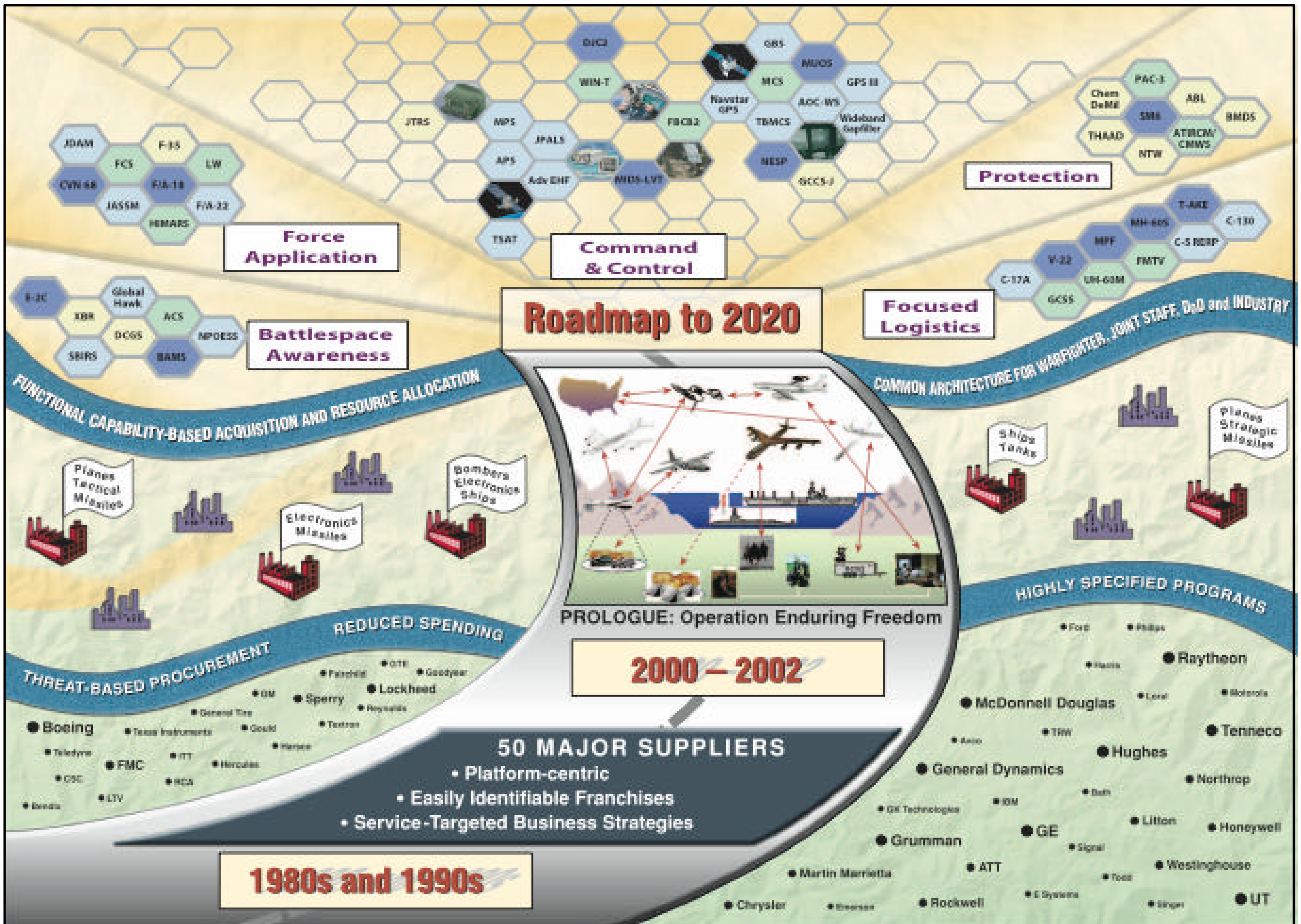

DEFENSE INDUSTRIAL BASE CAPABILITIES STUDY: COMMAND AND CONTROL

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A version of the cover graphic was used in *Transforming the Defense Industrial Base: A Roadmap* (ODUSD(IP), February 2003). This 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 new functional concepts. The top of the landscape shows the major Joint Staff functional concepts where materiel solutions play a major role: Battlespace Awareness, Command and Control, Force Application, Protection, and Focused Logistics, with representative programs indicated for each. Another functional concept, Network Centric Operations, is under development. These functional concepts, along with related joint operating and integrating concepts, are becoming the central theme for Department decision-making. We must stress, however, that these concepts are still evolving and must consider legacy programs, research and development (R&D) inititatives, as well as all new programs that provide 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 January - June 2004. Commander John Zimmerman, USN, led this effort. Lieutenant Colonel Chris Warack, USAF, Rosemary Carpenter, Dawn Vehmeier, Gary Powell, and other Industrial Policy staff also had major roles in the production of this report. Support was provided by Booz Allen Hamilton, Inc. (BAH) and the Institute for Defense Analyses (IDA). Among others, special thanks are due to John Williams and Carmen Alatorre-Martin of BAH, and Jim Woolsey and John Shea of IDA for their important contributions. The team would like to acknowledge the contributions of the four Red Teams, consisting of twenty-four 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. Report inquiries or technical inputs should be directed to Commander Zimmerman at (703) 602-4326 or Lieutenant Colonel Warack at (703) 602-4323.

DEFENSE INDUSTRIAL BASE CAPABILITIES STUDY: COMMAND AND CONTROL

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

JUNE 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 key 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 made in this capabilities-based context. This report deploys a methodology to link warfighting capabilities to industrial base capabilities.

An initial survey of the Joint Command and Control Functional Concept identified 255 capabilities directly enabling American warfighting leadership in this area. To enable these capabilities, 293 technologies qualified as ones where the United States should be ahead of any potential adversary.

An assessment for industrial base sufficiency of the 35 most pressing of these 293 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, and remedy any industrial base deficiencies identified.

Recommendations

1) ODUSD(IP) recommends that the Department implement the remedies in this report to address the industrial base issues identified in the Joint Command and Control Functional Concept area.

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

FOREWORD

Defense Industrial Base Capability Study: Command and Control (DIBCS C2) is the second of a five-part series which assesses the ability of the industrial base to produce the technologies and components most critical for 21st century American warfare as defined by the Joint Staff's functional concepts.[1] The first study in this series on Battlespace Awareness was published in January 2004.[2] Studies on Force Application, Protection, and Focused Logistics[3] will follow in four- to six-month intervals through mid-2005.

TO FOCUS THE DEPARTMENT AND INDUSTRIAL BASE ON 21ST CENTURY WARFIGHTING CAPABILITIES

The major purpose of these studies is to focus the Department and industrial base on areas which we believe to be most important—or which pose potential impediments—to 21st century warfare. In the process, we are also developing a construct which organizes the industrial base into the Joint Staff's functional concepts. This process underway in the Department already is underway in the defense industrial base as most of its major companies are reorganizing to reflect these functional concepts. By translating the Joint Staff's 21st century warfighting concepts into the technology and industrial base vernacular familiar to the inventors, engineers, laboratories, companies, and other participants that constitute the industrial base available to the Department, this body of work on industrial base capabilities reinforces this reshaping of the defense industrial base. For companies yet to become part of the defense industrial base, this defense industrial base capabilities study series should help guide them as to how particular technologies fit into the defense enterprise and which associated industrial capabilities are most crucial for future warfighting. The company compendia included in each study which list some of the companies important to each of the functional capability areas should help all companies better understand their industrial peer group in the functional capabilities construct. As a result, all companies should be able to craft more effective business and investment strategies focused on the Department's warfighting goals.

Within the Department, it is only with the consistent application of this new functional capabilities context at all levels of Department planning and execution—from program managers to contracting officers to senior Department decision-makers—that the

[1] See Chairman of the Joint Chief of Staff's Joint Capabilities and Integration Development System (JCIDS), CJCSI 3170.01C (June 2003), specifically the functional concepts—Battlespace Awareness, Command and Control, Force Application, Protection, and Focused Logistics—where we assess materiel, industrial base capabilities to be most relevant.
[2] This report can be viewed online and downloaded at http://www.acq.osd.mil/ip.
[3] A new functional concept, Network Centric Operations (NCO), is currently being developed. This study is based on the Joint Command and Control Functional Concept, dated February 2004, which at the time of its publishing incorporated some of the capabilities that will eventually migrate to the NCO Functional Concept. As the NCO Functional Concept is finalized, the DIBCS series will be reviewed for completeness in assessing the NCO industrial base capabilities.

Department will be able to effectively draw from the industrial base the functional capabilities required by 21st century warfighters. Existing and new start programs will have to be assessed in the functional capability context, and new processes within the Joint Staff and the Office of the Secretary of Defense are evolving to provide the necessary functional context.

With regard to defense industrial policy formulation, it is our hope that by translating warfighting concepts into industrial and technology vernacular, we will inspire future generations of scientists and industrialists to focus on the technology challenges most important to our national security. The focus on industrial base capabilities in this study series will provide additional rigor to Department policy formulation related to technology investment, program acquisition strategies, mergers and acquisitions, as well as export control. This study reports on two policy enhancements related to make/buy decisions and overall industrial base considerations implemented as a consequence of the *DIBCS BA* study recommendations. Future studies in this series will continue to report on policy and process enhancements important to this transition to a capabilities-based view of the defense enterprise.

We believe that this DIBCS series represents a continuation of the journey we embarked on in our study, *Transforming the Defense Industrial Base: A Roadmap*,[4] both with regard to its explicit recommendations—and its imperative to improve visibility into the military enterprise so that emerging defense suppliers can more readily participate in it.

***Transforming the Defense Industrial Base: A Roadmap* (February 2003) Recommendations:**

Recommendation 1: The Department should view the industrial base as being composed of operational effects-based sectors.

Recommendation 2: The Department should organize its decision-making processes (from program justification through budgeting and acquisition) to optimize operational effects—an integrated view of force structure; not programs, platforms, or weapons systems.

Recommendation 3: The Department should analyze the results of a systematic assessment of critical technology requirements in each operational effects-based sector.

Our work with the Joint Staff's functional concepts has also convinced us that in aggregate these concepts truly provide the "long forward pass" that—if pursued—will ensure that the American way of war remains way ahead of potential adversaries well into the 21st century. Indeed, our translation of the functional capabilities for Battlespace Awareness and Command and Control into the associated warfighting capabilities made clear that these concepts do not focus on the ordinary, mundane capabilities where parity would be sufficient: 82 percent of the capabilities in Battlespace Awareness and 74 percent in Command and Control represent warfighting capabilities where the Department must strive to continue to *be ahead* or *be way ahead* of potential adversaries. The fact that the analysis undertaken by the Senior Advisory

[4] This report can be viewed online and downloaded at http://www.acq.osd.mil/ip.

Group[5] and subject matter experts associated with these studies yielded this focus on the most difficult of military and technology challenges reinforces our view as to the foresight of these concepts.

This series of studies to date also has paid tribute to generations of our Department predecessors and decades of developments in the U.S. defense industrial base. Of the 546 warfighting capabilities and 563 technologies assessed as critical for U.S. military leadership,[6] in only a few areas are there concerns that available industrial capabilities may be insufficient. In the two studies to date, we determined that 469 companies and research institutions (56% U.S. and 44% non-U.S.) are making contributions to these important warfighting capabilities—certainly a solace to those who may fear that the defense industrial base has become too consolidated.

COMMAND AND CONTROL CHALLENGES

Three issues were identified in *DIBCS C2* which, we believe, merit special Department and industrial base attention: helmet mounted displays, optical intersatellite links, and swarming control tools. The latter issue surfaced when we added unmanned platform control as one of the *DIBCS C2* comprehensive capability areas associated with the Joint Command and Control Functional Concept (JC2FC).

Resolving command and control issues involving unmanned platforms is of paramount importance. First, the ability to demonstrate that unmanned platforms can autonomously and collectively control their own actions will exponentially boost planners' and warfighters'—and the public's—confidence that with man-in-the-loop operational concepts, unmanned platforms can be safely controlled and operated. This should lead to much wider acceptance and broad inclusion of unmanned systems in concepts and doctrines currently under development.[7] Second, the associated reduction in military manpower and weapons systems costs, as well as the increase in the expendability of military hardware, will have powerful implications for future force planning. Finally, the psychological impact on our enemies of facing increasingly *unmanned* U.S. military and other security forces is even more powerful.

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[5] For Senior Advisory Group membership, see page 8.

[6] This work has been accomplished over a 15-month period, and has consumed an estimated 10,000 man hours of effort on the part of the Department and contractor personnel.

[7] The FY2001 National Defense Authorization Act stipulated that "It shall be a goal of the Armed Forces to achieve the fielding of unmanned, remotely controlled technology such that…by 2010, one-third of the operational deep strike aircraft of the Armed Forces are unmanned…" While Congress was very forward-thinking in the development of this language, warfighters and planners continue to have safety concerns about operating unmanned vehicles autonomously in commercial air space, particularly when armed. However, future programs such as the Future Combat System, Sea Basing, and other system-of-systems concepts plan to make extensive use of unmanned assets beyond the 2010 timeframe. As these unmanned systems continue to prove their impact and reliability, and warfighters become more confident of their safe use, it may be possible to accelerate their incorporation into warfighting concepts.

Our *DIBCS C2* assessment also reminded us of the importance of commercial Information Technology (IT) to command and control—and overall military—capabilities. We determined that ten commercial IT capabilities are important enablers to U.S. warfighting leadership. For these commercial capabilities, the Department must continue to refine its ability to nimbly access technologies while for the most part leaving them in the commercial sector where they best thrive. We believe that the ability to use commercial technologies in our defense applications will increasingly represent a cost and capability advantage to the U.S. defense enterprise in all areas of warfare. The U.S. defense enterprise must draw on the best that the entire industrial base has to offer. This brings full circle the Department's long-standing commitment to provide the best possible access to emerging defense suppliers to benefit our warfighters.

> *"The energy and vitality that we see in smaller niche segments in our society, in technology, tends not to deal with government because … dealing with government is just a put-off. Who in the world wants to do it if he can avoid it? It's burdensome. It's ugly. It takes forever to get anything done… That means that government tends not to have the kind of interaction with the creativity and innovation that exists in our society."*
>
> – *Donald H. Rumsfeld, Secretary of Defense*
> *November 18, 2002*

Operational concepts demonstrated in recent conflicts should provide ample confidence in our ability to shift to this capabilities-based paradigm. The warfighters who mounted GPS on horseback and whose ingenuity produced so many other winning combinations—military and commercial, proven and untested—demonstrated the extent of the cultural change possible in 21st century warfare. The Joint Staff's functional concepts provide the design for future American warfare. It will be up to the Department to draw the best the industrial base has to offer to realize the capabilities envisioned.

