and distinguish sound from noise • Calculate and tag information with location reference • Find and establish the boundaries of an adversary's network • Determine and map the extent of the contamination from CBRNE weapons • Classify the particular type of CBRNE weapon used and display its area of coverage • Locate the buildings of interest on a map • Determine the high capacity nodes within communications system • Fuse various images, sounds, and vibrations of an area of interest and compare them with known entities • Set the boundaries of an adversary's network • Fuse all source data to provide a population composition in an area of interest • Analyze initial solar activity data for potentially adverse effects on radio communications

Analysis of Intelligence Information Be Ahead
• Distinguish and locate decoys and countermeasures • Distinguish subsurface decoys and countermeasures • Distinguish airborne decoys and countermeasures

Analysis of Intelligence Information Be Ahead
• Provide accurate electronic transmission information on type and location of transmitters; characterize the EW environment • Provide a description of the protection employed to secure the transmission • Provide accurate signal parameters and determine the purpose of a link • Develop automatic spatiotemporal change detection in digital imagery • Analyze multispectral imagery of the area of interest • Characterize an accurate description of the object to include its operational description • Identify the object using collected data • Convert the received signal to a more useable form • Analyze any sound detected for indications of adversary activity • Analyze the seismic data to characterize the source of the disturbance • Appraise and classify moving targets on land, in the sea or air • Process trajectory information to identify type and extrapolate target • Automatically correlate with known geographic features or across other domains and disciplines • Create a map to enter and exit an adversary's network • Decompose a network's security architecture • Identify and assess indications of possible use of CBRNE materials • Evaluate the data from a directed energy weapon system • Characterize and display the signal to break down its components • Map out the signal's reception area and location of its transmitters • Compare and contrast different sensor inputs for an area of interest • Compare and contrast previous inputs to identify any change in the area of interest • Integrate PNT data with mapping and geodesy information • Provide track analysis on moving targets to include place of origin and potential destination • Construct and visually display a network profile characterizing network parameters • Illustrate and display locale of harmful CBRNE agents and the rate of dissipation • Graphically analyze and compare building structures and composites • Integrate multiple processing techniques and various receptions of a signal to regenerate the original signal • Integrate multiple signal inputs to triangulate locations of transmitters and identify communication trunks • Study and analyze the signal protection methods used • Decompose information from communication systems to identify vulnerabilities, weaknesses, or dependencies • Compare multiple sensor inputs and integrate them to support a composite view of an area of interest • Perform added-value processing to images to generate maps, charts, etc.

Analysis of Intelligence Information Be Ahead
• Assess automatic spatiotemporal change detection • Assess the readiness level of the projectile system • Create an integrated, composite map of various adversary networks and any interoperability between them • Identify and characterize network security architectures • Analyze nuclear scintillation and plasma and EMP effects; and create a visualization of the event • Analyze data to identify CBRNE precursors prior to the employment of the weapon system • Compare and contrast various types of explosions • Generate combatant position based upon surveillance data • Evaluate and characterize the population by regionalization [urban and rural] • Through analysis at the molecular level of structures/materials classify vulnerabilities • Generate space weather trend analysis for any user specified activity • Assess global impact and characterize a potential environmental disaster • Assess attacks in the physical environment involving weapons of mass destruction

Analysis of Intelligence Information Be Way Ahead
• Differentiate between decoys/countermeasure and real ships/surfaced submarines • Differentiate between decoys and countermeasure and real objects effects • Eliminate decoys and countermeasure effects • Provide timely and accurate electronic transmission information; locate and characterize type of transmitters in the battlespace • Characterize the protection methods used • Recreate a broadcast signal • Identify and characterize the intercepted transmission • Recreate a non-broadcast or direct link signal • Recover signal from a high noise environment • Provide timely automatic spatiotemporal change detection in digital imagery • Analyze hyper and ultra-spectral imagery of the area of interest • Provide timely and accurate thermal information on an object in the battlespace • Characterize the object using collected data • Decompose a received signal to actionable information • Provide timely analysis of the type of sound and the object creating it • Provide timely analysis of the vibration and the cause • Assess the objective of moving targets • Very accurately determine geo-position of locations

Analysis of Intelligence Information **Be Way Ahead**
• Decompose a network into its constituent elements and associated data structures for a clear understanding of its capabilities • Assess weaknesses, vulnerabilities, and dependencies in an adversary's network • Identify CBRNE precursors prior to the employment of the weapon system • Analyze and disseminate chemical, biological, radiological, and nuclear agent detection, identification, location, and warning information • Characterize DE weapon • Identify the target of potential DE weapon use • Characterize threats (e.g. electronic, directed energy, projectile, moving target, etc.) • Analyze and display a visual picture of a building, its structure, and usage • Analyze and assess the information from the recovered signal (e.g., content, routing, origination, purpose, etc.) • Reconstruct conversations identifying participants • Reconstruct data and video transmissions • Characterize transmitters and antenna patterns to assess vulnerabilities and weaknesses • Assess and evaluate weaknesses, vulnerabilities, and dependencies in the protection methods employed • Assess various electronic transmissions and generate a single integrated communication signal picture • Integrate various sensor inputs to depict the EM battlespace • Analyze and contrast different sensor inputs for an area of interest; compile a single integrated picture • Add highly accurate positional data and other features to an image • Analyze and assess automatic spatiotemporal change detection in digital imagery in support of treaty verification • Exploit intelligence, surveillance, and reconnaissance to influence planning, to fuse multiple information sensors, and to characterize emerging threats • Predict the target and potential use of a projectile system • Predict re-entry of a man-made object, to include ground impact points • Breakdown network operations to identify vulnerabilities, weaknesses, or dependencies • Recreate all network security measures to identify the strengths and weaknesses of the security systems • Reconstruct operating systems and data structures from all source data • Predict the effects of nuclear scintillation and plasma on the battlefield • Predict the potential use of CBRNE weapons • Predict the use and target of a directed energy weapon system • Analyze and assess explosions to distinguish between the various types • Distinguish between combatants and non-combatants

Analysis of Intelligence Information Be Way Ahead
• Accomplish blue, red, and grey force tracking, as well as distinguish between them and civil population • Characterize and assess an adversary's intent • Integrating multiple inputs, create an urban population characterization • Exploit structures by conducting subatomic analysis to identify vulnerabilities

Manage Knowledge

This is the ability to: store, retrieve, filter, synergistically combine, and display information from a variety of sources in context in order to ensure that the right information reaches the right decision-maker in an actionable format in order to support superior decision-making. Knowledge management includes horizontal and vertical integration of information from sensors, analytic centers, and decision-makers. [BAFC, 31 October 2003]

Manage Knowledge Neutral
• Display raw imagery data

Manage Knowledge Equal
• Orthorectify imagery data with high fidelity • Present a single received signal • Present a single sensor input • Display mapping and geodesy information to commercial standards • Display an integrated picture of an environmental disaster (i.e. forest fires, volcanic eruptions) • Manage operationally significant information • Exchange products between different systems • Be compatible within coalition systems

Manage Knowledge Be Ahead
• Orthorectify imagery data with very high fidelity • Integrate various sensor inputs to develop and visualize situational awareness • Provide preliminary dissemination of battlefield analysis • Display analysis based on all source inputs • Synthesize voice transmissions • Reconstruct data structures and video clips • Display results of change detection analysis • Provide nautical and aero charts, field mapping, topographic information, earth observation, and spatial data • Display network configurations, highlighting vulnerabilities • Create demographic-like charts and diagrams to depict concentrations of populations • Provide weather charts and predictions to decision makers • Exchange data between different systems • Horizontal integration of coalition systems • Provide non-GPS position and navigation processing

Manage Knowledge Be Way Ahead
• Provide signal characteristics to other commands or agencies • Display precisely the location of the transmitters • Present single sensor input to assess an area of interest • Quantify and disseminate change detection information • Disseminate precise mapping and geodesy information • Display and disseminate track analysis of moving targets • Display the trajectory of a projectile • Display electronic, directed energy, projectile, moving target, etc. threat warning • Display weaknesses, vulnerabilities, and dependencies in an adversary's network • Develop/display precise situational awareness • Display elements of the battlespace for commanders • Present multiple sensor inputs to assess an area of interest • Securely disseminate analysis based on all source inputs to blue and grey forces as necessary • Display and disseminate accurate battle damage assessments • Provide transcripts of intercepted voice communications • Provide data structure documents and video of intercepted communications • Project graphically the impact of change detection analysis • Provide flight simulation, visualization, and forensic analysis • Display the trajectory or path of a craft whether in space, in the air, on the water, under the sea, or traversing between the various media • Disseminate key network information to decision makers • Disseminate demographic information to decision makers • Provide space weather/environment characteristics to decision makers • Cross cue information between different systems • Be interoperable among coalition forces • Provide GPS-based position and navigation processing

Model, Simulate & Forecast

This is the ability to utilize BA information to create an environment that allows for modeling, simulating, and forecasting in order to increase understanding, increase confidence, and decrease risk for decision-makers and military personnel. Modeling, simulation, and forecasting activities range from accurate and timely weather predictions through support of operational rehearsals, training exercises, and military education. [BAFC, 31 October, 2003]

Model, Simulate & Forecast **Be Way Ahead**
• Predict and disseminate the potential use of CBRNE weapons • Develop a model for predictive battlespace awareness • Perform and disseminate predictive battlespace awareness • Produce decision-quality predictive assessments • Predict snow depth, ice thickness, and ground freezing points • Predict space weather using current and historical data • Predict effects of solar activity • Predict impacts and effects of earth crossing natural objects • Predict weather and potential environmental disasters

Position, Navigation and Timing

This is the ability to provide a common reference for location and timing in other BA information.

Position, Navigation and Timing Equal
• Monitoring location of personnel and equipment in transit • Monitoring arrival of personnel and equipment in transit

Position, Navigation and Timing Be Ahead
• Sea, air, land position accuracy • Monitor location of personnel and equipment during combat operations • Position accuracy for combat search and rescue operations • Sea and land navigation • Sea, air, land timing to support simultaneity • Precise time tagging to produce synergistic precision strike effects • Timing to support combat search and rescue operations

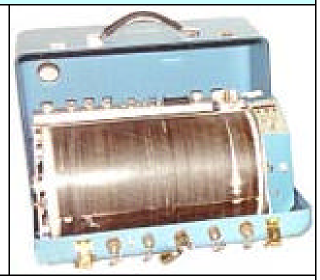
Position, Navigation and Timing Be Way Ahead
• Position accuracy for cooperative surveillance/reconnaissance operations, precision strike, space operations, mine detection and subsurface operations • Air navigation and cooperative operations • Navigation for combat search and rescue • Navigation for precision strike operations • Precise time tagging for cross system cooperative operations

Appendix B

Critical Technologies for Battlespace Awareness Organized by Broad Industrial Areas

Acoustic Sensing

Acoustic sensing technologies are used to detect, identify, and locate sound wave and seismic activity to characterize underground or underwater activities and facilities. These measurements allow characterizations for targeting and battle damage assessment.