> *"As the first war of this century has unfolded, it has stood many paradigms on their head. This is the war that has really staged 'Generation Digital' warriors with plug-and-play requirements. And it has truly been a come-as-you-are war with a brand new, transformational script. It has been multi-dimensional, unconventional—and asymmetric for our own purposes when required. It put GPS on horseback, Hellfire on unmanned Predators, and made air bosses out of sergeants on the ground as they called in carrier-based weapons an ocean away."*
>
> – *Suzanne D. Patrick, Deputy Under Secretary of Defense for Industrial Policy*
> *January 29, 2002*

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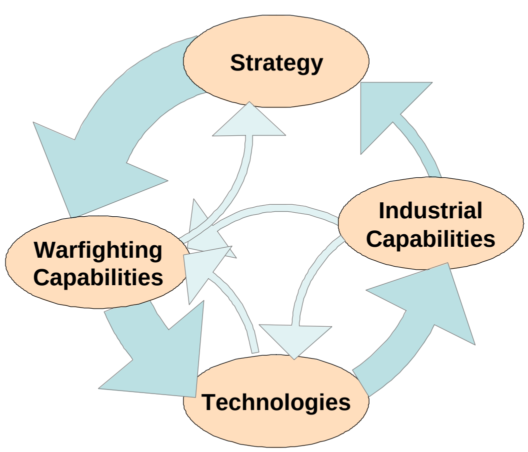
EXECUTIVE SUMMARY

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 is a systematic assessment of critical technologies needed in the 21st century defense industrial base to meet warfighter requirements as framed by the Joint Staff's functional concepts. In addition, the DIBCS series provides the basis for strengthening the industrial base that provides solutions to warfighting needs—and from which the Joint Staff develops its Joint Integrating Concepts and Joint Operating Concepts. This report addresses the second of those functional concepts, Joint Command and Control.

The DIBCS methodology associates enabling technologies with warfighter capabilities and assesses the industrial base's ability 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* capability leadership goal. Technologies 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* capability leadership goal. *Be way ahead* technologies must be highly innovative and often require effective competition among suppliers to be sustained. America's commitment to its warfighters requires the Department of Defense to select the most competitive and innovative suppliers for these technologies.

CAPABILITIES-BASED INFLUENCE CYCLE



Source: ODUSD(IP) and Booz Allen Hamilton

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

Finally, the DIBCS series recognizes that managing key industrial capabilities may require policy implementation; 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. The levers are: (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. The portals are: (1) science and technology; (2) the 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 COMMAND AND CONTROL

This study begins with understanding the Command and Control (C2) functional capability area. C2 capabilities provide the ability to recognize what needs to be done in a situation and to ensure that effective actions are taken. At its core, C2 is about decision-making and the individuals who make decisions. The Joint Staff's JC2FC lays out these warfighting capabilities in six basic C2 processes and seven collaborative C2 processes. The basic C2 capabilities are recognizable to warfighters as a version of the Observe-Orient-Decide-Act loop and capture the continuous and cyclical nature of C2. Collaborative C2 capabilities tie together the basic C2 process loops across echelons and functions. They are designed to provide decision-makers at all levels the flexible and agile command methodology necessary for 21st century warfighting.

COMMAND AND CONTROL RECOMMENDATIONS

The Department is committed to supplying the best technology possible to the warfighter and hundreds of companies around the world provide crucial C2 capabilities to the warfighter. A distinctive aspect of our analysis is the fact that a large portion of warfighting capabilities in the C2 sector are supported by commercial information technology (IT) products which are often foreign—products driven by the needs of the commercial marketplace and generally *not* by DoD requirements. However, as in all matters posing risks to the warfighter, the Department is committed to being vigilant in the use of these commercial products. The Department manifests this vigilance by militarizing commercial products in ways that allow the military capabilities to effectively incorporate commercial innovation; being alert to the composition of the non-U.S. supplier base for reasons of sufficient numbers of sources and security of supply; and recognizing the importance of operational assurance.

Our review identified 255 specific capabilities supporting C2. Of these, 189 were *be ahead* or *be way ahead* warfighting capabilities. Functional analysis of these capabilities yielded 293 associated critical enabling technologies. Of these, we assessed 35 of the most important of these technologies and 23 associated component technologies—for a total of 58 industrial assessments. The health of the defense portion of the C2 industrial base is evident by the small number of issues identified in our assessment. In general, U.S. defense suppliers hold a technological advantage over foreign competitors for C2 military technology.

RECOMMENDATION 1

We identified three industrial capabilities needing additional attention to obtain or sustain the desired degree of U.S. capability leadership or supplier sufficiency. The report recommends funding and other policy remedies to bolster the industrial base for:

- Helmet Mounted Displays used in military aviation and land warfare applications;

- Swarming Control Tools to permit the autonomous control of multiple entities; and

- Optical (Laser) Intersatellite Links, which enable two-way communication paths between satellites.

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.

RECOMMENDATION 2

Within the Department, ODUSD(IP) should continue to be the clearinghouse for industrial base deficiencies. ODUSD(IP) will continue to assess C2 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 of the Force Application, Protection, and Focused Logistics functional capabilities.

ODUSD(IP) maintains insight into Service, Defense Agency, and other Department industrial base activities in its day-to-day responsibilities. This role is Congressionally-mandated in its responsibility for preparing the *Annual Industrial Capabilities Report to Congress*.[9] In addition, in the interagency process, ODUSD(IP) coordinates on industrial base issues affecting the Department. For all of these reasons, ODUSD(IP) is uniquely positioned and qualified to serve in this capacity.

[9] See Section 2504 of Title 10, United States Code.

THE LARGER DIBCS EFFORT

C2 is the second of our industrial base assessments. Over the course of the next year, we will examine three additional functional capability areas. All DIBCS assessments will be informed by Joint Staff and other warfighting concepts that update and further define required warfighting capabilities.

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

PART I

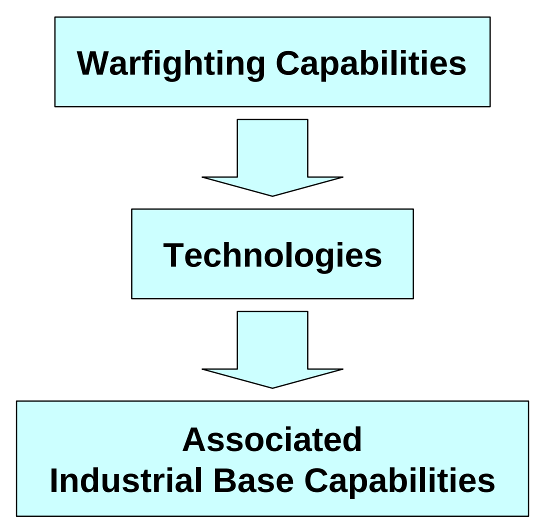
MEETING THE CHALLENGE

Our February 2003 report, *Transforming the Defense Industrial Base: A Roadmap*, reflected a revolutionary warfighting doctrine then germinating within the Department. Since then, the Department has organized around functional concepts defined by the Joint Staff that focus the Department's resources on the most essential operating effects that the U.S. warfighter must deliver in order to win. To assist the industrial base in responding to this new challenge, the DIBCS series communicates these needs and this capabilities-based approach, as well as recommends—and implements, as appropriate—associated policies.

ROADMAP TO THE FUTURE

The DIBCS series represents a structured, top-down analysis and policy framework with which decision-makers can harness the full power of competition to address key warfighting capabilities and unleash innovation in academia, industry, and the Government. The DIBCS series identifies warfighting capabilities, the critical enabling technologies that support those warfighting capabilities, and the industrial base capabilities associated with those technologies. The series also highlights industrial base concerns across life cycles of programs.

DEFENSE INDUSTRIAL BASE CAPABILITIES STUDY TRANSLATION PROCESS



Source: Booz Allen Hamilton and ODUSD(IP)

The Department's move towards capabilities-based planning will fundamentally change the defense enterprise. It is changing the manner in which the Department identifies and prioritizes military capability requirements, focusing its attention on enabling capabilities—often acquired in families- or systems-of-systems. Inherent in this shift are changes in doctrine and the way the Department manages the development and acquisition of these capabilities. How the Department looks at what it has and what it needs will also affect who participates in the defense industrial base—and challenge the Department to make better use of a broader base of suppliers.

The Joint Staff's initial five functional concepts where materiel solutions are most important are: Battlespace Awareness, Command and Control, Force Application, Protection, and Focused Logistics. Our translation of these concepts extends a common and comprehensive vernacular from the operators to the acquirers and industry. The landscape of the future, as depicted on the front cover of this report and illuminated on the front flyleaf, is still evolving. Accordingly, we continue to adjust our industrial capability assessments to reflect the latest evolution of the Joint Staff concepts. This integrated vision will improve the efficiency of resource and operational planning, and associated decision-making and program execution. Applying these tools with diligence will greatly increase the Department's confidence that crucial industrial base capabilities are available when needed to maintain U.S. warfighting superiority over potential adversaries. It will be up to the Department leadership to structure programs that effectively draw on industrial base capabilities to meet warfighters' 21st century requirements.

THE DEFENSE INDUSTRIAL BASE CAPABILITIES STUDY METHODOLOGY

The Department's industrial policy challenge is to evaluate the industrial base in this new capabilities-based framework and to recommend actions and policies to ensure the industrial base can develop the technologies and produce the systems and weapons required.

JOINT STAFF JOINT FUNCTIONAL CONCEPTS[10]	
Battlespace Awareness Global Hawk, DCGS, NPOESS, SBIRS-High, E-2 Advanced Hawkeye	Capabilities of commanders and force elements to understand their environment 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.
Command and Control FBCB2, JTRS, WIN-T, AOC-WS, GCCS, GBS, ADV-EHF, NESP	Capabilities that exercise authority and direction over forces to accomplish a mission. Involves planning, directing, coordinating, and controlling forces and operations. Provides the means to recognize what is needed and ensure that appropriate actions are taken.
Force Application SSGN, DDG 51, JDAM, JSOW, CVN 21, MM III,	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 C-130, CH-47, GCSS, MPF, T-AKE, C-17, FMTV, V-22, MH-60, C-5 RERP	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 Functional Concepts and ODUSD(IP)	

Beginning with Battlespace Awareness and now progressing to Command and Control, the DIBCS series assesses the sufficiency of the most crucial 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*.[11] The methodology is consistent with the operational ethos embodied in the U.S. defense industrial base: warfighting capabilities, and the warfighter as the primary constituent, must drive defense demand and the products the Department acquires.

[10] A sampling of major programs are aligned with each functional concept to provide an illustration of that area's scope. Not all of the warfighter capabilities supplied by a program fall into a single sector, however. All acronyms are defined in the Acronym List beginning on page 45.
[11] Published by Booz Allen Hamilton, August 2002.

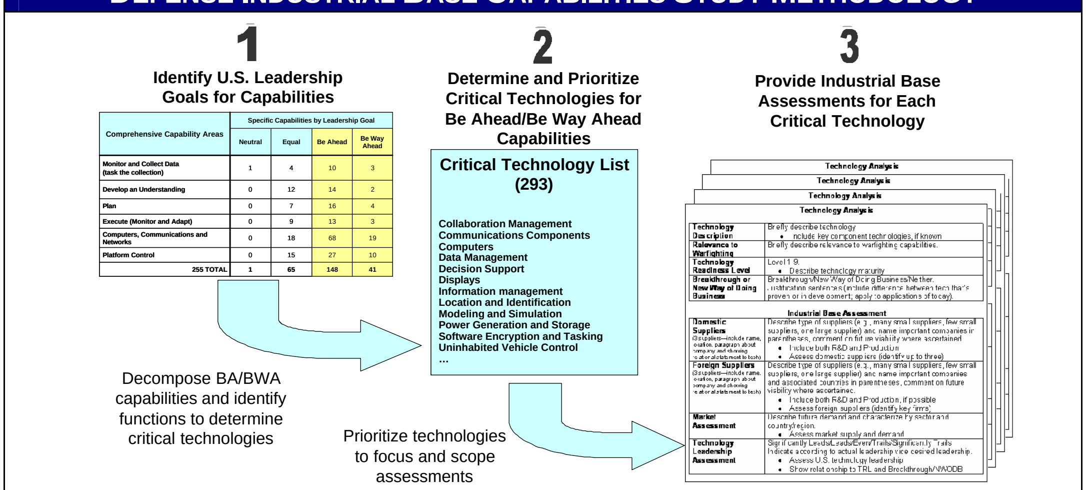
This methodology categorizes warfighter capabilities according to the advantage they give the United States over potential adversaries. As described in the table below, extra attention is focused on those warfighter capabilities where the United States should lead any potential adversary. Less attention 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.

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)	

In addition, operational concepts will change over time, and the Department should focus most on those capabilities where leadership will provide the warfighter the greatest advantage. Our methodology gives added weight to the most important of these technologies. Our objective 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 must have *be ahead* and *be way ahead (BA/BWA)* leadership goals.

Therefore, we focus on the warfighter capabilities where the Department needs to achieve and maintain the greatest lead; then we identify the key technologies that enable those capabilities and provide assessments of the associated industrial base. When an industrial base deficiency—whether immediate or projected—is identified, we examine it in more depth and recommend remedies using the portals and levers available to the Department. This analytical process, summarized in the chart below and elaborated on the next page, has three basic steps: identify warfighter capability leadership goals; determine and prioritize associated technologies; and assess the industrial base associated with those technologies.

Defense Industrial Base Capabilities Study Methodology



Source: Booz Allen Hamilton and ODUSD(IP)

1. Identify U.S. Leadership Goals for Warfighter Capabilities. This industrial base study series uses research and analysis teams of subject matter experts to identify detailed warfighter capabilities derived from each of the Joint Staff's functional concepts. 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.[12]

DIBCS C2* 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* ***LTG (Ret) Robert Noonan*** [(a)] *Deputy Chief of Staff, Intelligence, Army* *Commander, Army Intelligence and Security Command* *Director of Intelligence, USCENTCOM* ***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. 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 and Prioritize Critical Technologies for *BA/BWA* Capabilities. Next, the team identifies the key enabling technologies for those warfighting capabilities with leadership goals rated *be ahead* or *be way ahead*. The DIBCS SAG oversees a team of subject matter experts to identify and prioritize these technologies, using a variety of sources such as the *Joint Warfighting Science and Technology Plan*. The SAG then establishes the priority of a technology using three factors. The first factor is the importance of the technology in enabling warfighting impact in a breakthrough, transformational, or critically essential manner. Second, they consider the importance of the specific capability the technology enables; it is more important to enable a *Be Way Ahead* than a *Be Ahead* capability. The third factor is the span of impact of the technology in enabling multiple 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 C2, we focused on a limited number of high priority, critical technologies, which we examined in detail. The purpose of the initial assessment is to form a broad understanding of sufficiency and risk in the most important 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. We

[12] See Appendix A for DIBCS Command and Control capability framework.

documented the remaining technologies so they can be addressed to the same level of detail later, as resources permit.

Part of this assessment is to compare domestic industrial capabilities with foreign capabilities. To provide the best capability possible to the warfighter, the Department will look for best value throughout the global industrial base. If the Department uses a foreign supplier to support a *BA/BWA* capability, however, it must manage certain risks that this could entail. Broadly, these risks are: assurance of supply, technology security, and congruency of strategic interests. Assurance of supply relates to having access to the defense products the Department needs when it needs them. Technology security relates to controlling potential adversary access to the U.S. and global industrial base that supplies our warfighters. Congruency of strategic interest describes the desired alignment of corporate interests and strategic planning with U.S. 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 likely leverage the U.S. can have on the focus of foreign sources**.**

JUST THE BEGINNING

We believe that this capabilities-based framework will help decision-makers understand and address industrial base deficiencies. The first round of studies should be completed in 2005. However, this is just the beginning. The baseline will continue to evolve as the Joint Staff implements its joint functional concepts and as the Department simultaneously continues to assess the industrial base supplying those corresponding capabilities. The studies should help companies large and small—and indeed the whole of our defense industrial enterprise—have more direct insight into the crucial industrial base capabilities required for 21st century warfare. This insight should better inform individual firm investment decisions and strategic planning.

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. It also provides a firm basis for identifying industrial base deficiencies and potential remedies.

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Part II

Industrial Base Capabilities in Command and Control

Establishing leadership goals for U.S. warfighting capabilities and understanding the defense programs that will deploy them are crucial to defining technology and industrial base requirements. This study applies the DIBCS methodology to the Command and Control (C2) functional capability area, establishing leadership goals for C2 warfighting capabilities. Using this warfighter capabilities-based analysis, the study identifies technologies which enable the functional concept and provides an assessment of the industrial base for a prioritized subset of those technologies.

Refining the Command and Control Functional Capability Area

C2 is the ability to recognize what needs to be done in a situation and to ensure that effective actions are taken. At its core, C2 is about decision-making and the individuals who make decisions.[13] The Joint Staff, representing the warfighter, has developed the Joint Command and Control Functional Concept (JC2FC). The JC2FC lays out C2 warfighting capabilities in six basic C2 processes and seven collaborative C2 processes. The basic C2 capabilities are recognizable to warfighters as a version of the OODA loop.[14] Collaborative C2 capabilities tie together the basic C2 process loops across echelons and functions.[15] They provide warfighting decision-makers the flexible and agile command methodology necessary for 21st century warfighting.

JC2FC Capabilities	
Basic C2	• Monitor and Collect Data
	• Develop a Situational Understanding
	• Develop Courses of Action • Develop a Plan
	• Execute a Plan • Monitor the Execution and Adapt
Collaborative C2	• Networking • Interacting • Sharing Information • Sharing Awareness • Sharing Understanding • Deciding • Synchronizing

For this study, we grouped the Joint Staff's JC2FC capabilities to map them to enabling technologies and then to their associated industrial base. We fused basic C2 capabilities related to developing and planning courses of action into the comprehensive capability of "Plan." Similarly, we treated executing and adapting functions as the comprehensive capability to "Execute." The industrial capabilities that enable collaborative C2 functions basically are the same. Accordingly, we grouped computers, communications, and networks into one category.[16]

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[13] Joint Staff, *Command and Control Functional Concept*, January 1, 2004.
[14] Boyd, John, COL (ret). *Patterns of Conflict*. Briefing on competitive organizations, December 1986. The Observe-Orient-Decide-Act (OODA) loop captures the continuous and cyclical nature of C2.
[15] Joint Command and Control Functional Concept, February 2004, page 14.
[16] "Computers, Communications, and Networks" includes the *DIBCS BA* capability "Integrate Battlespace Awareness Networks" as indicated on page 14 of our first report, *DIBCS BA*.

We added "Platform Control" to this assessment. Although platforms themselves support various functional capabilities, the control of manned and unmanned platforms is most appropriately a C2 function and should be evaluated in *DIBCS C2*. The grouping of the JC2FC capabilities for *DIBCS C2* is shown opposite.

DIBCS C2 **COMPREHENSIVE CAPABILITY AREAS**
Monitor and Collect Data
Develop a Situational Understanding
Plan
Execute (Monitor and Adapt)
Computers, Communications, and Networks
Platform Control
Sources: Booz Allen Hamilton and ODUSD(IP)

After planning the original scope of the C2 capabilities assessment, the subject matter experts, under the guidance of the *DIBCS C2* SAG,[17] identified 255 specific warfighting capabilities associated with the six JC2FC capability areas. Next, we established capability leadership goals the United States should strive to maintain for each warfighting capability, as shown in the summary chart below.

COMMAND AND CONTROL OPERATIONAL CAPABILITIES SUMMARY CHART

DIBCS C2 Comprehensive Capability Areas	Specific Capabilities by Leadership Goal			
	Neutral	**Equal**	**Be Ahead**	**Be Way Ahead**
Monitor and Collect Data	1	4	10	3
Develop a Situational Understanding	0	12	14	2
Plan	0	7	16	4
Execute (Monitor and Adapt)	0	9	13	3
Computers, Communications, and Networks	0	18	68	19
Platform Control	0	15	27	10
255 TOTAL	**1**	**65**	**148**	**41**

Sources: Booz Allen Hamilton and ODUSD(IP)

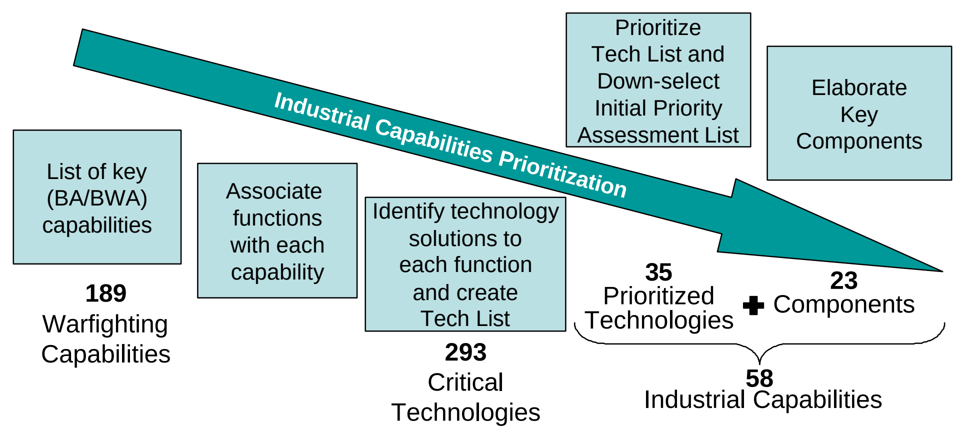
For example, in the "Monitor and Collect Data" capability area, we determined that it was acceptable for the United States to have *equal* capability relative to adversaries to task the collection of pre-conflict intelligence information. This sort of tasking is little different than the forwarding of information used in any commercial setting.[18] Similarly, in the "Develop an Understanding" capability area, we evaluated the development of

[17] For SAG membership refer to page 8.
[18] This represents the capability to *task* collection of intelligence, not the *capability* of sensors to collect information—the latter was evaluated in *DIBCS BA*.

synopses of intelligence produced by national level agencies as a *be ahead (BA)* capability. The U.S. requires that its networking intelligence sources have a significant advantage over adversaries when providing time-sensitive information. And finally, "Execute (Monitor and Adapt)," capabilities[19] that provide dynamic battlefield C2 represent the ultimate goal of collaborative C2: being able to adapt and execute as necessary during the course of battle. Therefore, we assessed these capabilities as *be way ahead (BWA)* capabilities.

We next identified the functions associated with each capability to create the technology list. We then assessed the industrial sufficiency for a prioritized set of critical technologies and components enabling *BA/BWA* warfighter capabilities. The illustration below summarizes this process.

COMMAND AND CONTROL TECHNOLOGY PRIORITIZATION PROCESS



Warfighting Capability: A specific ability derived from the Joint Staff C2FC

Critical Technology: A technical method enabling one or more *BA/BWA* warfighting capabilities

Component: A subset technology used in the assembly of an enabling technology

Industrial Capability: The ability of a manufacturer to supply or produce a technology

Sources: Booz Allen Hamilton and ODUSD(IP)

This study identified a total of 293 technologies enabling the 189 *BA/BWA* warfighter capabilities,[20] and categorized them into 10 broad industrial areas.

BROAD INDUSTRIAL AREAS FOR COMMAND AND CONTROL

- Collaborative Management
- Communication and Networking
- Computers
- Data Management
- Decision Support
- Displays
- Location and Identification
- Power Generation and Storage
- Software Encryption and Tasking
- Unmanned Vehicle

Sources: Booz Allen Hamilton and ODUSD(IP)

[19] Such as Force XXI Battle Command Brigade and Below and the Global Command and Control System.

[20] These warfighting capabilities and enabling technologies are discussed in Appendices A and B.

Of the 293 critical technologies identified, we evaluated industrial sufficiency for 35 of the most pressing critical technologies and 23 associated components.

35 TECHNOLOGY AREAS SELECTED FOR ASSESSMENT IN *DIBCS C2*	
1. 3rd Generation Wireless Device (UWCC – 3G)	19. Laser Communications (Lasercom)
2. 802-16 – Compatible Device	20. Micro-Scale Fuel Cell
3. Airborne Data Link	21. Miniaturized High-Capacity Low-Power Memory
4. Automated Sensor Cross-Cueing Tool	22. Miniaturized Low-Power Processor
5. Automated Sensor Cueing Tool	23. Miniaturized Mass Storage Device
6. Autonomous Satellite Control Software	24. Multi-Hop-Band-Mode-Function Jam Resistant Radio
7. Autonomous Vehicle Control Software	25. Nano-Composite Solar Cell
8. Bandwidth Accelerator	26. Next Generation Terrestrial Battery
9. Cave Automatic Virtual Environment (CAVE)	27. Next Generation Secure IFF Device
10. Cluster/Constellation Control Device	28. Over-the-Air Rekeying (OTAR) Device
11. Collaboration Intelligence Fusion Tool	29. Software-Programmable Radio
12. Collaborative Virtual Workspace	30. Speech Computer Control Tool
13. Course of Action (COA) Generation Software	31. Super Computing Processor
14. Dynamic Database Fusion Tool	32. Swarming Control Tools
15. Hardened Components	33. Ultra-Wideband Device
16. Helmet Mounted Display (HMDs)	34. Wavelength Division Multiplexing Tool
17. Intersatellite Links	35. Wearable Computer
18. Intraflight Data Link (IFDL)	
Sources: Booz Allen Hamilton and ODUSD (IP)	

This assessment identified a total of 226 companies, laboratories, and universities involved in the 58 technologies and components investigated. This supplier list is summarized in Appendix C. While the summary does not include every supplier in these industries, it illustrates the overall strength of the domestic C2 industrial base. It also indicates the strength of foreign suppliers in this industry segment.

A by-product of this analysis has been the successful application of a methodology that uses the Joint Staff's joint functional concepts as the basis for focusing the industrial base on those technologies likely to continue to assure the U.S. lead in high technology weapons systems. In *DIBCS BA*, our systematic assessment indicated that 82 percent of warfighting capabilities associated with the Battlespace Awareness functional concept were *BA/BWA* areas. In C2, *BA/BWA* capabilities were assessed to be on the same order: 74 percent. Hence, the use of the joint functional concepts, and our translation of these concepts for our DIBCS assessments, should help Department policies effectively focus the industrial base on these important *BA/BWA* capabilities. This in turn should ensure that the products for 21st century military operations envisioned in the joint functional concepts are available to the warfighter.

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 key C2 capabilities to the U.S. warfighter. A distinctive aspect of C2 is that commercial—and often foreign—information technology (IT) products support a large portion of C2 warfighting.[21] Commercial IT products generally are driven by the needs

[21] The need to assess IT industrial base capabilities was initially identified in *DIBCS BA* on page 16 and deferred from the *DIBCS BA* to *DIBCS C2*.

of the commercial marketplace, *not* by DoD requirements. The next section addresses ten commercial C2 industrial base issues and four defense sector C2 industrial base issues identified as areas of concern.

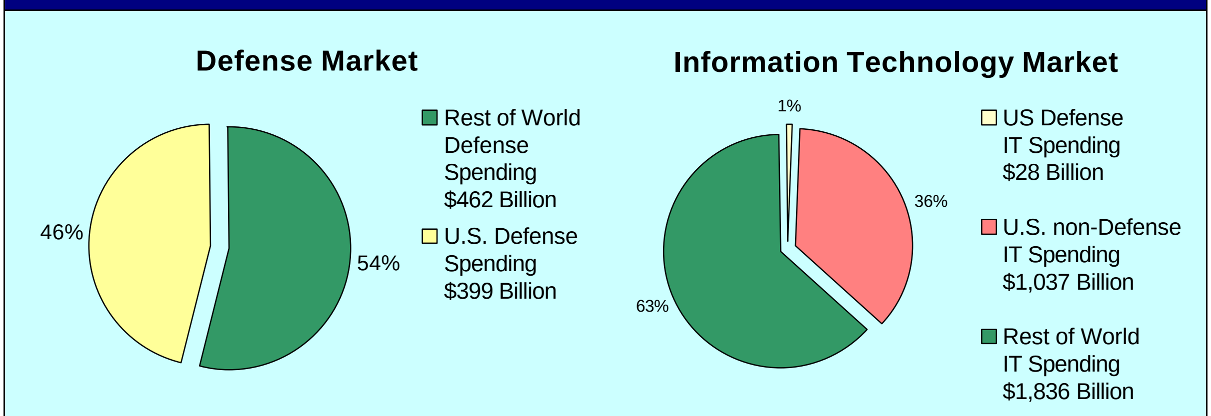
INDUSTRIAL AND TECHNOLOGY ISSUES FOR COMMAND AND CONTROL

Commercial IT and products represent the state-of-the-art in 21st century communications. They are produced globally and non-U.S. suppliers often are the best in the world. Weapons systems are, and will continue to be, designed to leverage these commercial technologies and products. Accordingly, DoD's acquisition community must devise and employ management strategies that more easily pull these commercial technologies into weapons systems. Not to do so would cede important military advantages to adversaries who could more nimbly leverage these commercial technologies for their own purposes. That said, the U.S. industrial base has demonstrated a unique capability to incorporate commercial technologies in highly innovative military applications, and our warfighters have displayed great ingenuity in adapting these applications during operations.

THE ROLE OF COMMERCIAL IT IN C2

As shown below, there are two IT markets of interest to the Department of Defense—the global commercial IT market and the defense-oriented IT market. The global commercial IT market dwarfs the defense IT market and the Department's leverage over that market is limited. Whereas U.S. defense spending accounts for roughly half the world's defense spending, U.S. defense IT spending accounts for only one percent of the world IT market. The tools used to leverage the defense market are highly unlikely to have the same effect in the commercial IT market.