- Acoustic Array
- Acoustic Doppler Current Profiler
- Acoustic HF (contact)
- Acoustic Localization
- Acoustic Sensors
- Active Electromagnetic Induction
- Advanced Underwater Distributed Sensor
- Cone Penetrometers
- Current State Sensors
- Digital Output Strong Motion Accelerometer & Accelerograph
- Doppler Acoustic
- Hydroacoustic Sensors
- Infrasound Sensors
- Low Frequency Passive Acoustic Sensors
- MEMS Tri-axial Seismic Accelerometers
- Passive Acoustic, Seismic, and Electromagnetic (PASEM) and Effluent Sensing Techniques
- Passive Acoustics Using a Digital Format
- Passive Acoustics Using an Analog Format
- Passive and Active Acoustical Monitoring Using Fixed Sensors
- Pulsed Power
- Seismic Sensors
- Surface Acoustic Wave
- Ultrasonic Distance Sensor
- Use of dataloggers in passive acoustics

Chemical, Biological, Radiological & Nuclear Event (CBRNE) Sensing

CBRNE technologies are used to identify, locate, characterize and track chemical, biological, radiological, and nuclear agents and areas of contamination in air, land, sea, and subsurface domains. Accurate identification and characterization facilitates quick and effective response, minimizing and even eliminating unnecessary loss of life.

- Aerosol Mass Spectrometer (AMS)
- Airborne Particle Collectors
- Alpha and Beta Detectors
- CBRNE Collectors/Filters
- CBRNE Sensors/Samplers/Dosimeters (Individually worn)
- Chemical / Biological Agent Water Monitor
- Chemical Imaging Sensor
- Combination of Seismic & Hydroacoustic Sensors
- Combination of Seismic, Radionuclides, & Infrasound Sensors
- Electronic Dosimeter
- Enhanced Nuclear Quadropole Resonance (NQR) Detection Capability
- Gamma Ray & Neutron Compact Sensor
- Gamma Ray Detectors (improved)
- Gas Chromatography - Mass Spectrometry (GC-MS)
- Imaging Doppler Interferometry (IDI)/ Frequency Domain Interferometry (FDI)
- Immunoassay Collection, Sampling, and Analysis
- Ion Mobility Spectrometry
- Ion Mobility Spectroscopy
- Ionization Chemical Detection
- Isotopic Neutron Spectroscopy
- Laser Induced Breakdown Spectroscopy
- Neutron Flux Detectors
- Particle Detectors
- Particulate Filtration Units
- Polarization (UV, IR) Spectroscopy
- Polymerase Chain Reaction (PCR)
- Thermographic Detection (hand held)
- Ultrasonic Imaging
- Ultrasound Sensors
- Ultrasound Technologies
- Vadose Zone Characterization System
- X-Ray Detectors

Combination Sensing

Combination sensing is the use of technologies that are used in combinations (e.g. microsensors) to accomplish varied applications more efficiently than single sensor approaches or where single sensor approaches cannot accomplish the mission.

- Autonomous Distributed Sensors (Acoustic and Magnetic)
- Coupling of TV Monitoring (Optics) with Passive Sonar
- Distributed, Unmanned, Networked Sensor Systems
- Microsensors
- Miniature Intrusion Detection System (MIDS)
- Multisensor Arrays
- Multispectral, Fiber-Optic-Based Sensors and Sensor Arrays
- Tunable Filter Multispectral Camera
- Unattended, Robotically Controlled Sensors

Electro-Optical (EO) Sensing

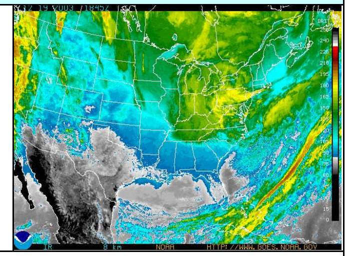
EO sensing technologies are used to collect, detect, and identify information from the visible portion of the electromagnetic spectrum. Applications include reconnaissance and surveillance, biological agent detection, missile and shellfire detection, atmospheric ozone-level detection, welding imagery, and flame sensing.

- CMOS Real-Time Focal-Plane Motion Sensor
- Distributed-Aperture Large Membrane Optics (visible to near-IR)
- Dynamically reconfigurable vision with high-performance CMOS active-pixel sensors (APS)
- Electronic Optical Beam Steering
- Electro-optical Sensors
- Enhanced Optical Sensor
- Enhanced Spectral Gamma Probe
- EO Sensor Arrays
- EO Warning Sensors
- Fast object location with CMOS APS
- Fiber Optic Surface Vision Sensor
- Matrix Transform Imager Architecture
- MOSAIC multi-camera imaging system
- Non-imaging compact photodetectors for motion detection
- Optical Sensors
- Optical Techniques for Standoff Weapon Detection
- Passive Optical Systems
- UV Optical Devices
- Visible Optical Devices

Graphic is courtesy of Space Imaging.

Environmental Sensing

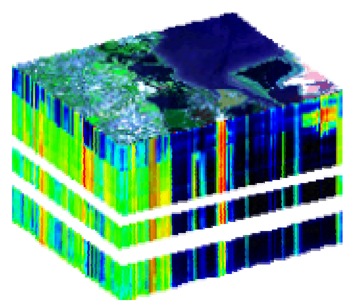
Environmental sensing technologies are used to detect, identify, and characterize environmental factors such as atmospheric conditions, weather, gravitational variations, cloud height, and wind. Knowledge of environmental conditions in an area is essential to mission planning and execution.



- Advanced Microwave Precipitation Radiometer (AMPR)
- Ceilometer
- Grating Spectrometer
- Gravimeter and Gravity Gradiometers
- Impedance-type Humidity Sensor
- Millimeter-Wave (MMW) MMIC Atmospheric Temperature and Humidity Sensors
- Radiosonde
- Remote Environmental Measuring Units (REMUS)
- Scatterometer Climate Record Pathfinder (SCP)
- Space Environmental Anomaly Sensors
- Spectral Gamma Probes
- Ultrasonic Wind Sensor

Hyperspectral Sensing

Hyperspectral sensors survey all or portions of a continuous spectrum of electromagnetic radiation being reflected from the surface of the earth, typically across the IR portions of the spectrum. These systems differ from conventional remote sensing in that they individually measure many narrowly defined spectral channels, where as conventional remote sensing looks at several broadly defined spectral regions. These technologies can passively detect and identify ground disturbances and material types, detect changes over time, and provide obscurant-penetrating 3-D imaging of structures, infrastructure, and underground man-made openings.



- 3-D Hyperspectral Imager
- Active Hyperspectral Imager
- High Spatial Resolution Thermal Infrared Spectrometer
- Hyperspectral Grating Spectrometer
- Hyperspectral Imager
- Imaging Spectrophotometry/Snapshot Imaging Polarimetry
- Multi-Spectral Active Optical Sensors
- Spatial Hyperspectral Imager

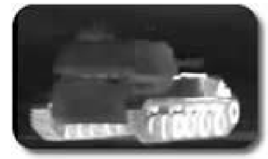
Information Technology (including Software/Algorithms)

Information technology consists of hardware, software technologies and algorithms use for various applications such as data processing, signal processing, information management, visualization, modeling and simulation.

- 3-D Battlefield Visualization
- Adaptive Sensor Fusion Architecture
- Adversary Modeling
- Archival Mass Storage (large capacity and rapid retrieval)
- Atmospheric Compensation Algorithms
- Atmospheric Modeling
- Automated Multisensor/MultiINT Fusion/Correlation Algorithms
- Automatic Sensor Cueing Algorithms
- Automatic Target Recognition Algorithms
- Battlefield Augmented Reality Display
- Change Detection Algorithms
- Cross-cueing Methods
- Data Compression Algorithms
- Decision Support Visualization
- Digital Elevation Models
- Distributed Geospatial Meta Databases
- Dynamic Database Fusion
- Dynamic Target Databases
- Future State Prediction Models
- Ground Moving Target Indicator Algorithms
- High Resolution Weather Forecasting Models
- High-capacity On-board Satellite Data Processing
- High-capacity On-board Satellite Data Storage
- Image Construction/Reconstruction Algorithms
- Image Management from hundreds to thousands of sensors or more
- Interoperability/Integration Standards and Architecture
- Lightweight 3-D Plasma Displays
- Massively Parallel Processors
- Multi-INT Workstations
- Multi-INT Visualization Techniques
- Non-volatile RAM
- Optical Processors
- Optical Storage
- Orbital Dynamics Algorithm
- Radiation Hardened Processors
- Radiation Hardened Storage
- Rapid Terrain Visualization
- Signal Outage Forecasting
- Signal/Target Geolocation and Mapping Algorithms
- Smart Data and Product Retrieval
- Spatial and Temporal registration Algorithms
- Target Classification Algorithms

Infrared (IR) Sensing

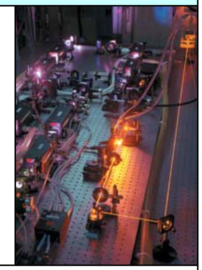
IR Sensing technologies are used to detect and measure light or radiation whose wavelength falls in the infrared portion of the electromagnetic spectrum, including the near-, mid-, and thermal-infrared ranges. This information is used to identify, analyze and characterize facilities, biomarkers and other activities relating to chemical, biological, radiological, and nuclear weapons. It is also used to support targeting of precision-guided munitions by providing focused area 3-D imagery of ground, mobile, and man-made objects, and tactical infrastructure, without being hindered by night, foliage, camouflage and obscurants.



- Adaptive Control for Thermal Imagers via Electro-Optic Effect Yielding Enhanced Sensors
- Forward Looking Infrared (FLIR)
- Fourier Transform Infrared Radiometer
- Infrared Countermeasure (IRCM) Sensors
- Infrared Sensor
- IR Radiometer
- IR Search and Track Sensor
- IR Thermal Imaging Cameras
- Long Wave Infrared Imaging
- Medium Wave Infrared
- MEMS-based Linear Arrays for Thermal Detectors
- Near IR Imaging
- Night Vision/Thermal Imagers
- Quantum Dot IR
- Staring Dual-Band IR Arrays
- Thermal Imaging
- Uncooled IR Micro-Bolometers

Laser Sensors

Laser sensor technologies use wave properties of light to measure distances and angles with extreme accuracy, as well as to illuminate/image objects and targets. These systems can be used for CBRNE applications, as well as for detection and tracking of moving airborne and orbiting objects and the detection and characterization of atmospheric changes and conditions.



- Doppler LIDAR
- Eye-safe Laser Rangefinder
- Forward Looking, Low-Grazing-Angle LIDAR and Sonar
- Hybrid/Multispectral Laser Imager
- Laser Altimetry
- Laser Imager
- Laser Interferometry
- Laser Long Scan System (LLSS)
- LIDAR
- LIDAR Bathymetry
- LIDAR Seeker with Autonomous Target Acquisition (ATA)
- Mass Spectrometry Particle Count
- Mass Spectroscopy Fourier Transform Infrared
- Scanning LIDAR Canopy Imager
- Underwater LIDAR

Magnetic Sensing

Magnetic sensing technologies detect and measure magnetic fields and small anomalies in the earth's magnetic pull. These measurements can be used to explore subsurface characteristics, as well as seismic activity.

- Current State Sensors
- Magnetic Field Sensors
- Magnetic Sensor Arrays
- Magnetic Sensor Technologies
- Magnetometer
- Micro Orientation Magnetometer Sensor
- Passive Magnetic Field Gradiometer
- Passive Magnetometry

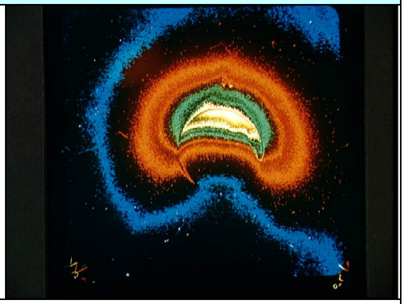
Microwave Sensing

Microwave sensing technologies measure the intensity of electromagnetic radiation in the microwave range of the electromagnetic spectrum. Since the intensity of this radiation is proportional to temperature, these technologies are often used for thermal energy detection, air turbulence analysis, and weather forecasting.

- Microwave Imagers
- Microwave Radiometer
- Passive Microwave Instruments
- Passive Microwave Radiometry

Other Imaging

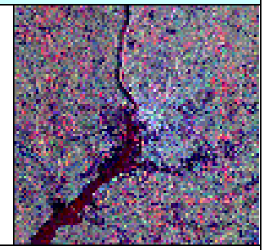
These technologies are used to create images through the detection and measurement of energy other than microwave, radar, infrared, sonar, hyperspectral, and electro-optical.



- Dual Sensor Radiometer Imaging
- Extreme Ultraviolet Sensor
- Fiber Optic Imager
- Gamma Ray Imaging
- Moderate Resolution Imaging Spectroradiometer
- Passive Millimeter-Wave (MMW) Imaging
- Quantum Imaging
- Ultraviolet Imaging
- X-Ray Imaging

Radar

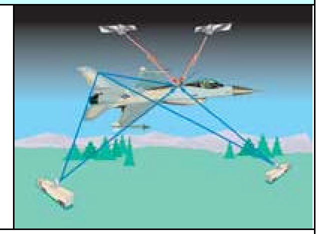
Radar technologies produce energy at radio wavelengths and then record and measure the resulting reflections from objects to generate imagery and other information. These technologies can be used for multiple applications, including terrain mapping, detection and tracking of mobile objects (friendly or otherwise), and accurate target location.



- Active Electronically Scanned Array (AESA) Radar
- Air-to-Ground Radar Imaging (AGRI) using High Resolution Radar (HRR) and SAR
- Bi/Multi Static Radar
- CW Doppler
- Doppler Radar
- Energy Focusing Ground Penetration Radar
- Foliage-penetrating (FOPEN) SAR
- FOPEN Ground Moving-Target Indicator (GMTI)
- Frequency Modulated Continuous Wave (FMCW)
- Ground Penetrating Radar
- Ground-based Radar
- High Power MMW ISAR
- Ice Penetrating Radar
- Inverse Synthetic Aperture Radar (ISAR)
- Microwave Radar
- Millimeter Wave (MMW) Radar
- Multi Source Correlator Tracker (MSCT)
- Multifunction Phased Array Radar
- Multispectral Countermine Detection
- Optical Synthesis of THz RF Waveforms
- Optically Generated Terahertz (THz) Radar
- Pulse Doppler Radar
- Radar Echo Sounding
- RF Phased Array Radar
- RF-Generated Terahertz Radar
- Side Looking Airborne Radar
- Synthetic Aperture Radar (SAR)
- Tunable ISAR
- Tunable SAR
- Ultra Wideband Radar
- Ultra Wideband SAR

Radio Frequency (RF) Sensing

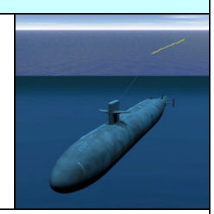
RF sensing technologies detect and measure radio frequency emissions. These systems can be used to allow for precise location and exploitation of electromagnetic transmissions (e.g. radar locations), as well as for early warning systems.



- Advanced multifunction Radio Frequency System (simultaneous multibeam)
- Advanced Radar Homing (ARH) Seeker Technology
- Digital Radio Frequency Tags
- Electromagnetic Induction Imaging
- Electromagnetic Induction/Electric Conductivity
- Electromagnetic Sensor
- Enhanced Electromagnetic Pulse Sensor
- Extremely Low Frequency/Very Low Frequency Type Sensors
- Information Dense Antennas (IDAs)
- Modulation Sideband Technology for Absolute Ranging (MSTAR)
- Passive RF Emitter-Related Sensors
- RF Doppler Sensors
- RF Sensors
- RF Warning Sensors
- RFID Tags

Sonar

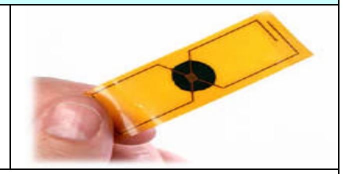
Sonar technologies use sound waves to detect and locate submerged objects or measure the distance to the bottom in a body of water.



- Active Broadband Sonar
- Biosonar (mammal-based sonars) for Mine Detection
- Higher-Resolution Sonar
- Lightweight, Broadband, Variable-Depth Sonar (LBVDS)
- Multi-Hydrophone Localization of Low Frequency Broadband Sources
- Sonar
- Synthetic Aperture Sonar
- Underwater, Unmanned Dual-Frequency Forward Look and Side Look Sonar Systems
- Variable-Depth Sonar (VDS)

Tagging

These technologies perform asset tagging through active energy emission by the target or by something attached to the target. This provides continuous knowledge of the location and status of friendly as well as enemy assets.



- Limpet Tagging (active) for Ships, Surfaced Submarines

Timing and Geopositioning Devices

These technologies employ various methods to obtain precise timing and positioning information. This precision enables more effective military coordination and targeting.

- Atomic Clock
- Fiber Optic Gyro IMU
- GPS Signal Analysis
- High-resolution Tri-axis Microelectromechanical Systems (MEMS) Accelerometer
- Improved GPS Receiver
- Interferometer Fiber Optic Gyroscope (IFOG)
- Laser-cooled Atomic Clock
- Maser Clock
- MEMS Capacitive Pressure Transducers
- MEMS Inertial Navigation System (INS)
- Meso INS
- Miniature Atomic Clock
- Precision Inertial Navigation Systems (PINS)
- Quantum Positioning System

APPENDIX C

A COMPENDIUM OF REPRESENTATIVE DEFENSE TECHNOLOGY SUPPLIERS WITH TRANSFORMATIONAL CAPABILITIES

NOTE: Companies listed are representative; the list is not exhaustive. Inclusion or exclusion does not imply future business opportunities with or endorsement by DoD.

Technology Suppliers [1]						
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**	**Technology**
AccuBeat Ltd.	n.a.	Jerusalem, Israel	n.a.	n.a.	www.accubeat.com	Atomic Clock
Acton Research Corp.	1998	Acton, MA	45	4	www.acton-research.com	Laser Interferometry
Aerial Facilities Ltd.	1970	Chesham, UK	200	17	www.aeriel.co.uk	Maser
AG Electro-Optics, Ltd.	1981	Tarporley, UK	17	3	www.ageo.co.uk	Laser Interferometry
Agilent Technologies	1999	Palo Alto, CA; Santa Clara, CA	36,000	6,010	www.agilent.com	Laser Interferometry Ground Penetrating Atomic Clock
AEG Infrarot-Module GmbH	1976	Heilbronn, Germany	240	27	www.aim-ir.com	Infrared Sensor Near IR Imaging
Akashi Corp.	1916	Zama, Japan	250	30	www.akashi-grp.co.jp	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
Alenia Aeronautica S.p.A.	1969	Pomigliano D'Arco, Italy	7,537	1,466	www.alenia-aeronautica.it	Ground Penetrating Radar
Alenia Spazio	1982	Turijn, Italy	2,200	578	www.alespazio.it	Ground Penetrating Radar
Alliance Engineering & Inspection, Ltd.	n.a.	Calgary, Canada	n.a.	n.a.	www.aeiltd.com	Ultrasonic Imaging
Andor Technology, Ltd.	1989	Belfast, Northern Ireland	79	12	www.andor-tech.com	Laser Induced Breakdown Spectroscopy Hyperspectral Imager
Applied Analytics, Inc.	1993	Chestnut Hill, MA	13	4	www.a-a-inc.com	Ultraviolet Imaging
Applied Scintillation Technologies	1983	Harlow, UK	23	2	www.appscintech.com	Ultraviolet Imaging
Array Systems Computing, Inc.	1981	Toronto, Canada	45	4	www.array.ca	Synthetic Aperture Sonar
AstroPower, Inc.	1998	Newark, DE	425	70	www.astropower.com	Active Electronically Scanned Array
ATC Semiconductor Devices	1992	St. Petersburg, Russia	n.a.	n.a.	www.atcsd.neva.ru	Laser Interferometry
Atlantic Nuclear Corp.	n.a.	Canton, MA	5	1	www.atnuke.com	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
AutoVision	n.a.	Los Angeles, CA	n.a.	n.a.	www.autovision.net	Hyperspectral Imager
Avalon Photonics Ltd.	2000	Zurich, Switzerland	30	2	www.avalon-photonic.com	Laser Interferometry
Avir, LLC	2001	Charlottesville, VA	n.a.	n.a.	www.avirsensors.com	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
Avitronics	n.a.	Centurion, South Africa	390	n.a.	www.avitronics.co.za	Passive RF Emitter-related Sensors
BAE Systems	1977	Farnborough, UK	90,000	12,662	www.baesystems.com	Laser Induced Breakdown Spectroscopy Polymerase Chain Reaction Device Long Wave Infrared Imaging MEMS Inertial Navigation System Active Electronically Scanned Array Foliage Penetrating SAR
- BAE Systems Avionics Ltd.	1989	Farnborough, UK	7,225	1,408	www.baesystems-avionics.com	Active Electronically Scanned Array
- BAE Systems N.A.	1999	Rockville, MD; Lexington, MA	22,610	3,932	www.na.baesystems.com	Passive RF Emitter-related Sensors Polymerase Chain Reaction Device Long Wave Infrared Imaging Staring Dual Band IR Arrays Near IR Imaging
Ball Aerospace & Technologies Corp.	1956	Boulder, CO	2,505	491	www.ballaerospace.com	Near IR Imaging Infrared Sensor
BEI Technologies	1983	San Francisco, CA	1,104	186	www.bei-tech.com	MEMS Inertial Navigation System
Bernhard Halle Nachfl. GmbH	1994	Berlin, Germany	15	5	www.b-halle.de	Ultraviolet Imaging
BigSky Laser Technologies	1981	Bozeman, MT	45	5	www.bigskylaser.com	Laser Induced Breakdown Spectroscopy