DOD MARKET INFLUENCE: DEFENSE AND INFORMATION TECHNOLOGY[22]



Source: Center for Defense Information, IT Association of America

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[22] Defense market figures for rest of world defense spending are for latest year available, usually 2002. United States defense spending is from the annual budget request for Fiscal Year 2004.

However, commercial IT products offer a number of benefits: (1) the technology is the most current and advanced available; (2) development costs are amortized over the broader commercial business base; and (3) there are numerous competitive suppliers. Accordingly, commercial IT products frequently offer better performance and are less expensive than technology procured solely for DoD applications. To the extent that the Department can utilize commercial IT, it should and does.

Clearly, there are some defense-unique IT needs that cannot be met by commercial IT products. In addition, DoD use of commercial IT products does pose certain risks. Because the Department has little influence on commercial IT suppliers, technological advances do not necessarily progress in directions that advance capabilities important to the Department—the problem of congruency of strategic interests. In fact, commercial IT may advance in directions that render products adapted for DoD needs obsolete. Commercial IT products are available worldwide and appropriately are not subject to export controls, since to limit export would unnecessarily hamper the success of these companies and their products. As a consequence, extremely advanced commercial technologies and products generally are available to potential adversaries. Finally, since the global commercial marketplace drives innovation in IT technologies and products, it is in the Department's interest that this global competitiveness be sustained—both by effective competition on the part of U.S. firms in the global marketplace, as well as by unimpeded access by the Department to global IT firms.

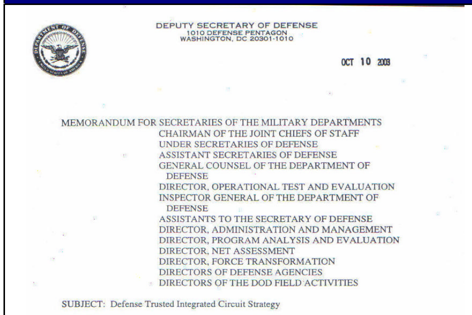
Therefore, for commercial technologies and products, the Department generally accepts parity with potential adversaries. It is in the creative, defense-specific ways the Department uses commercial IT capabilities that it maintains leadership in *BA/BWA* JC2FC warfighting capabilities. For example, even a system as complex—and essential to 21st century warfighting—as the Global Information Grid is based essentially on commercial components such as the global fiber, commercial routers, and commercial SATCOM that form its backbone. DoD's JC2FC leadership goals will not be achieved by replicating commercial IT capabilities in defense-dependent facilities or by attempting to restrict access to commercial capabilities. Indeed, attempts to create duplicative, dedicated defense IT capabilities could be counterproductive. Such attempts would drain DoD focus and resources from other defense needs while simultaneously removing the competitive pressures of the commercial marketplace that drive IT innovation. In addition, to attempt to replicate or match this commercial market with a defense-only IT industrial base would be exorbitantly expensive and over time would not be able to maintain parity with commercial products.

> *"If defense industries are cut off from commercial sources of advanced technology, forcibly disengaged from the global economy and forced to rely on a single customer's requirements for their business, their prospects for independent business success are diminished if not eliminated."*
>
> *- IT Association of America*
> *January 24, 2003*

In all such markets the Department is vigilant to appropriately mitigate risks. Foreign commercial IT products may pose unacceptable risks for certain sensitive applications. For such applications, special measures may need to be taken to ensure the correct information is provided to the correct recipients; and that the information and associated components are protected from those who would attempt to intercept, disrupt, or corrupt it.

In specific cases where mission sensitivity requires a particularly high level of operational assurance, the Department takes the appropriate steps. For example, the Department has determined that certain critical integrated circuits used in weapons systems and some integrated circuits used within communications infrastructures require additional security assurances and might need to be produced in a "trusted" semiconductor production facility.

DEFENSE TRUSTED INTEGRATED CIRCUIT STRATEGY


DEPUTY SECRETARY OF DEFENSE
1010 DEFENSE PENTAGON
WASHINGTON, DC 20301-1010

OCT 10 2003

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN OF THE JOINT CHIEFS OF STAFF
UNDER SECRETARIES OF DEFENSE
ASSISTANT SECRETARIES OF DEFENSE
GENERAL COUNSEL OF THE DEPARTMENT OF DEFENSE
DIRECTOR, OPERATIONAL TEST AND EVALUATION
INSPECTOR GENERAL OF THE DEPARTMENT OF DEFENSE
ASSISTANTS TO THE SECRETARY OF DEFENSE
DIRECTOR, ADMINISTRATION AND MANAGEMENT
DIRECTOR, PROGRAM ANALYSIS AND EVALUATION
DIRECTOR, NET ASSESSMENT
DIRECTOR, FORCE TRANSFORMATION
DIRECTORS OF DEFENSE AGENCIES
DIRECTORS OF THE DOD FIELD ACTIVITIES

SUBJECT: Defense Trusted Integrated Circuit Strategy

"The country needs a defense industrial base that includes leading edge, trusted commercial suppliers for critical integrated circuits used in sensitive defense weapons, intelligence and communication systems. The purpose of this memo is to establish a strategy to ensure that such suppliers exist."

Source: DEPSECDEF Memo

More than any other joint functional concept, C2 capabilities rely on commercial IT products for infrastructure, tools, and common business applications. As already indicated, the commercial IT market is global, very competitive, and very innovative. Technology is advancing rapidly. The Department is challenged to match its weapons system acquisition cycles and processes to the speed of the commercial marketplace.

The Department must also recognize that traditional acquisition levers employed by the Department are generally insufficient and ineffective to influence the commercial IT market because DoD influence over the market is so slight. Program managers and acquisition professionals will have to continue to develop unique defense applications for commercial products that creatively fuse defense and commercial IT products while allowing commercial firms to respond to commercial market demands. To achieve warfighting capability leadership goals, the acquisition community will have to be alert to state-of-the-art technological and industrial capabilities resident in the commercial IT market. Finally, DoD managers will have to better package program requirements with common standards and protocols to provide optimal on-ramps for commercial products.

COMMERCIAL IT ISSUES AFFECTING C2 WARFIGHTING CAPABILITIES

During the assessment of the 58 industrial capabilities that support *BA/BWA* JC2FC warfighting capabilities, we identified ten commercial IT technology areas in which the U.S. does not lead. In these cases, the Department is willing to use non-U.S. commercial IT suppliers to achieve warfighting advantages. Such reliance on non-U.S. IT suppliers must be consistent with U.S. national security requirements and must offer comparative advantages in performance, cost, and schedule. These technologies and their warfighting relevance are summarized below.

COMMERCIAL IT ISSUES AFFECTING C2

	Technology Area	Warfighting Relevance
U.S. Trails	3rd Generation Wireless Device	Allows rapid exchange of data and voice communications supporting Intelligence Preparation of the Battlespace (IPB), C2 and Battle Damage Assessment (BDA).
U.S. Trails	Mini High-Capacity Low-Power Memory (MHCLPM)	Provides computational storage to battery/fuel cell-powered mobile and portable electronic devices while maximizing recharge/refueling intervals.
U.S. Trails	Oxyride Battery	Power source for mobile and portable electronic devices.
U.S. Trails	Mini Mass-Storage Device	Portable local data and information repository support for electronic devices supporting navigation, IPB, identification and BDA.
U.S. Even	MHCLPM – MEMS Integrated Circuit	Micro-electro-mechanical system (MEMS)-based storage systems offer significant improvements over traditional MHCLPM, with predictions of postage stamp-sized several gigabyte memory cards.
U.S. Even	Wavelength Division Multiplexing Tool	Optimizes use of single optical fibers, thereby reducing information infrastructure support for communications and networking.
U.S. Even	Super Computer/ Quantum Computing	Provides high-throughput for computational intensive operations supporting IPB, cryptography, target ID, target recognition, and BDA.
U.S. Even	Super Computer – Optical Interconnects	Optical interconnects allow higher Input/Output (I/O) density, higher bandwidth and global interconnectivity between chips and computers.
U.S. Even	Lithium Ion Polymer Battery	Power source for mobile and portable electronic devices.
U.S. Even	802.16 Wireless Net Compatibility Device	Provides reliable, multi-user voice and data connectivity supporting tactical communications over metropolitan areas.

Sources: Booz Allen Hamilton and ODUSD (IP)

In four of these areas (3rd Generation Wireless Device, Miniature High-Capacity Low-Power Memory (MHCLPM), Oxyride Battery, and Miniature Mass-Storage Storage Device), U.S. suppliers trail competitors in the global commercial IT market. While U.S. suppliers are competitive in product design, marketing, and software, they do not lead in the manufacture of these products. Most of these products are manufactured in Asia. In the six other commercial IT technology areas shown in the table above, U.S. suppliers are even with the most advanced global suppliers.

The Department is adept at cost-effectively fielding militarily-superior warfighting capabilities that are enabled by commercial IT products. It does so by combining discrete commercial IT products (whether produced by U.S. or non-U.S. suppliers) in innovative ways and by creatively fusing state-of-the-art commercial and defense-unique products. The effective leveraging of myriad commercial products for military capabilities will be an important hallmark of all 21st century U.S. warfighting. However, as in all matters posing risks to the warfighter, the Department is committed to being vigilant in the use of these commercial products. The Department manifests this vigilance by militarizing commercial products in ways that allow the military capabilities to effectively incorporate commercial innovation; being alert to the composition of the non-U.S. supplier base for reasons of sufficient numbers of sources and security of supply; and recognizing the importance of operational assurance.

ISSUES IN THE DEFENSE SECTOR OF THE C2 INDUSTRIAL BASE

The health of the defense portion of the C2 industrial base is evident in the small number of issues identified. In general, U.S. defense suppliers hold a technological lead over foreign competitors for C2 military technology. However, we identified two areas, Helmet Mounted Displays and Swarming Control Tools, where U.S. technology leadership was questionable. We also identified one area in which supplier sufficiency was an issue: Optical Intersatellite Links.[23]

ISSUES IN THE DEFENSE SECTOR OF THE C2 INDUSTRIAL BASE				
Technology	**Industrial Base Sufficiency Analysis**			**Rationale** (for associated remedies, see page 34)
	Domestic Sources	**Foreign Sources**		
Helmet Mounted Display	5	4		Traditionally used for pilot applications, use of HMDs is now expanding into land warfare and U.S. leadership may be insufficient given new applications and essentiality to future warfighting concepts.
Swarming Control Tools	Many[24]	Many[24]		U.S. research efforts are even with foreign institutions, with many foreign developers performing research in this technology area essential for remote vehicle control.
Optical (Laser) Intersatellite Links	2	3		Competition with European and Japanese developers has been growing. Market is still small and presently two suppliers are adequate.

Helmet Mounted Displays. Helmet mounted displays (HMDs) have been used for years in military aviation applications and are beginning to expand into land warfare applications. They involve multiple components, typically including a visor display on which imagery is projected, a cable linking the helmet display to a computer system, and a head tracking device to create full situational awareness. HMDs provide operators: (1) visual interfaces with networks that synergize actionable data and information supporting remote sensing; (2) intelligence preparation of the battlespace; (3) identification and characterization of engagement; and (4) battle damage assessment. This technology is important to the basic and collaborative C2 capabilities of "Situational Understanding," "Sharing Information," and "Sharing Understanding."

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[23] Two additional C2 industrial capabilities would have been included were it not for ongoing Department actions. Recognizing the limited market for Radiation Hardened Components, the Department has established a Title III Program project to capitalize two competing manufacturing processes that leverage innovation from the commercial electronics industry to meet critical defense requirements. Multi-Hop, Multi-Band, Multi-Mode, Multi-Function, Jam-Resistant Radios also figured prominently in our assessment of essential elements of the future battlespace, where their jam-resistant capabilities are the only capabilities differentiating them from similar commercial systems. We believe that the Joint Tactical Radio System program will develop myriad applications of these technologies, and we will continue to monitor the development of the associated industrial base for this capability.

[24] Swarming Control Tools are still in R&D, not production.

There are five domestic suppliers and four foreign suppliers of this technology. Market demand will likely grow with high technology applications to land warfare. The United States does not have clear leadership in this technology area for aviation applications and may not be able to easily establish leadership in other applications.

Swarming Control Tools. Swarming can be defined as useful self-organization of multiple entities through local interactions. The word "useful" emphasizes an interest in engineering systems that, while self-organizing, are answerable to an entity outside of the system boundary for their behavior. Self-organization distinguishes swarming from conventional man-in-the-loop control schemes.

The notion of autonomously controlling multiple entities is a major motivator for developing swarming control tools. There are significant scale benefits achievable with the ability to control multiple, disparate entities, such as vehicles, communications systems, and sensor systems. For example, a swarm of unmanned vehicles (UVs) could be networked to provide maximum sensor coverage and search capability over a specified area. Once a discovery was made by an unmanned air vehicle (UAV), it would signal the swarm of UVs, which could then unite around the discovery and set forth to accomplish a task the swarm was programmed to perform. As this technology further develops it will provide a number of Basic C2 capabilities within the "Execute (Monitor, and Adapt)" area.

We assess U.S. technological leadership as *even* for swarming control tools for UVs. Multiple U.S. universities and national laboratories are performing research and development. Many foreign developers and researchers also are active in this technology. Given the criticality of breakthroughs in this area to 21st century American warfare, the Department should encourage technology advances, the transition to design and manufacturing, and then oversee the development of a suitable number of domestic suppliers.

Optical (Laser) Intersatellite Links. Intersatellite links (ISLs) are two-way communication paths between satellites. Radio frequency (RF) and optical (laser) are the two primary communication media for an ISL. RF has been used frequently in the past. However, for similar weight and power, optical satellite communication offers greatly increased data transfer rates and lower probability of signal intercept.

Laser satellite communication networks will be an integral part of the new, transformational defense global information infrastructure. It is an enabling technology for many specific C2 capabilities, including "Situational Understanding," "Shared Information," "Shared Awareness," "Shared Understanding," and "Networking." It offers the opportunity for high bandwidth, internet-like global networking through space.

U.S. technology ISL leads foreign competitors. However, only two domestic suppliers (Northrop Grumman and Ball Aerospace) are active in ISLs and continued monitoring of the development of this industrial base is necessary. For now, this is a small market and two providers appear sufficient.

The Department should closely monitor both commercial and defense-oriented C2 critical technologies and associated industrial capabilities. Additionally, the Department must recognize that commercial technology plays an increasing role in supporting key warfighting capabilities. Therefore, the Department must develop new approaches to access these technologies and to employ them creatively. These new approaches likely will require a cultural shift within the acquisition community, which arguably is already underway.