[1] **Companies listed are representative; the list is not exhaustive. Inclusion or exclusion does not imply future business opportunities with or endorsement by DoD.**

Sources: SEC Filings, Orbis Bureau van Dijk databases, RDS Business and Industry database, LexisNexis Academic Universe, S&P reports, Hoover's, US Major Companies Database, Yahoo Finance, US Business Directory, Dun & Bradstreet, and First Equity research.

Technology Suppliers [1]						
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**	**Technology**
Bookham Technology Plc	1988	Abingdon, UK	779	54	www.bookham.com	Active Electronically Scanned Array
BP Solar International LLC	1995	Linthicum Heights, MD	700	54	www.bpsolar.com	Active Electronically Scanned Array
Bruker Daltonics, Inc., ABC Detector Division	1980	Billerica, MA	670	116	www.daltonics.bruker.com	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
Burlington Resources, Inc.	1988	Houston, TX	2,167	2,964	www.br-inc.com	Laser Induced Breakdown Spectroscopy
Camber Corp.	1990	Huntsville, AL	900	140	www.camber.com	Polymerase Chain Reaction Device
Canon, Inc.	1937	Tokyo, Japan	97,802	14,491	www.canon.com	Laser Interferometry
Carl Zeiss-Stiftung	1889	Oberkochen, Germany	34,500	4,218	www.zeiss.com	Ultraviolet Imaging
Cellonics	2000	Singapore	n.a.	n.a.	www.cellonics.com	Ground Penetrating Radar
Centronic Ltd.	1945	New Addington, UK	72	6	www.centronic.co.uk	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
Cal Crystal Lab, Inc.	1979	Anaheim, CA	18	4	www.calcrystal.com	Atomic Clock
Channel Technologies Inc.	1984	Santa Barbara, CA	475	24	www.channelindustries.com	Lightweight, Broadband, Variable-Depth Sonar
- Harris Acoustic Products Corp.	1999	Walpole, MA	45	4	www.harrisacoustic.com	Lightweight, Broadband, Variable-Depth Sonar
Charles Strake Draper Laboratory - non-profit	n.a.	n.a.	n.a.	n.a.	www.draper.com	MEMS Inertial Navigation System
Coherent Technologies Inc.	1984	Louisville, CO	150	19	www.ctilidar.com	Active Hyperspectral Imager Laser Induced Breakdown Spectroscopy
Coherent, Inc.	1966	Santa Clara, CA	2,190	397	www.coherentinc.com	Laser Interferometry
Collective Protection Inc.	n.a.	La Jolla, CA	3	0	www.collectiveprotectioninc.com	Polymerase Chain Reaction Device
Cree Research	1987	Durham, NC	893	155	www.cree.com	Active Electronically Scanned Array
Crossbow Technology, Inc.	1995	San Jose, CA	40	4	www.xbow.com	MEMS Inertial Navigation System
Crystal GmbH	1990	Berlin, Germany	20	1	www.crystal-gmbh.com	Near IR Imaging Staring Dual Band IR Arrays
CSPI	1968	Billerica, MA	144	28	www.cspi.com	Foliage Penetrating SAR
Compound Semiconductor Technologies Global Ltd.	1998	Glasgow, Scotland	n.a.	n.a.	www.compoundsemi.co.uk	Atomic Clock
CVI Laser Corp.	1972	Albuquerque, NM	250	25	www.cvilaser.com	Laser Interferometry
Cyterra Corp.	2000	Waltham, MA	50	8	www.cyterracorp.com	Ground Penetrating Radar
Daedalon Corp.	1971	Salem, MA	12	1	www.daedalon.com	Ultrasonic Imaging
Davidson Optronics, Inc.	1969	West Covina, CA	22	2	www.davidsonoptronics.com	Laser Interferometry
Decade Optical Systems, Inc.	1990	Albuquerque, NM	49	4	www.sslasers.com	Laser Interferometry
Delft Electronic Products B.V.	1990	Roden, Netherlands	100	n.a.	www.delftinstruments.nl	Ultraviolet Imaging
DRS Technologies, Inc.	1968	Parsippany, NJ	5,700	517	www.drs.com	Long Wave Infrared Imaging
- DRS Infrared Technologies	1998	Parsippany, NJ; Dallas, TX	238	55	www.drs.com	Staring Dual Band IR Arrays Near IR Imaging
E. I. Du Pont De Nemours & Company	1802	Wilmington, DE	79,000	24,522	www.dupont.com	Maser
Eastman Kodak	1880	Rochester, NY	70,000	13	www.kodak.com	Hyperspectral Imager
Ebara Solar, Inc.	1993	Belle Vernon, PA	87	5	www.ebarasolar.com	Active Electronically Scanned Array
Ecertec, Ltd.	2000	Leeds, UK	n.a.	n.a.	www.ecertec.com	Lightweight, Broadband, Variable-Depth Sonar
Edmund Optics, Inc.	1942	Barrington, NJ	350	46	www.edmundoptics.com	Ultraviolet Imaging
EDO Corp.	1925	New York, NY	1,931	329	www.edocorp.com	Passive RF Emitter-related Sensors
- EDO Electro-Ceramic Products	1958	Salt Lake City, UT	200	14	www.edoceramic.com	Lightweight, Broadband, Variable-Depth Sonar

[1] **Companies listed are representative; the list is not exhaustive. Inclusion or exclusion does not imply future business opportunities with or endorsement by DoD.**

Sources: SEC Filings, Orbis Bureau van Dijk databases, RDS Business and Industry database, LexisNexis Academic Universe, S&P reports, Hoover's, US Major Companies Database, Yahoo Finance, US Business Directory, Dun & Bradstreet, and First Equity research.

Technology Suppliers [1]						
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**	**Technology**
E2V Technologies Ltd.	1947	Chelmsford, UK	1,279	117	e2vtechnologies.com	Active Electronically Scanned Array
Elisra Electronic Systems Ltd.	1966	Bnai Brak, Israel	1,600	357	www.elisra.com	Passive RF Emitter-related Sensors
EL-OP Electro-Optics Industries Ltd.	1999	Rehovot, Israel	120	271	el-op.co.il	Laser Interferometry
EMR Corp.	1980	Phoenix, AZ	28	2	www.emrcorp.com	Maser
EMS Technologies	1968	Norcross, GA; Montreal, Quebec; Ottawa, Ontario	1,700	310	www.ems-t.com	Active Electronically Scanned Array
Equilasers, Inc.	1994	Santa Clara, CA	7	2	www.equilasers.com	Laser Induced Breakdown Spectroscopy
ERA Technology	1920	Leatherhead, UK	314	34	www.era.co.uk	Ground Penetrating Radar
Ericsson Microwave Systems AB	1929	Molndal, Sweden	1,500	1,036	www.ericsson.com/microwave	Active Electronically Scanned Array
European Aeronautic Defense and Space Company (EADS)	2000	Paris, France	103,967	31,753	www.eads.com	Ground Penetrating Radar
- EADS Astrium Ltd.	1989	Stevenage, UK	2,984	471	www.astrium-space.com	Ground Penetrating Radar
EWA, Inc.	1977	Herndon, VA	100	5	www.ewa.com	Passive RF Emitter-related Sensors
Excel Precision Corp.	1984	Santa Clara, CA	25	2	www.excelprecision.com	Laser Interferometry
Exponential Energy LLP	n.a.	Austin, TX	n.a.	n.a.	www.exponentialenergy.com	Laser Induced Breakdown Spectroscopy
Frequency Electronics Inc.	1961	Mitchel Field, NY	340	32	www.freqelec.com	Atomic Clock
Filtronic Plc	1994	Shipley, UK	2,900	400	www.filtronic.com	Foliage Penetrating SAR Active Electronically Scanned Array
FireComms Ltd.	n.a.	Cork, Ireland	n.a.	n.a.	www.firecomms.com	Laser Interferometry
Flight Landata, Inc.	1991	Lawrence, MA	n.a.	n.a.	www.flidata.com	Hyperspectral Imager
FLIR Systems, Inc.	1978	Portland, OR	480	261	www.flir.com	Near IR Imaging Long Wave Infrared Imaging
- Indigo Systems Corp.	1996	Goleta, CA; Santa Barbara, CA	192	55	www.indigosystems.com	Long Wave Infrared Imaging Long Wave Infrared Imaging Near IR Imaging
Fujian JDSU CASIX, Inc.	1992	Fuzhou, China	460	5	www.casix.com	Laser Interferometry
Fuji Photo Optical Co, Ltd.	1934	Saitama, Japan	3,200	1,123	www.fujinon.co.jp	Laser Interferometry
Gage Applied, Inc.	1987	Lachine, Canada	75	7	www.gage-applied.com	Ground Penetrating Radar
GE Panametrics Inc.	1960	Waltham, MA	1,000	100	www.panametrics.com	Ultrasonic Imaging
GeoAcoustics, Ltd.	1991	Great Yarmouth, UK	35	n.a.	www.geoacoustics.com	Sonar
Geophysical Survey Systems	1990	North Salem, NH	53	8	www.geophysical.com	Ground Penetrating Radar
GER Corp.	1977	Millbrook, NY	35	5	www.ger.com	Hyperspectral Imager
Global Precision Optics	1991	Anderson, SC	4	2	www.globalprecisionoptics.com	Ultraviolet Imaging
Goodrich Corp.	1870	Charlotte, NC	22,900	3,910	www.goodrich.com	Hyperspectral Imager
Halliburton Co.	1919	Houston, TX	83,000	12,572	www.halliburton.com	Laser Induced Breakdown Spectroscopy
- Halliburton Energy Services, Inc.	1996	Houston, TX	6,065	372	www.halliburton.com	Laser Induced Breakdown Spectroscopy
Hamamatsu Corp.	1953	Hamamatsu, Japan	2,772	493	www.hpk.co.jp	Hyperspectral Imager Ultraviolet Imaging
Hamamatsu Photonics K.K.	1953	Hamamatsu, Japan	2,130	430	www.hamamatsu.com	Near IR Imaging
Harris Corp.	1926	Melbourne, FL	9,700	1,876	www.harris.com	Active Electronically Scanned Array
Hewlett-Packard	1939	Palo Alto, CA	141,000	56,588	www.hp.com	Atomic Clock
Hexamite	n.a.	Umina, Australia	n.a.	n.a.	www.hexamite.com	Ultrasonic Imaging
High Power Devices, Inc.	1994	North Brunswick, NJ	20	3	www.hpdinc.com	Laser Interferometry

[1] **Companies listed are representative; the list is not exhaustive. Inclusion or exclusion does not imply future business opportunities with or endorsement by DoD.**

Sources: SEC Filings, Orbis Bureau van Dijk databases, RDS Business and Industry database, LexisNexis Academic Universe, S&P reports, Hoover's, US Major Companies Database, Yahoo Finance, US Business Directory, Dun & Bradstreet, and First Equity research.

Technology Suppliers [1]

Company Name	Est.	Location	Employees	Sales (US$M)	Website	Technology
Hitachi Ltd.	1920	Ibaraki-ken, Japan	339,572	26,417	www.hitachi.com	Interferometric Fiber Optic Gyroscope
Holo-Or, Ltd.	1989	Rehovot, Israel	n.a.	n.a.	www.holoor.co.il	Laser Interferometry
Honeywell VCSEL Optical Products	1899	Morristown, NJ; Richardson, TX; Phoenix, AZ	108,000	22,274	content.honeywell.com/vcsel	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques Laser Interferometry Interferometric Fiber Optic Gyroscope
Hudson Research Inc.	1992	New Rochelle, NY	n.a.	n.a.	www.hudsonresearch.com	Hyperspectral Imager
ILC Industries Inc.	1984	Bohemia, NY	997	76	n.a.	Active Electronically Scanned Array
- ILC Dover	1947	Dover, DE	n.a.	n.a.	www.ilcdover.com	Active Electronically Scanned Array
Imagenex Technology Corp.	n.a.	Port Coquitlam, BC	16	4	www.imagenex.com	Sonar
Imasonic S.A.	1989	Besançon, France	48	4	www.imasonic.com	Active Electronically Scanned Array
Imego AB	1999	Göteborg, Sweden	20	2	www.imego.se	MEMS Inertial Navigation System
Imperium, Inc.	1996	Silver Spring, MD	7	4	www.imperiuminc.com	Ultrasonic Imaging
Imagilent	1986	Pittsford, NY	30	3	www.imagilent.com	Ultrasonic Imaging
Infrared Components Corp.	1991	Utica, NY	20	4	www.infraredcomponents.com	Infrared Sensors
Infrared Integrated System (IRISYS)	1996	Towchester, UK	n.a.	2	www.irysis.co.uk	Long Wave Infrared Imaging
Infrared Optical Products	n.a.	Farmingdale, NY	1	0	www.infraredopticalproducts.com	Near IR Imaging Staring Dual Band IR Arrays
Instrument Systems	1986	Munich, Germany	28	5	www.instrumentsystems.de	Hyperspectral Imager
Integrated Spectronics Pty Ltd.	1989	Baulkham Hills, Australia	n.a.	n.a.	www.intspec.com	Hyperspectral Imager
Intellite, Inc.	2000	Albuquerque, NM	n.a.	n.a.	www.intellite.com	Laser Interferometry
Interquip Ltd.	1978	Hong Kong, China	n.a.	18	www.interquip.com	Maser
- Interquip Electronics (Shenzhen) Co. Ltd.	1986	Guandong Province, China	370	n.a.	www.interquip.com	Maser
Irvine Sensors	1980	Costa Mesa, CA	90	11	www.irvine-sensors.com	MEMS Inertial Navigation System
IQE	1999	Cardiff, Wales	400	35	www.iqep.com	Laser Interferometry
Itres Research	1979	Alberta, Canada	25	3	www.itres.com	Hyperspectral Imager
Ixsea	2000	Marly-le-Roi, France	26	4	www.ixsea-oceano.com	Interferometric Fiber Optic Gyroscope
Janos Technology, Inc.	2000	Townsend, VT	69	8	www.janostech.com	Long Wave Infrared Imaging
Japan Aviation Electronics Industry, Ltd.	1953	Tokyo, Japan	4,146	634	www.jae.co.jp/e-top	Interferometric Fiber Optic Gyroscope
- JSR Ultrasonics	1986	Pittsford, NY	30	n.a.	www.jsrultrasonics.com	Ultrasonic Imaging
Kearfott Guidance and Navigation Corp.	1988	Wayne, NJ	1,500	185	www.kearfott.com	MEMS Inertial Navigation System
Kernco, Inc.	1978	Danvers, MA	15	1	www.kernco.com	Atomic Clock
Kestrel Corp.	1993	Albuquerque, NM	25	2	www.kestrelcorp.com	Active Hyperspectral Imager Hyperspectral Imager
KI4U, Inc.	1999	Gonzales, TX	10	8	www.ki4u.com	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
Koden Electronics Co.	1947	Yamanashi-ken, Japan	281	52	www.koden-electronics.co.jp	Ground Penetrating Radar
KODO Technical Research Co., Ltd.	1997	Kyunggi-do, Korea	13	1	www.kodotr.co.kr	Ultrasonic Imaging

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Technology Suppliers [1]						
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**	**Technology**
Kongsberg Maritime	n.a.	Horten, Norway	2,425	3,603	www.kongsberg-simrad.com	Synthetic Aperture Sonar
KVARZ	n.a.	Nizhny Novgorod, Russia	n.a.	n.a.	www.kvarz.ru	Maser
KVH Industries, Inc.	1978	Middletown, RI	224	48	www.kvh.com	Interferometric Fiber Optic Gyroscope
Kyocera	1959	Kyoto, Japan	47,666	3,744	global.kyocera.com	Active Electronically Scanned Array
L'Garde, Inc.	1971	Tustin, CA	16	3	www.lgarde.com	Active Electronically Scanned Array
L-3 Communications	1997	New York, NY	27,000	4,010	www.l-3com.com	Passive RF Emitter-related Sensors Lightweight, Broadband, Variable-Depth Sonar
- Applied Physics Specialties	1964	Don Mills, Canada	55	2	www.apphysic.com	Long Wave Infrared Imaging
- L3 Randtron Antenna Systems	1972	Menlo Park, CA	n.a.	n.a.	www.l-3com.com/randtron	Ground Penetrating Radar
Laser 2000, Ltd.	n.a.	UK	n.a.	n.a.	www.laser2000.co.uk	Laser Interferometry
Laser Analysis Technologies, P/L	n.a.	Bayswater, Australia	n.a.	n.a.	www.laseranalysis.com	Biosensor: Laser Induced Breakdown Spectroscopy
Laser Components, GmbH	1982	Germany	60	11	www.lasercomponents.de	Laser Interferometry
Laser Industries Ltd.	n.a.	Tel Aviv, Israel	60	25	n.a.	Laser Interferometry
LaVision	1989	Goettingen, Germany	35	n.a.	www.lavision.de	Active Hyperspectral Imager
LeCroy Corp.	1963	Chestnut Ridge, NY	424	112	www.lecroy.com	Ground Penetrating Radar
Light Age, Inc.	1989	Somerset, NJ	30	8	www.light-age.com	Active Hyperspectral Imager
Lockheed Martin Corp.	1912	Bethesda, MD	125,000	26,580	www.lockheedmartin.com	Polymerase Chain Reaction Device LIDAR Seekers with Autonomous Target Acquisition
- Lockheed Martin Maritime Systems & Sensors (MS2)	n.a.	Manassas, VA	n.a.	n.a.	n.a.	Lightweight, Broadband, Variable-Depth Sonar
- Lockheed-Martin Space Systems	n.a.	Denver, CO	n.a.	5,300	n.a.	Ground Penetrating Radar
LOT-Oriel	n.a.	Darmstadt, Germany	n.a.	n.a.	www.lot-oriel.com/index.htm	Hyperspectral Imager
Lumenis	2001	New York, NY	1,420	349	www.lumenis.com	Laser Interferometry
Mala GeoScience	n.a.	Mala, Sweden	n.a.	n.a.	www.malags.se	Ground Penetrating Radar
Malibu Research Associates	1975	Calabassas, CA	28	6	www.maliburesearch.com	Ground Penetrating Radar
MARIMATECH	1989	Aarhus, Denmark	n.a.	n.a.	www.marimatech.com	Sonar
Maser Technology (NZ) Ltd.	1983	Auckland, New Zealand	n.a.	n.a.	www.maser.co.nz	Maser
Materials Systems	1991	Littleton, MA	8	2	www.matsysinc.com	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
MBB	n.a.	Munich, Germany	n.a.	n.a.	www.mbb-gelma.de	Active Electronically Scanned Array
McPherson, Inc.	1981	Chelmsford, MA	49	8	www.mcphersoninc.com	Ultraviolet Imaging
Medway Optics	2002	Kent, UK	n.a.	n.a.	www.medwayoptics.com	Near IR Imaging Staring Dual Band Infrared Arrays
Melles Griot, Inc.	1997	Carlsbad, CA	39	425	www.mellesgriot.com	Laser Interferometry
Metratek	n.a.	Hillsboro, OR	1	0	www.metratek.com	Ground Penetrating Radar
MicroInfinity	n.a.	Seoul, South Korea	n.a.	n.a.	www.m-inf.com	MEMS Inertial Navigation System
MicroLas Lasersystem GmbH	1991	Gottingen, Germany	44	13	www.microlas.de	Ultraviolet Imaging
Micronas Semiconductor Holding AG	1989	Zurich, Switzerland	1,687	45	www.micronas.com	Ultraviolet Imaging
Microwave Circuits, Inc.	1994	Washington, DC	60	4	www.micckts.com	Maser
Mission Research Corp.	1970	Santa Barbara, CA; Dayton, OH	520	117	www.mission.com	Foliage Penetrating SAR