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PART III

POLICY IMPLICATIONS

The Department recognizes the inherent link between delivering desired operational effects to the battlefield and developing innovative, leading-edge technologies for defense systems. It is continuing to shape acquisition strategies that challenge program managers to plan for and encourage industrial base innovation. In keeping with the policy construct developed in our previous study, *DIBCS BA*, the Department is encouraging program managers to apply policy levers to enhance innovation and competitive opportunities within the industrial base throughout a program's lifecycle. Specific remedies for the C2 issues identified in Part II will be discussed in Part IV. This more general discussion of policy implications for the defense industrial base is intended to outline policy levers to enhance industrial base innovation and competition; offer specific C2 examples where, in our view, programs have—or have not—successfully applied available policies; and provide current policy refinements intended to benefit the industrial base.

APPLYING POLICY LEVERS TO ENHANCE INNOVATION AND COMPETITION[25]

Maintaining the U.S. warfighting advantage requires continuous innovation of operational capabilities. Key among many factors driving innovation is the competition among ideas and the application of those ideas. The *DIBCS BA* study posited that the most effective way to encourage innovation within the industrial base is to apply three major policy levers through appropriate portals throughout the weapon system lifecycle. Our analysis led us to focus on five primary portals (as depicted on the next page) through which the Department can assure sufficiency of sources and innovation—and potentially tap into particularly innovative technology to pollinate it among other applications.

> *"Managers in all life cycle phases recognize the benefits of multiple suppliers. For immature systems in S&T and development, multiple suppliers mean multiple sources of good ideas with consequent risk reduction in addition to the potential economic benefits of competition. However, multiple suppliers require additional funding with attendant increase in program cost. This can force a tradeoff between the benefits and cost unless the program is resourced to maintain competition."*
>
> *- Red Team Member*

Early in responding to an emerging warfighting requirement, crucial industrial capabilities may be resident in too few potential suppliers to generate confidence in timely delivery of effective warfighting capabilities. 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. These situations present portals of opportunity through which the Department can promote sufficiency of sources and innovation.

[25] For a fuller discussion of portals and levers, see our previous study, *DIBCS BA*, January 2004.

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 should act in the make/buy decisions and throughout programs' life cycles to induce innovation in critical technologies.

In our construct, management decisions and options can be examined systematically using an array of portals and levers. Portals generally correspond to program phases. In the case of applying remedies, the phase of the program determines which portals can be applied. The *science and technology* portal should be open nearly continuously for the 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 *laboratory to manufacturing* and the *weapon systems design* portals represent more limited windows of opportunity. In this construct, 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.

MAJOR INNOVATION PORTALS AND POLICY LEVERS IN THE INDUSTRIAL PROCESS

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

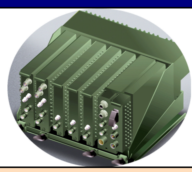
Proper use of these portals and levers by Department program managers and industry will:
- Promote a systematic approach to address industrial base development
- Incentivize innovation in industrial base capabilities
- Avoid/resolve industrial base deficiencies

Source: ODUSD (IP)

C2 Examples of Applying Policy Levers

This report uses a number of examples to illustrate the portals and levers approach. 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. The examples are not intended to reflect on the overall status or outcome of the program. We also provide examples of how interagency decisions on mergers and acquisitions have reinforced competition and innovation in the industrial base.

AMF JTRS EXAMPLE



- Funds two stages of competition to glean best technological solutions
- Optimizes sub-tier radio competition

The Airborne, Maritime/Fixed Joint Tactical Radio System (AMF JTRS) program illustrates how both the *fund innovation* and *optimize acquisition strategy* levers can help address these challenges. To maximize competition at the prime contractor level, the program manager created an acquisition strategy that funds competition and innovation in two stages. Contractors vying for the role of prime system contractor first can compete to become one of two firms receiving contracts for development work in the pre-System Development and Demonstration (pre-SDD) phase. Innovative technology solutions produced by this competition will be incorporated in the second competition, which will select the prime system contractor for SDD and Low Rate Initial Production (LRIP). This two-staged competition provides incentives for competing contractors to offer innovative ideas early in the process, since government funding will be provided to two firms for continued technology development. The second phase incorporates the lessons learned in the first phase, and by remaining open to all bidders, makes one more sweep to collect industry's innovative solutions before selecting the SDD and LRIP prime contractor.

Prime contractor competition is not the only way to induce innovation. The AMF JTRS program's acquisition strategy also includes two features to stimulate competition and innovation at the lower tiers of the supply chain. First, the program strategy specifies that each prime system contractor must qualify two radio producers. These two producers will compete for subsequent production contracts, even though the prime system contractor will be unchanged. The radios will be supplied to the prime system contractor as government furnished equipment. Secondly, the program specifies that the prime system contractor cannot be a radio producer, eliminating vertical integration issues for this key component. By using the *acquisition strategy* lever at the *weapon system design* portal, the program manager has affected future portals as well. The strategy ensures that system design will accommodate multiple radios, that multiple sources will be qualified, and that vertical integration will not bias decisions toward the integrating contractor. This, in turn, means that the program office will have viable options when the program reaches the make/buy portal during production.

FBCB2 EXAMPLE

- Mitigated aggressive schedule risks by qualifying two suppliers
- Uses common software and interface requirements to include more suppliers

Careful use of the acquisition policy lever can continue to pay dividends even as priorities evolve over a program's life cycle, as shown in the Force XXI Battle Command Brigade and Below (FBCB2) program. The Department initially viewed this program's aggressive schedule as a primary source of program risk. As one of several measures implemented to mitigate this risk, the program manager developed an acquisition strategy that would make two vendors available and qualified to build the ruggedized computers at the heart of the system. The program office also required the computers to be built with common interfaces and common software requirements, while freeing vendors to utilize unique internal designs that meet performance requirements. In this way, if one vendor's concept or production runs into trouble and threatens the aggressive schedule goals, another would be available to step in. Though instituted to mitigate schedule risk, this construct has the added benefit of creating price competition that will result in program cost savings.

E-10A EXAMPLE

- Optimizes contractor management to retain technology and integration capability
- Preserves competitors for important BMC2 capabilities

Competition is a key driver of innovation and reduced costs. However, any winner-take-all competition for a complex system runs the risk of sacrificing valuable innovation from the competitors who are not selected. The losing team may include several firms with substantial technology and integration capability that are unlikely to be on more than one team. This downside to winner-take-all competition is particularly acute when integrated architecture is a key design challenge, and also when there are few suppliers of key technology components. The E-10A Multi-sensor Command and Control Aircraft (MC2A), designed to ultimately replace the EP-3, RC-135 (Rivet Joint), E-3 Sentry, and the Joint Surveillance Target Attack Radar System (JSTARS), exemplifies this situation.

The E-10A subsystems must work together seamlessly, and will demand much from the aircraft infrastructure and electronic architecture that connects them. Initially, the E-10A will include the new ground surveillance and cruise missile defense radar now being jointly developed by Raytheon and Northrop Grumman under the Multi-Platform Radar Technology Insertion Program. The system will also provide the Ground Moving Target Indication (GMTI) function of Northrop Grumman's JSTARS. Eventually, it may include the airborne warning and control function now served by Boeing's Airborne Warning and Control System (AWACS) aircraft as well.

As a central command and control node with multiple functions, the E-10A program requirements place high priority on interoperability and on commonality among various functions. The program office faced challenges associated with having few competitors for certain technologies. The program manager chose to address these needs by developing an acquisition strategy that employed a national team concept, in effect combining three companies (Northrop Grumman, Raytheon, and Boeing) into an entity referred to as the MC2A Trico—while still competing the most innovative subsystem.

The program manager chose the Trico arrangement to pool integration activities rather than risk losing the contributions of any of these highly capable firms. This structure also maximizes opportunities to create an architecture that will perform all functions efficiently. This ensured that the dominant and proven providers of key capability were included in the technology development phase of the program.

However, for the Battle Management Command and Control System (BMC2), the most innovative subsystem where technologies can provide crucial, leap-ahead capabilities, the program manager judged that the benefits of competition outweighed the risks. This portion of the E-10A program will be competed in the traditional manner. Teams led by Lockheed-Martin, Northrop Grumman, and Boeing will compete in a final downselect. The winning team will be a subcontractor to the Trico.

This arrangement is not without risks. The Trico arrangement does limit competition and the benefits that competition brings. The competition for the BMC2 portion creates contractual and conflict-of-interest challenges, as members of the Trico will be competing to build to an architecture the Trico is designing. But the arrangement certainly demonstrates a creative approach to a difficult and changing environment, and illustrates that there may be no single application of levers and portals that is appropriate for all facets of a given program. It is hoped that the Trico would ensure "best of breed" considerations determine the final selection. It is up to the Department to closely monitor decisions on this program.

MMA EXAMPLE

- Will maximize innovation opportunities through the use of open architectures
- Will capture technology advancements through maximum use of commercial systems

The past paradigm in which defense requirements pulled commercial technology forward—where it would otherwise have developed slowly, if at all—is shifting as the Department moves increasingly towards a network-centric approach to warfare, with priorities on communication and computation. In this evolving paradigm, the Department must learn to use advanced technologies developed in the commercial world for warfighting technology solutions.

Portals and levers can be brought into play here, as well—less to drive innovation and competition than to reap the benefits of technologies and products created in the non-defense marketplace. Many programs in the C2 sector, and throughout the defense portfolio, reflect the importance of open architectures and commercial parts, particularly in information and communications technology. Open architectures in these areas facilitate external innovation and reduce risks associated with future obsolescence.

The Multi-mission Maritime Aircraft (MMA) program will use the *acquisition strategy* lever at the *weapon system design* portal to maximize the use of open command, control, and navigation system architectures. It will also use commercial parts in the communication and processing areas. The MMA mission, requiring large capacity and long loiter time but no supersonic, offensive, or defensive capability, lends itself to commercial aircraft and/or engines. By maximizing the use of commercial or other widely available systems, subsystems, and components, the program office will capture refinements driven by decades of competition, and will realize savings in both procurement and maintenance costs.

Today's program managers must be analytical in their assessment of the environment in which their program exists, and pick levers that allow them to balance conflicting goals. In this way, they will make decisions that have long-term positive impacts on innovation and competition while also accomplishing the near-term program goals of meeting cost, schedule, and performance requirements. While program managers are entrusted, as a community, with helping to create an innovative, competitive defense industrial base through their collective actions at the tactical level of their own programs, the Department exercises oversight of these individual actions and their collective impacts through various fora of programmatic and budgetary reviews.

BOEING – HUGHES EXAMPLE

- Proposed merger of two satellite providers
- Transaction allowed with firewalls and agreement to offer components to competitors
- Remedies preserved competition for future while enhancing the development of advanced capabilities

Sometimes circumstances occur when it becomes necessary for the Department to step in and apply corrective measures in order to preserve a robust, innovative industrial base. Mergers and other financial transactions can affect the defense industrial base. In such cases, the Department can work with the antitrust authorities (the Department of Justice and the Federal Trade Commission) to block mergers or, if necessary, secure judgments that force restrictions on the acquiring firm in order to preserve competition in key technologies for crucial capabilities.

For example, Boeing's acquisition of Hughes' Space and Communications businesses highlighted a situation in which the Department worked in cooperation with the antitrust regulators to preserve competition in technologies critical to its C2 capabilities. In February 2000, Boeing announced it would acquire Hughes' Space and Communications businesses for $3.75 billion. Both Boeing and Hughes produced satellites, but the specific product lines were different. Boeing focused on military navigation and Hughes focused on commercial and military communication.

The Department reviewed the transaction and identified concerns about Boeing's ability to exercise its vertically integrated capabilities to harm satellite competitors by denying them key satellite components (e.g., traveling wave tubes and solar cells). To alleviate these concerns, Boeing provided the Department a letter of agreement that stipulated that it would act as a merchant supplier for specific components. The Department also was concerned that Boeing's position as a launch operator would provide it inappropriate access to satellite competitor proprietary data. The courts issued a consent decree requiring Boeing to establish an internal firewall to prevent other satellite manufacturers' proprietary data from flowing to Boeing/Hughes satellite operations. The actions of the Defense and Justice Departments are designed to preserve competition and innovation. They also established a precedent for other mergers such as the subsequent Northrop Grumman - TRW merger.

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 crucial industrial base capabilities. Along with the levers available to program managers, the Department can apply *external measures* and work with the regulatory agencies to retain innovation and remedy deficiencies.

RECENT POLICY ENHANCEMENTS

Consistent with the portals and levers construct, the Department is also in the process of issuing and refining acquisition strategy guidelines. These will challenge program managers to develop plans to induce and sustain competition—the key to innovation—throughout a program's life cycle. Such plans are essential. Early in the technology development phase, program managers make decisions that have significant effects on innovation and the industrial base. Traditionally, program managers have focused on minimizing program cost, maintaining program schedule, and optimizing program performance. This somewhat narrow focus sometimes has resulted in decisions that may be acceptable in the short term but can have a deleterious effect on competition and the program—as well as the industrial base—in the long term. The intent of the new acquisition strategy enhancements is to encourage the program manager to create opportunities for competition and innovation.

In addition to the Department's general focus on the program managers' role in shaping the industrial base, it has two new initiatives to specifically focus the program manager on actions necessary to maintain a robust industrial base. These two initiatives revise the contractual make-buy policy and add broad acquisition strategy guidance to the *Interim Defense Acquisition Deskbook.*

The revised guidance associated with prime contractor selection of suppliers for subsystems and components is intended to counteract the effects of a high degree of consolidation among prime contractors. This initiative recognizes that highly consolidated prime contractors can more easily shut out competition with decisions to make subsystems and components in-house rather than buy from other subcontractors. Such decisions discourage competition and innovation by favoring in-house capabilities or long-term teammate products over more innovative solutions available elsewhere. Recognizing that most true innovation comes from subcontractors, the Department is developing policy guidelines[26] to ensure that program managers and contracting officers

[26] "Selection of Contractors for Subsystems and Components," USD(AT&L), memo in coordination.

retain both insight into the subcontractor selection process and an ability to influence that selection.

For example, when establishing the contract fee structure, program managers and contracting officers would be encouraged to give more value to the contractor's effective use of competition throughout the life of the program. Additionally, the program manager will be required to retain oversight of the subcontractor selection process by requiring the prime contractor to submit a plan explaining how it will ensure subcontractor competitions will be conducted fairly and result in the best value for the Department. The program manager may require that certain subcontracts be let only after explicit DoD approval if there is determined to be bias in selection of a subcontractor or that potential bias cannot be adequately mitigated.

The Department is also adding broad acquisition strategy guidelines to its *Acquisition Deskbook* to help the program manager better focus on nurturing innovation and competition in the decisions made throughout the life of the program. The new acquisition strategy guidelines, to be published in late summer 2004, will challenge the program manager to identify the critical technologies related to the capabilities described in the Initial Capabilities Document, and to assess the sufficiency of the industrial base to provide those critical technologies. The guidelines will encourage the program manager to reflect in the acquisition strategy a plan to induce and sustain competition throughout the program lifecycle. Finally, to promote synergies that facilitate competition and innovation, the program manager is encouraged to identify, where feasible, other programs that could employ the same technologies.