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Technology Suppliers [1]						
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**	**Technology**
Mitsubishi Precision Co., Ltd.	1962	Kamakura, Japan	936	180	www.mpcnet.co.jp	Interferometric Fiber Optic Gyroscope
MRTZ	n.a.	Moscow, Russia	n.a.	n.a.	n.a.	Ultrasonic Imaging
MTI-Milliren Technologies, Inc.	1990	Newburyport, MA	68	5	www.mti-milliren.com	Atomic Clock
MTM Power	1990	Germany	113	10	www.mtm-power.com	Lightweight, Broadband, Variable-Depth Sonar
Multispectral Co.	1989	Sao Paulo, Brazil	n.a.	n.a.	www.multispectral.com.br	Ground Penetrating Radar
Neptune Sonar	1990	East Yorkshire, UK	n.a.	n.a.	www.neptune-sonar.co.uk	Lightweight, Broadband, Variable-Depth Sonar
New England Photoconductor	n.a.	Norton, MA	6	n.a.	www.nepcorp.com	Near IR Imaging
New Focus Inc.	1990	San Jose, CA	750	33	www.newfocus.com	Atomic Clock
Northrop Grumman Corp.	1985	Los Angeles, CA	117,300	17,206	www.northgrum.com	Passive Emitter-related Sensors Interferometric Fiber Optic Gyroscope Ground Penetrating Radar Synthetic Aperture Sonar Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques Staring Dual Band Infrared Arrays
- Northrop Grumman Electronic Systems	n.a.	Linthicum, Maryland	22,000	5,339	n.a.	Active Electronically Scanned Array Ground Penetrating Radar
- Northrop Grumman Integrated Systems Sector	n.a.	El Segundo, California	12,000	3,273	n.a.	Active Electronically Scanned Array
- Northrop Grumman Navigation Systems Division	n.a.	n.a.	n.a.	n.a.	n.a.	MEMS Inertial Navigation System
- Northrop Grumman Space Technology	n.a.	Redondo Beach, California	9,000	2,500	n.a.	Active Electronically Scanned Array Active Hyperspectral Imager Hyperspectral Imager
- Northrop Grumman's Systems Development and Technology Division	n.a.	n.a.	n.a.	n.a.	n.a.	Active Electronically Scanned Array
- Westinghouse Communication and Information Systems (CISCO)	n.a.	n.a.	n.a.	n.a.	n.a.	Atomic Clock Active Electronically Scanned Array
Novalux	1996	Sunnyvale, CA	145	13	www.novalux.com	Laser Interferometry
Nuclear Research Corp.	1950	Warrington, PA	225	27	n.a.	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
NUVONYX, Inc.	1997	Bridgeton, MO	17	2	www.nuvonyx.com	Laser Interferometry
Ocean Engineering Group	1995	Long Beach, CA	n.a.	n.a.	www.oceanengineeringgroup.com	Sonar: Synthetic Aperture Sonar
Ocean Optics, Inc.	1989	Dunedin, FL; Netherlands	100	18	n.a.	Laser Induced Breakdown Spectroscopy
OPCO Laboratory Inc.	1976	Fitchburg, MA	20	2	www.opcolab.com	Near IR Imaging Staring Dual Band Infrared Arrays
Optech, Inc.	1974	Toronto, Canada	n.a.	n.a.	www.optech.on.ca	Active Hyperspectral Imager
Optical Coating Laboratory, Inc.	2000	Santa Rosa, CA	1,500	96	www.ocli.com	Laser Interferometry
Optical Device Engineering Corp.	n.a.	Tuscon, AZ	n.a.	n.a.	www.odecorp.com	Near IR Imaging
Opto-Knowledge Systems, Inc.	n.a.	Torrance, CA	n.a.	625	www.techexpo.com/firms/oksi.	Hyperspectral Imager Active Hyperspectral Imager
Orca Photonic Systems	1993	Redmond, WA	9	2	www.orcaphoton.com	Active Hyperspectral Imager
ORZIV Ltd.	n.a.	Beit Aran, Israel	n.a.	n.a.	www.orziv.com	Laser Interferometry

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Technology Suppliers [1]						
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**	**Technology**
Oscilloquartz	1949	Neuchâtel, Switzerland	n.a.	n.a.	www.oscilloquartz.com	Atomic Clock
Pacific Wave Industries	1995	Los Angeles, CA	20	2	www.pacificwaveind.com	Active Electronically Scanned Array
Packaging Technologies and Inspection, LLC	n.a.	Tuckahoe, NY	n.a.	n.a.	www.packagingtechnologies.com	Ultrasonic Imaging
Patria	n.a.	Tampere, Finland	83	5	n.a.	Lightweight, Broadband, Variable-Depth Sonar
PerkinElmer, Inc.	1947	Wellesley, MA; Fremont, CA	10,700	1,504	www.perkinelmer.com	Hyperspectral Imager Atomic Clock
Photon, Inc.	1980	San Jose, CA	20	2	www.photon-inc.com	Ultraviolet Imaging
Photonic Systems, Inc.	1998	Burlington, Ma	12	1	www.photonicsinc.com	Active Electronically Scanned Array
Physical Sciences Inc.	1973	Andover, MA; San Ramon, CA	150	25	www.psicorp.com	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques Active Hyperspectral Imager
Physik Instrumente GmbH	1970	Karlsruhe, Germany; Palmback, Germany	112	24	www.physikinstrumente.com	Near IR Imaging
- Polytec PI, Inc.	n.a.	Tustin, Ca; Auburn, MA	35	24	www.polytecpi.com	Near Infrared Imaging Staring Dual Band Infrared Arrays
Picometrics SA	n.a.	Ramonville, France	n.a.	n.a.	www.picometrics.com	Active Hyperspectral Imager
Picosecond Pulse Labs	1980	Boulder, CO	n.a.	n.a.	www.picosecond.com	Ground Penetrating Radar
Piezo Technologies	1999	Indianapolis, IN	65	7	www.piezotechnologies.com	Ultrasonic Imaging
Plextek Ltd.	1989	Essex, UK; Great Chesterford, UK	88	9	www.plextek.com	Active Electronically Scanned Array Ground Penetrating Radar
Precision Time and Frequency, Inc.	n.a.	Peabody, MA	n.a.	n.a.	n.a.	Maser
PulsiCom	n.a.	Israel	n.a.	n.a.	n.a.	Ground Penetrating Radar
PVP Advanced EO Systems, Inc.	n.a.	Orange, CA	28	3	www.pvpaeo.com	Long Wave Infrared Imaging
Qdrive	n.a.	Troy, NJ	n.a.	n.a.	www.qdrive.com	Infrared Sensor
QinetiQ, Ltd.	n.a.	Farnborough, UK	9,000	931	www.qinetiq.com	Staring Dual Band Infrared Arrays
- Quantum Electronics & Sensor Technologies (Quest)	n.a.	Malvern, UK	n.a.	n.a.	www.electro-optics.co.uk	Long Wave Infrared Imaging
QorTek, Inc.	n.a.	Williamsport, PA	n.a.	n.a.	www.qortek.com	Lightweight, Broadband, Variable-Depth Sonar
Quartzlock, Ltd.	n.a.	Totnes Devon, UK	n.a.	n.a.	www.quartzlock.com	Maser
Questar Corp.	1950	New Hope, PA	20	1	www.questarcorporation.com	Ultraviolet Imaging
QWIP Technologies	n.a.	Altadena, CA	7	2	www.qwip.com	Long Wave Infrared Imaging
Radant Technologies, Inc.	1979	Stow, MA	80	9	www.radanttechnologies.com	Ground Penetrating Radar
RAE Systems, Inc.	1991	Sunnyvale, CA	295	21	www.raesystems.com	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
RAMET C.H.M.	1992	Zlin Region, Czech Republic	225	168	www.rametchm.cz	Passive RF Emitter-related Sensors

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Technology Suppliers [1]						
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**	**Technology**
Raytheon	1922	Falls Church, VA	76,400	16,760	www.raytheon.com	Infrared Sensors Long Wave Infrared Imaging Passive RF Emitter-related Sensors Ground Penetrating Radar
- Raytheon ELCAN Systems	1952	Richardson, TX	200	15	www.elcan.com	Long Wave Infrared Imaging
- Raytheon Electronic Systems	n.a.	n.a.	n.a.	9,018	n.a.	Active Electronically Scanned Array Synthetic Aperture Sonar
- Raytheon Infrared Operations (SBRC)	n.a.	Goleta, CA	n.a.	n.a.	n.a.	Near IR Imaging
- Raytheon Missile Defense Systems	n.a.	n.a.	n.a.	3,038	n.a.	Active Electronically Scanned Array
- Raytheon Space and Airborne Systems (SAS)	n.a.	El Segundo, CA	n.a.	3,243	n.a.	Active Electronically Scanned Array LIDAR Seekers with Autonomous Target Acquisition
Research International	n.a.	Monroe, WA	n.a.	n.a.	www.resrchintl.com	Polymerase Chain Reaction Device
Ricciardi Technologies	1992	Fairfax, VA	29	5	www.rti-world.com	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
Ricor	n.a.	En Harod Ihud, Israel	n.a.	n.a.	www.ricor.com	Infrared Sensor
Rockwell Collins	n.a.	Cedar Rapids, IA	14,500	2,500	www.rockwellcollins.com	MEMS Inertial Navigation System
- Rockwell Scientific	n.a.	Thousand Oaks, CA	450	48	www.rsc.rockwell.com www.rockwellscientific.com	Long Wave Infrared Imaging Near IR Imaging Staring Dual Band Infrared Arrays Ultraviolet Imaging Active Electronically Scanned Array
Royal Dutch/Shell Group	n.a.	The Hague, Netherlands	117,000	179,431	www.shell.com	Laser Induced Breakdown Spectroscopy
Russian Institute for Radionavigation and Time (RINT)	1956	St. Petersburg, Russia	n.a.	n.a.	www.rirt.ru	Atomic Clock
Saint-Gobain Crystals & Detectors	n.a.	Denver, CO	6,250	1	www.bicron.com	Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques
SatCon Technologies	1985	Cambridge, MA	280	42	www.satcon.com	MEMS Inertial Navigation System
Schott Glas	1884	Mainz, Germany	19,786	1,893	www.schott.com	Laser Interferometry
Sciencetech, Inc.	1985	Concord, Canada; London, UK	20	1	www.sciencetech-inc.com	Hyperspectral Imager
Scientific Imaging Technologies	1993	Tigard, OR	n.a.	n.a.	www.site-inc.com/index2.html	Hyperspectral Imager Ultraviolet Imaging
Scientific Research Institute of Instrument Engineering (NIIP)	1944	Moscow, Russia	n.a.	n.a.	n.a.	Active Electronically Scanned Array
SCIOPT Enterprises	1982	San Jose, CA	n.a.	n.a.	www.sciopt.com	Hyperspectral Imager
Semi-Conductor Devices (SCD)	1976	Haifa, Israel	315	60	www.scd.co.il	Laser Interferometry
Sensors Unlimited, Inc.	1991	Princeton, NJ	45	5	www.sensorsinc.com	Near IR Imaging
Sextant Labs, Inc.	n.a.	Colorado Springs, CO	n.a.	n.a.	www.sextantlabs.com	Laser Interferometry
Silicon Sensing Systems	1998	Plymouth, England	25	52	www.siliconsensing.com	MEMS Inertial Navigation System
Sira Electro-Optics, Ltd.	1918	Chislehurst, UK	41	4	www.siraeo.co.uk	Active Hyperspectral Imager Hyperspectral Imager
Smiths Detection	1950	London, UK	276	84	www.smiths-detection.com	Polymerase Chain Reaction Device Laser Induced Breakdown Spectroscopy Passive Acoustic, Seismic and Electromagnetic Sensors and Effluent Sensing Techniques

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Technology Suppliers [1]						
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**	**Technology**
Sofradir	1986	Paris, France; Chatenay-Malabry, France	n.a.	n.a.	www.sofradir.com	Long Wave Infrared Imaging Near IR Staring Dual Band Infrared Arrays
Sollid Optics, Inc.	1985	Los Alamos, NM	n.a.	n.a.	www.sollidoptics.com	Laser Induced Breakdown Spectroscopy
Sonaer Ultrasonics	n.a.	Farmingdale, NY	n.a.	n.a.	www.sonozap.com	Ultrasonic Imaging
Sophia Wireless	1997	Chantilly, VA	7	1	www.sophiawireless.com	Active Electronically Scanned Array
SP3 Optics	n.a.	UK	n.a.	n.a.	www.sp3plus.co.uk	Laser Interferometry
Spectra Physics	1961	Mountain View, CA	800	65	www.spectraphysics.com	Laser Induced Breakdown Spectroscopy Laser Interferometry
- CIDTEC	1987	Liverpool, NY	25	4	www.cidtec.com	Laser Induced Breakdown Spectroscopy
- Corion Corp.	1969	Franklin, MA	75	6	www.corion.com	Laser Induced Breakdown Spectroscopy
- Hilger Crystals, Ltd.	1874	Margate, UK	n.a.	n.a.	www.hilger-crystals.co.uk	Laser Induced Breakdown Spectroscopy
- Laser Science, Inc.	1981	n.a.	n.a.	n.a.	www.spectraphysics.com/lsi-jumppage.html	Laser Induced Breakdown Spectroscopy
- Richardson Gratings	1947	Rochester, NY	150	45	www.gratinglab.com	Laser Induced Breakdown Spectroscopy
Spectracom Corp.	2000	Rochester, NY	40	4	www.spectracom.com	Atomic Clock
Spectral Applied Research Inc.	1989	Concord, Canada	7	n.a.	www.spectral.ca	Active Hyperspectral Imager
SRI International	1946	Menlo Park, CA	1,400	180	www.sri.com	Laser Induced Breakdown Spectroscopy
SRS Technologies	1970	Newport Beach, CA	535	74	www.srs.com	Active Electronically Scanned Array
Stanford Research Systems	1980	Sunnyvale, CA	47	15	www.thinksrs.com	Atomic Clock
Star Tech Instruments	n.a.	Danbury, CT	n.a.	n.a.	www.startechinstruments.com	Ultraviolet Imaging
Stirling Technology, Inc.	1984	Athens, OH	15	4	www.stirling-tech.com	Infrared Sensor
Sumitomo Heavy Industries Group	1934	Tokyo, Japan	11,777	3,704	www.shi.co.jp	Infrared Sensor
Surface Optics Corp.	1977	San Diego, CA	30	5	www.surfaceoptics.com	Hyperspectral Imagery: Optical Spectrometer
Swales Aerospace	1978	Beltsville, MD	950	144	www.swales.com	MEMS Inertial Navigation System
Symmetricom, Inc.	1956	San Jose, CA	900	73	www.symmetricom.com	Atomic Clock Maser
- Datum Systems Inc.	1996	San Jose, CA	6	2	www.datum.com	Atomic Clock Maser
Systems Planning and Analysis, Inc.	1972	Alexandria, VA	250	35	www.spa.com	Laser Induced Breakdown Spectroscopy
T - CZ, Ltd.	n.a.	Praha 4, Czech Republic	220	162	www.tcz.cz	Maser
Technology Service Corp.	1993	Silver Spring, MD	250	35	www.tsc.com	Foliage Penetrating SAR
Tektronix, Inc.	1946	Beaverton, OR	4,165	843	www.tek.com	Ground Penetrating Radar
Telic Optics, Inc.	1986	North Billerica, MA	30	6	www.telic.com	Long Wave Infrared Imaging
Temex	1997	Sevres, France	25	91	www.temex-components.com	Atomic Clock
Thales Group	1968	France	10,678	60,662	www.thalesgroup.com	Active Electronically Scanned Array Staring Dual Band Infrared Arrays Foliage Penetrating SAR
- Thales Optics	1966	Rhyl, Wales	450	64	www.thales-optics.co.uk	Near IR Imaging Staring Dual Band Infrared Arrays
- Thales Optronics	1888	Glasgow, Scotland	4,400	592	www.thales-optronics.com	Long Wave Infrared Imaging
- Thales Underwater Systems	1995	Valbonne, France	1,150	145	www.tms-sonar.com/index2.php	Lightweight, Broadband, Variable-Depth Sonar

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Technology Suppliers [1]						
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**	**Technology**
The Aerospace Corp.	1960	El Segundo, CA	3,260	506	www.aero.org	Atomic Clock
Time Domain Corp.	1987	Huntsville, AL	93	1	www.timedomain.com	Ground Penetrating Radar
Toshiba Corp.	1904	Tokyo, Japan	166,000	23,977	www.toshiba.com	Active Electronically Scanned Array
Tradeways Ltd.	1974	Annapolis, MD	10	3	www.tradewaysusa.com	Polymerase Chain Reaction Device
TRS Ceramics, Inc.	1991	State College, PA	34	3	www.trsceramics.com	Lightweight, Broadband, Variable-Depth Sonar
TXC Corp of Taiwan	1983	Taipei City, Taiwan	582	n.a.	www.txc.com.tw/index_e2.htm	Atomic Clock
Tyco International	1960	Princeton, NJ	267,500	35,590	www.tyco.com	Active Electronically Scanned Array
- M/A-COM	1999	Lowell, MA	4,000	308	www.macom.com	Active Electronically Scanned Array
ULIS	1983	Veurey-Voroize, France	30	5	www.ulis-ir.com	Long Wave Infrared Imaging Near IR Imaging
ULM Photonics	2000	Ulm, Germany	n.a.	n.a.	www.ulm-photonics.de	Laser Interferometry
Ultra-Lum, Inc.	1988	Claremont, CA	15	1	www.ultralum.com	Ultraviolet Imaging
Veeco Instruments, Inc.	1998	Woodbury, NY	1,460	298	www.veeco.com.	Laser Interferometry
von Horner & Sulger GmbH	1971	Schwetzingen, Germany	20	n.a.	www.vh-s.de	Hyperspectral Imager
Western Marine Electronics	1965	Woodinville, WA	n.a.	n.a.	www.wesmar.com	Sonar
XenICs nv	n.a.	Leuven, Brussels	n.a.	n.a.	www.xenics.com	Long Wave Infrared Imaging Near IR Imaging
Zaslon	n.a.	Russia	n.a.	n.a.	n.a.	Active Electronically Scanned Array
Zarlink Semiconductor,	n.a.	Ottawa, Canada	n.a.	194	www.zarlink.com	Laser Interferometry

[1] **Companies listed are representative; the list is not exhaustive. Inclusion or exclusion does not imply future business opportunities with or endorsement by DoD.**

Sources: SEC Filings, Orbis Bureau van Dijk databases, RDS Business and Industry database, LexisNexis Academic Universe, S&P reports, Hoover's, US Major Companies Database, Yahoo Finance, US Business Directory, Dun & Bradstreet, and First Equity research.

APPENDIX D

INNOVATION PROGRAM DESCRIPTIONS

DEPARTMENT OF DEFENSE: SELECT INNOVATION FUNDING PROGRAMS

Quick Reaction Special Projects Fund

The Quick Reaction Fund (QRF) is one of three projects in the Quick Reaction Special Projects program. Each project is designed to address different issues with technology transition. The other two projects are Defense Acquisition Challenge program and the Technology Transition Initiative. Without adequate funding, there will be a loss of opportunities to maximize the use of evolutionary acquisition through taking advantage of technology breakthroughs and rapidly inserting them into warfighting systems.

The QRF provides the flexibility to respond to emergent DoD issues and addresses technological surprises and needs in real time. With the rate of technology maturation, there is a need to take advantage of technology breakthroughs in rapidly evolving disciplines. This initiative focuses on new ideas or technology opportunities.

The QRF is designed to develop and demonstrate rapidly maturing capabilities within 12 months. The QRF is managed by DDR&E; each proposal is vetted through technology experts and the Joint Staff. Projects selected are expected to demonstrate something within 12 months. The goal is to select and fund a proposal within 30 days; some have gone through in days.