ACQUISITION GUIDEBOOK

INTERIM
DEFENSE
ACQUISITION
DESKBOOK
October 30, 2002

(Formerly the DoD 5000.2-R, dated April 5, 2002)
(See FOREWORD, next page.)

- Assess the capacity of the industrial base to support development of key technologies
- Induce and sustain competition throughout the program lifecycle

Source: OUSD(AT&L)

The Department will provide particular oversight on contractual arrangements relating to technologies identified as critical in the DIBCS series to ensure appropriate actions relative to the intended development of these building blocks of the defense industrial base. This will be accomplished through the review of acquisition strategies in DUSD(IP)'s role in the acquisition oversight process and by continuous monitoring of DIBCS critical technologies as programs progress.

In applying these policy levers, the Department is working to maximize the opportunities for obtaining innovative technologies and products throughout a program's life cycle. Through proper development and implementation of acquisition strategies, program managers will better leverage and develop innovative technologies and industrial base capabilities that support warfighting requirements.

Program managers are the tactical actors on the front lines of shaping the defense industrial base. They are the stewards of technological capabilities necessary to meet 21st century warfighting requirements. The Department must continue to challenge these managers to plan for innovation throughout a program's life cycle, thereby ensuring the sufficiency of the industrial base to support key warfighting capabilities.

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Part IV

Policy Remedies for Command and Control 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 Command and Control *be ahead* and *be way ahead* warfighting capabilities. Our initial assessment of the crucial industrial capabilities in the JC2FC capability area identified three issues that can benefit from these lessons learned. Examination of the remaining crucial industrial capabilities undoubtedly will uncover additional issues. Appropriate remedies for those issues will be considered at that time.

We judged forty-five C2 technologies and their associated industrial base to be sufficient, as shown in the table below. Some of the technologies listed are still in development. In those situations a sufficient number of U.S. industry and research institutions exhibited an overall lead in technology and sufficient numbers to provide confidence that an adequate supplier base will develop.

45 Command and Control Technologies with Sufficient Industrial Base Capabilities[27]	
1. Airborne Data Link	24. Miniaturized Mass-Storage Device
2. - Field Programmable Array	25. - Nano-Electromechanical System (NEMs)
3. - Software Definable Transceiver	26. Multi-Hop-Band-Mode-Function Jam Resistant Radio
4. Bandwidth Accelerator	27. - Adaptive Transceiver
5. CAVE Automatic Virtual Environment	28. - Antenna
6. - Stereoscopic Eyewear	29. Nano-Composite Solar Cell
7. - Stereoscopic Projection	30. - Inorganic Semiconductor Nanorods
8. Collaborative Intelligence Fusion Tool	31. Next Generation Battery
9. Collaborative Virtual Workspace	32. - Nickel-Metal Hydride Battery
10. Course of Action Generation Software	33. Next Generation Secure IFF
11. Dynamic Database Fusion Tool	34. - Laser Interrogator
12. Encryption – Over-the-Air-Rekeying (OTAR) Device	35. Satellite Control – Autonomous Satellite Control Software
13. Hardened Components	36. – Cluster/Constellation Control
14. - Novel Shielding Materials	37. Software Programmable Radios
15. Helmet Mounted Displays – Head Tracking Display[28]	38. - Adaptive Computing System-on-Chip
16. Helmet Mounted Displays – Retinal Display[28]	39. Super Computer Processor
17. Laser Communications	40. Tasking – Automated Sensor Cross-Cueing Tool
18. Micro-Scale Fuel Cells	41. Tasking – Automated Sensor Cueing Tool
19. - Catalytic Micro-Combustors	42. UV Control – Autonomous Vehicle Control Software
20. - Micro-Reformers	43. UV Speech Computer Control Tool
21. Mini Mass-Storage Device	44. Wearable Computer
22. - Compact Holographic Memory	45. Wireless Network – Ultra Wideband Device
23. Miniaturized Low-Power Processors	
Sources: Booz Allen Hamilton and ODUSD (IP)	

[27] Indented technologies are subsidiary components of the technologies.
[28] While helmet mounted *displays* are a C2 industrial base capability issue, the industrial base for the associated component technologies was evaluated as sufficient.

In addition to the technology areas and concerns previously discussed with respect to commercial IT, three issues were identified for key Command and Control warfighting capabilities amenable to direct Department action, as summarized in the chart below.

These are provided for consideration within the Department. The recommendations use the portals and levers construct developed in the *DIBCS BA* study and as further expanded in this study.

COMMAND AND CONTROL 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**
Helmet Mounted Display	R&D/ Prod[29]	5	4		Fund innovation in non-aviation applications	In near term programs, maximize competitive opportunities for weapon system design	Deny foreign acquisition of U.S. firms, particularly for non-aviation applications
Swarming Control Tools	R&D	Many[30]	Many[30]		Invest in R&D to demonstrate technology and establish producers	Structure competitions to encourage new industry participants	Deny teaming agreements/ transactions that limit innovation
Optical (Laser) Intersatellite Links	Prod	2	3		Continue investing in transition to manufacturing	Structure competitions to encourage new industry participants	Deny teaming agreements/ transactions that limit innovation

Sources: Booz Allen Hamilton and ODUSD (IP)

<u>Helmet Mounted Displays (HMDs)</u>. HMDs are an important technology for current and future warfighters. This technology started as a pilot aid to improve situational awareness without distracting them from the operational environment. Current developments in HMDs seek to perform the same function for land warfare applications. The importance of HMDs for enabling knowledge-empowered warriors cannot be over-emphasized in a network-centric force.

U.S. industry currently has sufficient domestic sources, but no clear technology advantage over foreign suppliers. To develop a technology leadership advantage, the Department should fund innovative non-aviation applications. The Department should also structure acquisition strategies and leverage weapon system designs to promote competition and innovation among suppliers. To assure the necessary breadth in the domestic HMD industrial base, the Department should be prepared to deny any attempts by foreign firms to acquire HMD suppliers, especially those involved in non-aviation applications.

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[29] Aviation applications are in production; other applications are in R&D.
[30] The "many" domestic and foreign sources listed are all involved in swarming R&D.

Swarming Control Tools. Swarm intelligence is a shift in mindset from centralized control to decentralized control and distributed intelligence; and from predefined solutions to emergent, self-organizing strategies and tactics. This research is still in the early stages but clearly represents a breakthrough technology. Funding innovation in this important technology area began in April 2003, when the Defense Advanced Research Projects Agency (DARPA) awarded a contract to Icosystem to apply principles of swarm intelligence to the control of robotic swarms. To ensure further development of additional domestic sources that can produce the innovations necessary to achieve a technology lead, the Department must appropriately control intellectual property rights so that they are available to multiple potential manufacturers within the *lab to manufacturing* portal. Once swarming control tools enter the production stage, the Department must be ready to stage competitions to develop sufficient sources and deny potential mergers or teaming agreements if those transactions threaten innovation offered by multiple sources.

Optical (Laser) Intersatellite Links. There are a plethora of suppliers involved in the development, manufacture, and distribution of satellite communication components. Both small startup firms and major defense suppliers, including teams among such firms, are involved in satellite communications. However, we found only two companies that are suppliers of intersatellite optical communications. This breakthrough technology provides for the transfer of far more information with improved quality and less likely interception, at lower power rates. The Department should require competition of components during design of optical intersatellite links to encourage increased participation from multiple satellite communication companies and the development of new industry participants. Finally, the Department must be aware of, and block, any attempts to establish teaming arrangements or other structures that would further limit participants in this critical technology area.

In addition to these specific remedies recommended for specific JCFC2 issues identified in this study, these DIBCS assessments to date have reinforced our conviction of the soundness of this methodology and the importance of ODUSD(IP)'s role as the clearinghouse for industrial base deficiencies—those identified within the Department or elsewhere. ODUSD(IP) should continue to be the clearinghouse for industrial base deficiencies and will further assess Command and Control 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 Force Application, Protection, and Focused Logistics.

For other defense industrial base issues and assessments, ODUSD(IP) maintains insight into Service, Defense Agency, and other Department industrial base activities in its day-to-day responsibilities. This role is Congressionally-mandated in its responsibility for preparing the *Annual Industrial Capabilities Report to Congress*.[31] In addition, in the interagency process, ODUSD(IP) coordinates on industrial base issues affecting the Department. For all of these reasons, ODUSD(IP) is uniquely positioned and qualified to serve in this capacity.

[31] See Section 2504 of Title 10, United States Code.

The Department should continue to closely monitor C2 *BA/BWA* warfighting capabilities, and their enabling technologies and associate industrial base. The Department also should be prepared to deploy appropriate policy levers to maximize innovation and competition within the industrial base when deficiencies are identified. The methodology developed for the *DIBCS C2* and the associated portals and levers provide the Department with the necessary tools. Applying these tools with diligence will greatly increase confidence that critical technologies and associated industrial base capabilities are available when needed to maintain the U.S. warfighting superiority over any potential adversary.

AFTERWORD

As we complete this second industrial base capability assessment of the five-part DIBCS series, we continue to be proud of its scope and the meticulous and systematic analytical work underlying its findings. *DIBCS C2* has identified over 200 companies and research institutions providing nearly 300 critical technologies associated with the almost 200 *BA/BWA* warfighting capabilities associated with JC2FC. This effort has represented the analytical collaboration of over 100 individuals in our Senior Advisory Group, among the subject matter experts, as well as additional expertise sought from industry, government, and academia—not to speak of the staff of the Deputy Under Secretary of Defense (Industrial Policy). Red Teams added valuable perspective, and indeed, while our initial work had posed Airborne Data Link capabilities as a potential issue, the Industry Red Team associated with this study was able to reassure us that industry was already far along in developing this technology in multiple applications. Although difficult to quantify, we estimate that over 5,000 manhours have been sourced from the Department, our Booz Allen Hamilton and Institute for Defense Analyses teammates, and myriad individuals from the defense industrial base drawn into this analytical quest.

The rigor of the analysis is evident in the care with which capabilities and technologies were prioritized; the creativity with which potential applications were envisioned; and the comprehensiveness with which remedies to issues were articulated. Where *BA/BWA* defense industrial base capabilities were viewed at risk, no measure was left unexplored as a potential remedy: from R&D funding and successful product transition in a sufficient number of suppliers to the blocking of teaming agreements or other transactions that might continue to limit innovation.

The scope and value of this work—and the Joint Command and Control Functional Concept—is further evident in the vast differences in the nature of the issues identified as potential impediments for 21st century warfighting. The requirement for innovative helmet mounted displays applicable to all forms of warfare addresses communications issues at the level of the individual warfighter. Swarming control tools have mostly to do with robotic and unmanned technologies which will keep the individual warfighter out of harm's way to an increasing extent. The issues related to optical intersatellite links remind us of the importance of space as a frontier of 21st American warfare. Notably, none of these issues relate to platforms or their major subsystems—a further tribute to the effectiveness of the Joint Staff's capability focus in moving the Department from platforms to the more important—and subtle—capabilities associated with them.

As the study goes to print, we are already well into the *DIBCS Force Application* "spiral" of the DIBCS series. Once the DIBCS series is complete, we will have identified and analyzed thousands of warfighter capabilities, technologies, and companies associated with the Joint Staff's functional concepts—and will be providing real-time, actionable remedies to any insufficiencies identified. We owe the warfighter nothing less.

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Acronyms

ABL	Airborne Laser
ACS	Advanced Deployable System
ACTD	Advanced Concept Technology Demonstration
AEHF	Advanced Extremely High Frequency
AH-64	Apache Helicopter
AMF JTRS	Airborne, Maritime/Fixed Station Joint Tactical Radio System
APS	Advanced Polar System
AOC-WS	Air Operations Center – Weapon System
ATIRCM/CMWS	Advanced Threat Infrared Countermeasure/Common Missile Warning System
AWACS	Airborne Warning and Control System
BA	Battlespace Awareness
BA/BWA	Be Ahead and Be Way Ahead
BAH	Booz Allen Hamilton, Inc.
BAMS	Broad Area Maritime Surveillance
BDA	Battle Damage Assessment
BMC2	Battle Management Command and Control System
BMDS	Ballistic Missile Defense Program
C2	Command and Control
C-5 RERP	C-5 Reliability Enhancement and Re-Engining Program
C-17A	Globemaster III Advanced Cargo Aircraft
C-130	Hercules Cargo Aircraft
C3I	Command, Control, Communications, and Intelligence
CAVE	Cave Automatic Virtual Environment
CEO	Chief Executive Officer
CFIUS	Committee on Foreign Investment in the United States
CH-47	Cargo Helicopter Upgrade
Chem DeMil	Chemical Demilitarization Program
CJCSI	Chairman of the Joint Chief of Staff's Instruction
COA	Course of Action
COTS	Commercial Off-the-Shelf
CVN	Nuclear-powered Aircraft Carrier
DARPA	Defense Advanced Research Projects Agency
DCGS	Distributed Common Ground System
DDG	Guided Missile Destroyer
DDX	Future Destroyer
DIBCS	Defense Industrial Base Capability Study
DJC2	Deployable Joint Command and Control
DoD	Department of Defense
DoJ	Department of Justice
DDR&E	Director, Defense Research and Engineering
DSCS/GBS	Defense Satellite Communications System/Global Broadcast Service
DUSD (IP)	Deputy Under Secretary of Defense (Industrial Policy)

E-2C	Advanced Hawkeye Aircraft
E-3	Sentry Airborne Warning and Control System (AWACS) Aircraft
E-10A	Multi-Sensor Command and Control Aircraft
EP-3	Aries (Airborne Reconnaissance Integrated Electronic System)
F/A-18	Hornet Fighter/Attack Aircraft
F/A-22	Raptor Fighter/Attack Aircraft
F-35	Joint Strike Fighter
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
GCCS-J	Joint Global Command & Control Systems
Global Hawk	High Altitude Endurance Unmanned Aerial Vehicle
GMTI	Ground Moving Target Indication
GPS	Global Positioning System
H-S-R	Hart-Scott-Rodino
HIMARS	High Mobility Artillery Rocket System
HMD	Helmet Mounted Display
ID	Identification
IDA	Institute for Defense Analyses
IFDL	Intraflight Data Link
IFF	Indentification Friend or Foe
I/O	Input/Output
IPB	Intelligence Preparation of the Battlespace
ISL	Intersatellite Link
IT	Information Technology
J6	Joint Staff, Command, Control, Communications, and Computer Systems Directorate
J8	United State Joint Forces Command, Joint Requirements and Integration Directorate
JASSM	Joint Air-to-Surface Standoff Missile
JC2FC	Joint Command and Control Functional Concept
JCIDS	Joint Capabilities and Integration Development System
JDAM	Joint Direct Attack Munition
JPALS	Joint Precision Approach and Landing System
JSF	Joint Strike Fighter
JSOW	Joint Standoff Weapon
JSTARS	Joint Surveillance Target Attack Radar System
JTRS	Joint Tactical Radio System
LRIP	Low Rate Initial Production
LW	Land Warrior
MC2A	Multi-sensor Command and Control Aircraft
MCS	Maneuver Control System

MEMS	Micro-electro-mechanical System
MHCLPM	Mini High-Capacity Low-Power Memory
MIDS-LVT	Multi-functional Information Distribution System-Low Volume Terminal
MH-60S	Multi-Mission Helicopter Upgrade
MM III	Minuteman III
MMA	Multi-mission Maritime Aircraft
MPF	Maritime Prepositioning Force
MPS	Mission Planning System
MUOS	Mobile User Objective System
NCO	Net Centric Operations
NEMS	Nano-Electromechanical System
NESP	Navy EHF Satellite Communication Program
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NTW	Navy Theater Wide
OODA	Observe-Orient-Decide-Act
OSD	Office of the Secretary of Defense
OTAR	Over-the-Air Rekeying
PAC-3	Patriot Advanced Capability-Phase 3
QRSP	Quick Reaction Special Projects Program
R&D	Research and Development
RC-135	Operational Flight Trainer
RF	Radio Frequency
S&T	Science and Technology
SAG	Senior Advisory Group
SATCOM	Satellite Communication
SBIR	Small Business Innovation Research program
SBIRS-High	Space-Based Infrared System - High
SDD	System Development and Demonstration
SM 6	Standard Surface-to-Air Missile 6
SSGN	Nuclear-Powered Cruise Missile Submarine
T-AKE	Lewis and Clark Class of Auxiliary Dry Cargo Ships
TBMCS	Theater Battle Management Core Systems
THAAD	Theater High Altitude Area Defense
TSAT	Transformational Satellite Communication System
UAV	Unmanned Aerial Vehicle
UH-60M	Blackhawk Utility Helicopter Upgrade
USAF	United States Air Force
USCENTCOM	United States Central Command
USD(AT&L)	Under Secretary of Defense (Acquisition, Technology, and Logistics)
USN	United States Navy
USSPACECOM	United States Space Command
UV	Unmanned Vehicle
UWCC	Universal Wireless Communications Consortium
V-22	Osprey Joint Advanced Vertical Lift Aircraft
Wideband	Wideband Communications Satellite System (fills the gap between

Gapfiller	DSCS/GBS and Advanced Wideband System)
WIN-T	Warfighter Information Network-Tactical
XBR	X-Band Radar

Appendix A

DIBCS Command and Control Capability Framework

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Monitor & Collect Data

An initial picture or impression developed by a commander of the operational environment by observing the situation and orchestrating the collection of different types of information from different sources.

Obtain Information on Adversary Forces and Assets Equal
• Provide tasking to gather relevant Intelligence Preparation of Battlespace (IPB) concerning adversary states/actors/inhabitants of an area

Obtain Information on Adversary Forces and Assets Be Ahead
• Provide tasking to locate, identify, track, and observe adversary forces/actors anywhere (all domains)/anytime in near-real-time; to include assessment of size, deployment, and status
• Provide tasking for persistent surveillance of adversary leadership figures, facilities, proliferation mechanisms and high value forces in the face of adversary denial and deception efforts
• Provide tasking to gather data concerning adversary intent and methodology for carrying out the movement, deployment, and maintenance of forces
• Provide tasking to identify all classes of targets and their status
• Provide tasking for early warning of hostile actions

Obtain Information on Adversary Forces and Assets Be Way Ahead
• Provide shared control to synchronize cross-domain, cross-discipline collection efforts, execution of sensors, and exploitation of outputs
• Understand and detect potential adversaries' counter collection and denial (CC&D) against our monitor and collection capabilities
• Provide tasking to sense, identify, and track as necessary suspected CBRNE effluents, biomarkers, or facilities

Obtain Information on Non-Aligned Forces and Assets Equal
• Provide tasking to gather relevant intelligence preparation of the battlefield (IPB) data concerning the non-aligned states/actors/inhabitants of an area

Obtain Information on Non-Aligned Forces and Assets Be Ahead
• Provide tasking to locate, identify, track and observe non-aligned forces/actors anywhere (all domains)/anytime in near-real-time

Monitor & Collect Data – Continued

Obtain Information on Friendly Forces and Assets Be Ahead
• Provide tasking to blue forces (Joint and Combined) to report location and status of friendly forces/actors -- prompt and timely, in many cases on a near-continuous/real-time basis

Obtain Geospatial Information Equal
• Provide tasking to obtain precise mapping and geodesy information

Obtain Weather Information Be Ahead
• Provide tasking to provide continuous, highly accurate information on current and projected environmental conditions that will affect the ability of assigned forces to plan, execute, and support the plan

Obtain Logistics Information Neutral
• Task the engineering evaluation of structures to determine suitability for a particular use

Obtain Logistics Information Be Ahead
• Task, collect, fuse, and assess friendly unit/equipment/weapon systems status reports (SORTS/SITREPS)
• Obtain data from logistics C2 systems to include total asset visibility, management for assets being processed, moved or stored from supplier to consumer, and in-transit tracking of mobility operations (Note: Logistics C2 is part of the Focused Logistics sector)

Obtain Political and Military Information Equal
• Monitor and report world events and relevant government/public indicators/reactions relevant to the campaign

Develop a Situational Understanding

Once the information is collected, commanders then develop an initial understanding by putting it into a context, thus creating situational awareness. The context is created by deducing patterns of interaction among the various factors in the operational environment. These patterns are the result of a combination of the commanders' previous experience and own intuition.

Develop, Display, and Assess Tailored COP Equal
• Exploit and integrate National Geospatial-Intelligence Agency (old NIMA) geospatial information systems (GIS) data in original, untransformed formats, civil/commercial data, and selected allied GIS data
• Enable Commanders to become aware of the information flowing within their Area of Responsibility (AOR) to facilitate adjustments to meet operational mission requirements

Develop, Display, and Assess Tailored COP Be Ahead
• Maintain and provide a clear, consistent, accurate, and protected Common Operational Picture of the battlespace that is tailorable so that it is relevant to individual needs
• Develop synopses of intelligence produced by the national level agencies (NSA, CIA, DIA, etc.)
• Display information in a manner that provides battlespace visualization and facilitates situational awareness
• Ensure the real-time feedback to the Commander and distributed staff on the current situation, status of forces and status of the Commander's critical information requirements
• Differentiate friendlies, neutrals, non-combatants, and their assets in processing and displays
• Identify, profile, and track primary antagonists
• Provide a means to filter out superfluous information to the level of fidelity as determined by the local Commander
• Periodically and on-demand receive, maintain, and transmit operational data with higher, peer, and lower staff elements
• Understand the phenomenologies or activities that could be undermining the understanding of the situation
• Understand intelligence resource utilization and performance in separate domains

Develop a Situational Understanding – Continued

Develop, Display, and Assess Tailored COP **Be Way Ahead**
• Receive, process, correlate, and display information (including raw, processed, and fused intelligence; also mission planning/results) from all sources, and at all classification levels, in forms that enable timely, actionable decisions at all levels of conflict
• Perform collaboration, synchronization, integration, exploitation, analysis, and production of observed data and information for operational use and decision making

Identify Political/Military Goals and Constraints **Equal**
• Identify U.S. policy goals and the estimated goals of other parties
• Identify the general politico-military environment that would establish the probable preconditions for execution of the plan
• Outline political decisions needed from other countries to achieve U.S. policy goals and conduct effective U.S. military operations to attain U.S. military missions.
• Summarize competing political goals that could cause conflict
• Characterize known operational constraints (ROE, treaties, domestic and international airspace, restricted waters, etc.)
• Analyze the assigned mission (includes assigned strategic military and politico-military objectives) and related tasks in the context of the next higher echelon's campaign plan or operations order, and analyze the strategic aim

Assess Adversary Capabilities and Intentions **Be Ahead**
• Identify adversary senior leadership, strengths, capabilities, vulnerabilities, and critical nodes/gaps
• Characterize emerging threats in time to influence future countermeasure developments
• Produce decision-quality predictive assessments and recommendations from any combination of stored and/or real-time information
• Develop Commander's assessment of situation and probable Red Courses of Action, prioritized according to Commander's assessment of threats to their mission

Develop a Situational Understanding – Continued

Project Weather and Logistics **Equal**
• Analyze projected environmental conditions to assess impact on ability of assigned forces to plan, execute, and support the plan
• Understand force lists and force movement requirements for force deployment
• Analyze current Personnel Status Report (PERSTAT) and resources or supplies on hand or available for allied/coalition or friendly force mission accomplishment
• Analyze current adversary personnel status and resources or supplies on hand or available to be used to conduct operations against friendly forces

Issue Commander's Intent **Be Ahead**
• Communicate Mission, Commander's Intent, and CONOPS guidance - to include desired end state
• Provide Commander's assessment of probable enemy COAs, prioritized according to Commander's assessment of threats to their mission; identify adversary strengths, capabilities, vulnerabilities and critical gaps

Develop Courses of Action (COA), Develop a Plan

The commander decides on a course of action. Deciding on a course of action in structured or analytical decisionmaking consists of developing several alternatives, assessing the alternatives, and then selecting the best one.

Design Candidate COAs **Be Ahead**
• Develop friendly COAs
• Assess previous operations to determine opportunities for improvement
• Determine branches and sequels for COAs
• Establish measures of effectiveness (MOEs), controls, or standards to measure outcomes to determine if desired end state was accomplished
• View the adversary as an integrated system-of-systems (political, military, economic, social, infrastructure, and information (PMESII)) and leverage networked knowledge and understanding of the adversary and battlespace environment to better identify probabilities and possibilities for the Commander

Design Candidate COAs **Be Way Ahead**
• Identify desired/anticipated/potential unintended first, second, and third order effects of each course of action

Assess COAs and Select Preferred COA **Be Ahead**
• Assess friendly COAs and select preferred (Note: Defines Commander's intent for that COA and plan)
• Identify vulnerabilities and potential operational miscues that an adversary may exploit from candidate COAs

Develop Detailed Plan for Deployment, Employment, and Sustainment of Forces **Equal**
• Merge, generate and tailor force lists and force movement requirements
• Forecast logistics requirements, identify and address shortfalls
• Determine required/available force protection personnel/capabilities required to meet protection priorities
• Coordinate required political actions/approvals
• Conduct legal review of plan
• Develop media communications plan
• Develop exit strategies

Develop Courses of Action (COA), Develop a Plan - Continued

Develop Detailed Plan for Deployment, Employment, and Sustainment of Forces Be Ahead
• Develop plan (campaign or operational) in concert with rules of engagement, treaties, agreements, and other identified constraints
• Scrutinize the environment, factors, and conditions that must be understood to successfully apply combat power, protect the force, complete the mission, and minimize collateral damage. This includes the air, land, sea, space domains and the included enemy and friendly forces; facilities; weather; terrain; the electromagnetic spectrum; and the information environment within the operational areas and areas of interest.
• Determine tasks, which involves determining the measurable, concrete steps that must be taken to accomplish the objective(s)
• Prioritize and sequence tasks to accomplish the mission and desired effects in concert with the Commander's Intent
• Match resources to the tasks to be accomplished
• Deconflict air, space, maritime, land and information capabilities and effects
• Plan to leverage technologies and techniques to allow joint forces to focus more precise actions and resources against an adversary's key nodes and vulnerabilities to achieve specific effects

Develop Detailed Plan for Deployment, Employment, and Sustainment of Forces Be Way Ahead
• Collaboratively develop operations intelligence, Operations Plans (OPLANS), Contingency Plans (CONPLANS), and ISR collection plans that can be rapidly disseminated by Integrated Tasking Orders
• Develop effects-based operations plans and orders by determining the capability of theater infrastructure and allocated assets to support force projections and sustainability requirements
• Identify and interpret kinetic and non-kinetic effect-based operational requirements, then identify and address subsequent analytical and informational requirements and shortfalls

Execute (Monitor and Adapt)

Once the decision is made, the commander puts the decision into action or instructs others to act in support of the chosen course of action and exercises leadership to motivate others in executing the decision. Monitoring the execution of the plan allows the commander to observe the results of the decisions and to adapt as the process starts again.

Issue Commander's Guidance/Tasking/Plan **Equal**
• Verify receipt and understanding of orders by units
• Accept status updates from units

Issue Commander's Guidance/Tasking/Plan **Be Ahead**
• Provide direction to subordinates and friendly forces to conduct the plan. Direction includes (as necessary) Commander's Intent, situation assessment, plan dissemination, mission orders, tasking, ROE, etc.
• Request tasking of supporting assets not controlled by the Commander (e.g. ISR collection, etc.)

Rehearse the Plan **Equal**
• Work on contingency skills and Standard Operating Procedures (SOP) with complete task force and OPCON augmentees to complete the mission

Rehearse the Plan **Be Ahead**
• Continuously conduct collaborative planning and rehearsal among higher, peer and lower staff elements
• Rehearse the mission with all elements to include OPCON augmentees

Synchronize Forces and Execute **Equal**
• Delegate authority as required to execute operations
• Monitor, task, and re-assess mobility assets
• Allow C2 authority and functionality transfer from one site to a designated alternate site as part of routine operations or in the event a primary site is rendered non-operational

Execute (Monitor and Adapt) - Continued

Synchronize Forces and Execute **Be Ahead**
• Prepare to execute operations (deploy forces, position logistics, etc.)
• Monitor, direct, and dynamically control operations in all domains and at all levels of command from unit through National/Joint and/or Coalition, to include battlefield C2 capabilities, ensuring total force coordination
• Provide tasking/retasking of weapons/forces to respond to time sensitive targets (includes enroute tasking/retasking, targeting, and other required mission information)
• Prioritize, integrate, and address changing information requirements

Synchronize Forces and Execute **Be Way Ahead**
• Ensure continuous real-time situational awareness of the status of assigned or cooperating Joint and Combined forces and the joint operations area (JOA)
• Obtain and monitor decision-quality targeting information in real-time, and provide decision-quality predictive kinetic and non-kinetic targeting assessments and recommendations to support ongoing operations. Enables time sensitive targeting

Assess Progress of Operation **Equal**
• Assess attacks against friendly assets in physical or infosphere battlespace
• Monitor rules of engagement, treaties, and agreements compliance. Recommend changes to and monitor subordinate command requests for changes to ROE

Assess Progress of Operation **Be Ahead**
• Collect, fuse, and assess (in real-time) events and battle damage/effects-based assessment reports impacting strategic, operational, and tactical operations
• Monitor subordinate Commander's tactical operations in support of tasked effects

Execute (Monitor and Adapt) - Continued

Adjust Guidance/Tasking/Plan **Be Ahead**
• Dynamically adjust guidance/plan and retask from hour-to-hour or minute-to-minute to respond to enemy actions/counteractions, detection, evasion and counter collection and denial (CC&D)
• Provide ad hoc tasking of sensors from forward locations by supported Commanders
• Initiate new C2 cycle when situation or plan execution dictates

Adjust Guidance/Tasking/Plan **Be Way Ahead**
• Dynamically retask forces (to include ISR collection assets), as required by the situation, and provide immediate information to Commander for current operations purposes

Miscellaneous **Equal**
• Disseminate information to the media

Computers, Communications, and Networks

Sharing information assures that all commanders are operating from the same baseline of information. It improves the quality of awareness and understanding. Sharing awareness is sharing an initial understanding of the operational environment and improves commanders' understanding because each of them is working from the same basic information about the operational environment. Sharing understanding (including sharing commander's intent) is a deeper understanding of the operational environment framed by the experience and intuition of commanders across echelons and functions. Sharing understanding allows C2 to be more decentralized and more responsive to small but important changes in the operational environment. It improves the overall speed and quality of decisions. Networking is the connecting together all of the decisionmakers across echelons and functions. Networking is enabled by a communications and data infrastructure employing a robust set of standards that facilitate the exchange of information. It also facilitates the interaction across echelons and functions.