A limited data call was released in January 2003 to nominate promising technologies for FY03 execution. The data call was open ended and was intended to respond to emerging warfighting needs at anytime. The execution process for this initiative consists of both technical and relevance needs reviews conducted by the technology community and the Joint Staff. To date over 200 proposals have been received. Due to the limited amount of funds in FY 03 (~$6M), only 5-6 programs will be funded. Currently the Gryphon, Dragon Eye, Guided Integrated Fuze, Low Cost Guided Imaging Rocket, and WMD Integration Software Tool have been funded at approx. $1M each.

http://www.acq.osd.mil/qrsp/index.html

Quick Reaction Special Projects: Defense Acquisition Challenge Program

The Defense Acquisition Challenge Program (DACP) is funded as one of three projects under the new Quick Reaction Special Projects (QRSP) program. QRSP was created to provide DoD acquisition programs the flexibility to respond to emergent needs within the budget cycle and the opportunity to leverage rapidly evolving technologies. DACP funds the test and evaluation of technologies or products that have the potential to improve performance, affordability, manufacturability, or operational capability of current acquisition programs.

The DACP Program was established in FY03 as a sub-element under the Quick Reaction Special Projects. Direction is provided by Office of the Deputy Under Secretary of Defense (Advanced Systems & Concepts) (AS&C). The program is managed and executed by the Comparative Testing Office (CTO), formerly the Foreign Comparative Testing (FCT) program.

DACP allows any person or organization within or outside the DoD the opportunity to propose enhancements or alternatives to a product, process, or technology at the component, subsystem, or system level that will result in an improvement to performance, affordability, manufacturability, or operational capability.

https://bids.acqcenter.com/dacp

Quick Reaction Special Projects: Defense Technology Transition Initiative

Promising technologies that can improve military capabilities can languish for years waiting for acquisition and operational funding. The Technology Transition Initiative (TTI) addresses the funding gaps that often exist between the time a technology is demonstrated and the time it is procured for use in an intended weapons system.

The Technology Transition Initiative was authorized by Section 242 of the Defense Authorization Act for FY 2003. The purpose of the initiative is to facilitate the rapid transition of new technologies from science and technology into acquisition programs. The statute requires DOD to establish a Technology Transition Manager reporting directly to the Under Secretary of Defense (Acquisition, Technology and Logistics) and a Technology Transition Council consisting of:

- Acquisition Executives from each military department
- Members of the Joint Requirements Oversight Council.
- Science and Technology Executives from each military department and each Defense Agency

The Technology Transition Manager chairs the Technology Transition Council. The manager, in consultation with the council, selects projects to be funded under the initiative.

The TTI program got underway in FY03. Guidance implementing the statutory language was issued and a working group consisting of a representative from each of the Technology Transition Council participants was established to assist the Council in the implementation of the statute. Existing project proposals were used to streamline the process and appropriately take into consideration the war-fighter's priorities without re-tasking.

The working group reviewed unfunded Advanced Concept Technology Demonstration (ACTD) transition issues, Quick Reaction Special Project proposals and existing projects on the Counter Terrorism Task Force list for possible TTI projects, taking into account any changes that may have occurred since the lists were created. In addition, the Services were allowed the opportunity to submit additional proposals. Thirteen projects were selected from these candidates. Incremental funding was used in order to get all 13 projects initiated during FY03.

The working group supporting the council will perform strategic planning to examine alternate methods for identifying promising TTI projects in FY 2004 and beyond. The final plan will be presented to the council for approval.

Advanced Concept Technology Demonstrations Program

Significant changes in threats and an accelerated pace of technology development challenge the Department's ability to effectively respond to rapidly evolving military needs. Major Combatant Commanders require special support for transformational joint capabilities not included in Military Service Program Objective Memorandums for core mission areas. The Advanced Concept Technology Demonstrations (ACTD) program rapidly develops, demonstrates and fields new technological capabilities and complementary concept of operations to the warfighter in response to Joint Requirements Oversight Council (JROC) validated joint requirements.

The ACTD program is rapidly and continually fielding technologies that are: transformational, combat terrorism and protect our homeland. The program was initiated in 1994. Thirty-six months later, the program yielded the Predator unmanned aerial vehicle. By 1999, 20 percent of the ACTD products were deployed in support of Operation Allied Force, NATO's intervention in Kosovo. From 2001 through 2003, products from over 30 ACTDs were deployed in support of Operation Enduring Freedom in Afghanistan, Operation Noble Eagle in the United States and Operation Iraqi Freedom. To date, 129 ACTDs have been initiated. Program participants include the Military Services, Defense and Federal Agencies, Combatant Commanders and Coalition partners.

ACTDs emphasize technology assessment and integration, rather than technology development, by providing prototype capability to the warfighter and supporting the evaluation of the capability. These evaluations include field demonstrations and operational employment in military exercises. ACTDs allow the warfighter to evaluate a technology's military utility before committing to a major acquisition effort; to develop concept of operations for employing this technology; and to retain a low-cost residual operational capability.

ACTDs typically last two to four years through the demonstration of military utility and address a wide range of capabilities, such as: advanced command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) systems, advanced planning, chemical and biological detection systems, unmanned vehicles, force protection, focused logistics, network-centric warfare, homeland security and counter-terrorism efforts. The selection process includes coordination with all the Military Services and Combatant Commanders, followed by the JROC's validation/prioritization, with final approval by the Under Secretary of Defense for Acquisition, Technology, and Logistics, USD (AT&L).

Each year Congress requires DOD to submit an annual report notifying the defense committees of all ongoing and new start ACTDs prior to the program obligating any defense wide Research Development Testing and Evaluation (RDT&E) resources.

http://www.acq.osd.mil/actd/

Defense Production Act, Title III Program

The timely availability of production capabilities is essential to providing the technologies needed for national defense and to maintain the technological and operational superiority. Title III of the Defense Production Act (DPA) provides the Department of Defense with a powerful set of tools to ensure the timely creation and availability of domestic production capabilities to meet defense needs. A key objective of the Title III Program is to accelerate the transition of advanced technologies to affordable production and promote the rapid insertion of these technologies into systems. Congress recently renewed the authority for the DPA by extending it through 2008.

The Title III Program is unique among DOD programs. It is the only program whose focus is on establishing or maintaining a domestic production capacity needed to support national defense requirements. The Title III Program accelerates the transition of science and technology investments by providing domestic industry with a variety of incentives that reduce the risks associated with the capitalization and investments required to establish the needed production capacity. These incentives include purchases or purchase commitments, and the purchase or lease of advanced manufacturing equipment for installation in government or privately owned facilities, and the development of substitutes.

Title III authorities are being used to establish domestic production capabilities for a variety of defense essential technologies. Significant DPA, Title III activities include:

- **Radiation Hardened Capital Expansion (CAPEX) Project –** This project was directed by the Under Secretary of Defense (Acquisition, Technology &

Logistics) and is modernizing and upgrading the obsolescent manufacturing facilities of the remaining domestic radiation hardened microelectronics producers to enable them to produce the advanced radiation hardened microelectronic devices needed to meet the performance requirements of defense space and missile systems.

- **Radiation Hardened Microprocessor –** This project began in 2003 and will enable a new generation of radiation hardened computers for space applications. The current generation of radiation hardened computers does not have the processing power needed for future space systems.

http://www.dtic.mil/dpatitle3/

Small Business Innovation Research and Small Business Technology Transfer Programs

Established in 1983 by Public Law (PL) 97-219, the DoD Small Business Innovation Research (SBIR) Program funds early-stage research and development (R&D) projects at small technology companies—projects which serve a DoD need and have the potential for commercialization in private sector and/or military markets. The program, funded at approximately $850 million per year, is part of a larger (approximately $2 billion) federal SBIR program administered by ten federal agencies.

In 1992, through PL 302-564, Congress established the Small Business Technology Transfer (STTR) program on a pilot basis. STTR is similar in structure to SBIR but funds *cooperative* R&D projects involving a small business and a university, federally-funded R&D center, or non-profit research institution.

The Department is required by law to allocate 2.5 percent of its extramural research, development, test and evaluation (RDT&E) budget (6.1 through 6.7) in each fiscal year to fund R&D projects with small businesses through the DoD SBIR program, and 0.3 percent to fund the STTR program. The Department delegates to each Military Department and Defense Agency which has in excess of $100 million RDT&E funds the responsibility for assessing its own extramural RDT&E budget and allocating the resulting SBIR funds within the Department/Agency.

As part of its SBIR program, the Department issues an SBIR research solicitation, describing its R&D needs and inviting R&D proposals from small companies. Companies apply first for a six-month Phase I award of up to $100,000 to test the scientific, technical, and commercial merit and feasibility of a particular concept. If Phase I proves successful, the company may be awarded a two-year Phase II award of $750,000 to further develop the concept, usually to the prototype stage. Proposals are judged competitively on the basis of scientific and technical merit, qualifications of the company, and commercial potential.

Following completion of Phase II, small companies are expected to obtain funding from the private sector and/or non-SBIR government sources to further develop the concept into a product for sale in private sector and/or military markets. The STTR Program, modeled substantially on the SBIR Program, has only one solicitation per year that solicits proposals that include a cooperative effort between small businesses and research institutions.

The Department has implemented improvements in its SBIR/STTR programs, as well as a new plan for the rapid transition of SBIR technologies into DoD acquisition programs. These improvements were developed in response to section 818 of the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999.

http://www.acq.osd.mil/sadbu/sbir/

Manufacturing Technology (ManTech) Program

Accelerated transition of emerging technologies from the laboratory to product application is vital to ensure the Department retains its warfighting edge. Manufacturing Technology (ManTech) programs mature and validate manufacturing processes for emerging, defense-critical technologies, driving the timeline, affordability, and technology producibility level while shortening upgrade and deployment cycle time for key weapons, subsystems, and components. For example, some ManTech programs focus on motivating defense industry investments in automated, numerically-controlled machine tool fabrication for composite structures; transitioning novel MEMS device fabrication for missiles and precision munitions; and improving welding and joining processes for titanium structures for aircraft and ships.

ManTech implements the Under Secretary of Defense (Acquisition, Technology and Logistics) goals for speeding technology transition from the laboratories to acquisition systems, enabling evolutionary acquisition and improving the health of the industrial base.

The ManTech program is adapting to establish collaborative investments that facilitate evolutionary acquisition and transformation goals, with a focus on accelerating transition of Advanced Technology Demonstrations (ATDs), and Advanced Concept Technology Demonstrations (ACTDs) and other technology-based products to the warfighter. ManTech works to provide effective, timely, and affordable combat power to the warfighters and to reduce the risk associated with achieving mature technology readiness levels.

http://www.dodmantech.com/