Communications **Equal**
• Provide transport systems with a transmission priority scheme to ensure that higher priority traffic arrives at its destination ahead of routine or lower priority traffic
• Provide continuous earth coverage in order to support worldwide operations
• Provide an open communications architecture (e.g. net-centric or web-based) for enhanced interaction and interoperability among different levels of command and operating units belonging to U.S. and/or allied forces
• Provide communications with U.S. and host nation authorities [local, civil, and federal] for conducting crisis management/disaster relief operations as well as operations other than war
• Provide connectivity to civil agencies and organizations and to commercial industry partners for the purposes of using their capabilities in support of military operations
• Integrate commercial services into communications capabilities to take advantage of the latest communications technologies
• Communicate with civilian authorities in managing the consequences of natural and man-made hazards to assist those authorities

Computers, Communications, and Networks - Continued

Communications Be Ahead
• Allow senior leadership [national to theater] to directly communicate with fielded forces or initiate weapons employment without support from intermediate levels of command for the purpose of rapid execution
• Provide bandwidth on demand to all operational levels to allow for fast and complete transmission of all types of required data for commanding and controlling forces
• Provide connectivity to all fixed and mobile locations/users to provide connectivity for the purpose of controlling forces and coordinating force movements
• Provide contingency communications in the event of the loss of normal communications systems in order to maintain continuity of command and operations
• Provide secure battlespace connectivity for the assessment, planning and conduct of all types of operations
• Provide required connectivity to geographically separated, operational and support units and facilities for the purposes of reporting status of forces / equipment and new requirements
• Provide connectivity to combatants in order for them to determine and communicate information requirements and push information as required
• Provide communications capability to deployed forces and command centers en route to forward areas for mission planning
• Provide a system that optimizes the use of the electromagnetic spectrum through efficient frequency reuse and advanced modulation, compression, and filtering techniques, and complies with DoD, National, and International spectrum management policies as appropriate
• Provide an environmental EM characterization of the battlespace, identifying conditions adverse to communications, for the purposes of optimizing and efficiently configuring/reconfiguring the existing communications systems
• Employ assured interoperable communication and information systems consistent with the Global Information Grid (GIG) Architecture
• Communicate with government branches (executive, legislative, judicial) in catastrophic emergency for the purpose of coordinating continuity of government (COG) responsibilities

Computers, Communications, and Networks - Continued

Communications Be Way Ahead
• Provide a global communications capability, meeting all information requirements, between and among all levels of command, and operational and support units for commanding and controlling armed forces.
• Provide secure communications for disarming and disablement of selected weapons from the time of weapon release through impact/detonation
• Establish a seamless battlespace for obtaining and maintaining information superiority
• Provide robust, survivable communications, with graceful degradation and rapid restorable capability, for the purposes of continuity of command and control of forces worldwide
• Provide communication systems that utilize multiple means of connectivity to avoid any single point of failure, transmission security, and scalable communications in order to meet the needs of the users
• Provide global, interoperable, integrated, protected, survivable and high throughput information access and bandwidth on demand
• Provide robust communication in a harsh environment in order to maintain continuity of operations
• Link secure terrestrial nodes to forces worldwide by a redundant system of satellite, terrestrial wireless, and hardened landline technologies

Computers, Communications, and Networks – Continued

Networks **Be Ahead**
• Integrate land, air, sea, space, and information systems deployed worldwide into the network(s)
• Provide networks which are fault-tolerant
• Provide a system that can perform automated fault management for the network including problem detection, fault isolation and diagnosis, problem tracking until corrective actions are completed and historical archiving
• Command and control networks in a manner that seamlessly integrates with overall C2 and battle management
• Provide dynamic network management by gathering, storing, and using knowledge about the GIG using systems that have the capability to create/modify/distribute global information grid (GIG) network plans and orders
• Provide end-to-end network situational awareness, to support network management, through a system that has the capability to automatically generate and provide an integrated/correlated presentation of the networks and all associated network assets (includes automated dynamic system loading and bandwidth monitoring for the internal network, external network links, interfaces, and communications systems)
• Allow the operating system and key applications (e.g. TBMCS, Air Defense System Integrator {ADSI}) to provide the network operations centers automated reports that detail the status of critical processors and key operating system parameters for specified C2ISR and operating systems
• Maintain information flow to meet warfighter and warfighting support forces (for logistics, personnel, etc.) requirements
• Provide the means for prioritization of information flows within a theater, using theater apportioned resources, and enable dissemination of information in accordance with the Commanders' dissemination policies and user profiles
• Perform remote network device configuration/reconfiguration of objects that have existing DoD joint tactical architecture (JTA) management capabilities
• Transfer control rapidly on one or more objects or groups of varying size and reestablish control when relinquished without hindering end-to-end visibility by the senior network manager, while maintaining continuous control
• Provide tailorable, automatic notification to users of changes in policy, changes in user information requirements, information becoming available or change, changes in network status that impact information flow, changes in provider and user systems status, the delivery/receipt of information, status of services, product availability, or a conflict within the delivery plan

Computers, Communications, and Networks – Continued

Networks **Be Way Ahead**
• Provide highly networked forces to increase Commanders' and forces' flexibility and situational awareness via sharing of information and enabling collaboration
• Provide dynamic, multi-path and survivable networks

Collaboration **Be Ahead**
• Provide ability for users to operate in a multilingual environment as feasible using available, state-of-art, commercial off the shelf systems
• Translate foreign language information (electronic or hardcopy) in near-real time
• Establish communities of interest across the enterprise and dynamically modify their membership to work specific problems
• Provide an advanced suite that includes enroute user workstation capability for audio, video, video teleconference, text chat, whiteboard and application sharing, including initiation and management of virtual collaboration
• Enable and host global knowledge collaboration on demand
• Allow operational procedures to quickly but naturally evolve as a direct consequence of net-centric capabilities

Collaboration **Be Way Ahead**
• Provide tools and other C2 applications necessary for vertical and horizontal virtual/collaborative/distributed planning, execution, and coordination with other Commanders and organizations involved in operations (includes capability to coordinate intelligence, logistics, and information operations)

Computers, Communications, and Networks - Continued

Computer-to-Computer Information Exchange **Be Ahead**
• Provide access to data from disparate and geographically dispersed sources that can be supported with low latency
• Generate and disseminate friendly position and identification machine-to-machine, beyond the line of sight, and throughout a Joint/Coalition environment to enable audio and/or visual fratricide warning to weapons systems operators
• Deliver information to legacy and coalition systems as directed
• Perform ad-hoc, dynamic data transfer for mobile and agile forces and systems using standard interoperable information sets
• Link sensor and discovery information to data management and visualization tools
• Provide automated dissemination and receipt confirmation of selected battlespace situational awareness and Combat ID to warfighting Commanders

Computer-to-Computer Information Exchange **Be Way Ahead**
• Quickly and readily access all national security data/information/knowledge holdings to facilitate sharing while maintaining needed protection
• Ensure transmission of the right information (accurate, complete, most current) to the right nodes (C2, ISR, and weapons platforms - including munitions in flight), over the right communications path in the right format for integration and action
• Provide seamless machine-to-machine interfaces amongst technical collection systems to ensure no activity of interest goes unnoticed or unanalyzed
• Provide automated dissemination and tasking to platforms and weapons without need for human interface (e.g. targeting and mission data to weapons)

Computers, Communications, and Networks - Continued

Provide Information Assurance (IA) **Be Ahead**
• Provide communication protection and security at all appropriate levels
• Provide uniform, rule-based access to data/information/knowledge
• Track and report the status of the satisfaction of information requirements from the point of information request to the delivery of requested information
• Identify the source of information and its validity
• Automatically assign attributes (trusted tagging to include classification and access restrictions) to information that will govern its dissemination and also to convey the attributes of information to the transport system
• Rapidly identify individuals across the enterprise with "need-to-know" credentials
• Facilitate access to information at appropriate levels of security within minutes after access permission is administratively granted
• Manage all relevant sources of information in the infosphere in a manner that identifies duplication and ensures the relevance, timeliness and accuracy of the final information product

Provide Information Assurance (IA) **Be Way Ahead**
• Provide a global, interoperable, multi-level secure infosphere environment to store and manage all relevant information (Unclass to SCI, to include NATO releasable, allied releasable, coalition (multinational) releasable, and SAR/SAP)

Knowledge Management **Equal**
• Acquire needed information by search queries
• Perform automated de-classification using a filter software to enhance rapid information sharing with coalition members, interagency players, and non-governmental organizations
• Generate recurring reports using templates to gather and assemble information from selected databases - should be capable of automatically populating fields fro

Computers, Communications, and Networks - Continued

Knowledge Management Be Ahead
• Provide each theater CINC a standardized, core command and control capability that is tailorable to meet the C2 needs of the task force, and is adaptable to facilitate air, land, and sea-based operations
• Provide parallel C2 processes for monitoring and understanding the operational environment and synchronizing actions of assigned forces
• Exploit reach-back/reach-forward capability to support all locations, levels, and environments and provide access to standard databases and subject matter experts
• Provide automated availability of assets and in-transit visibility
• Provide decision support tools at each command level for use in planning and command and control (C2) of day-to-day and contingency operations
• Perform data mining that automatically derives relevant data and information
• Provide automated, continuous, highly accurate information on current conditions and any forecast environmental conditions that will affect the ability of assigned forces to plan, execute, and assess aerospace powers support to the campaign plan
• Automate dissemination of the presence of atmospheric or solar activity that may adversely affect communications or GPS accuracy and differential between that and international or unintentional manmade jamming or interference
• Allow an information producer's products to become known to the user population
• Provide capability to rapidly generate data for critical actionable information needs from sources including past data, current data, desired data, multi-level data
• Provide knowledge bases and linkages to external knowledge bases (U.S. or allies/coalition partners) to provide the foundation and groundwork to put data into context, convert, and aggregate into information

Computers, Communications, and Networks - Continued

Knowledge Management **Be Way Ahead**
• Provide a secure, assured/robust, survivable, and readily accessible, global command and control capability between and among the President, SECDEF, Combatant Commanders, DoD Agencies, interagency departments, selected allies, and assigned/augmenting forces
• Provide robust C2 capabilities at all force levels to ensure continued operation when under attack or damaged

Data Fusion/Correlation/Management **Equal**
• Maintain standardized information management - describe, transport and store data in a consistent manner across enterprises
• Maintain and store intelligence preparation of the battlespace and preparation battlespace awareness information
• Assist users in efficiently identifying their information requirements in a manner that captures the key attributes associated with those requirements
• Provide and maintain shared data prioritization scheme and rule sets
• Provide and maintain shared data prioritization scheme and rule sets

Data Fusion/Correlation/Management **Be Ahead**
• Provide standard metadata for input and output data including time, location (lat, long, altitude, frequency, cyberspace, subject, etc.) using automatic metadata tagging
• Preserve, transport and exploit data from non-ISR sources
• Provide systems that will automatically accomplish continuous data synchronization, replication, update, storage, and export for critical databases
• Separate "what is known" from "sources and methods" in data repositories
• Rapidly generate data and information profiles for previously unobserved events

Data Fusion/Correlation/Management **Be Way Ahead**
• Receive, process, correlate, and fuse track data at all classification levels and disseminate it throughout the GIG. This includes integration and examination of all sources of intelligence and information concerning friendly forces to derive a complete assessment of activity.

Computers, Communications, and Networks - Continued

Modeling, Simulation, and Analysis Be Ahead
• Model and simulate any relevant system
• Automated production of Course of Action (COA) options for operations
• Perform dynamic predictive capability
• Automate plan evaluation
• Provide visualization and analysis capability to manage and access the effectiveness and progress of campaigns, to include operational and combat assessments, option assessment in execution, and support plan rehearsal

Displays Be Ahead
• Provide integrated data display visualization at all force levels and appropriate to that force level
• Conduct interface and translation among service tactical C2 systems for Common Tactical Picture (CTP)
• Present information to and accept information from humans using a combination of visual, aural, tactile, and/or other unique sensory method

Miscellaneous Equal
• Systems must have the physical robustness to allow them to be transported through sand, spray, and humidity with no operational damage
• Systems should have a NBC filtering environmental control unit to partially mitigate the risk of NBC contamination
• Provide processing systems, display systems, and other critical data systems that can operate without prime power generation source or other external power for an extended period of time (e.g. 45 min, etc.) - Un-interruptible Power Source

Platform Control

Air Equal
• Provide ability for pilots to monitor speed, altitude, orientation and other status of their aircraft (avionics)
• Provide ability for pilots to control the aircraft's movement (speed, heading, orientation, altitude, status, etc.)
• Provide on-board ability for the vehicle to recognize and report obstacles/potential collisions
• Provide ability for the vehicle to recognize and report on-board system anomalies

Air Be Ahead
• Provide ability for pilots to monitor and control (to include tasking and retasking) the aircraft's on-board subsystems and payloads
• Provide ability for unmanned vehicle controllers to remotely monitor and control the vehicle's movement (speed, heading, orientation, altitude, status, etc.)
• Provide ability for unmanned vehicle controllers to remotely monitor and control (to include tasking and retasking) the vehicle's on-board subsystems and payloads
• Provide ability for the vehicle to respond by autonomous maneuvers to avoid obstacles/collisions
• Provide on-board ability for the vehicle to respond to on-board system anomalies (e.g. safing, self-healing, etc.)
• Provide on-board ability for the vehicle to recognize and report threats to and attacks on the vehicle
• Provide ability for unmanned vehicles to autonomously communicate with other unmanned vehicles (accomplish tasks such as crosslinking data/commands, networking, traveling in formation, acting in concert with one another, etc.)

Air Be Way Ahead
• Provide ability for pilots to monitor and respond to all relevant control, tasking/retasking, threat, and execution information
• Provide autonomous ability for the vehicle to take prompt defensive measures (may include on-board self-defense capabilities)
• Provide ability for unmanned vehicle controllers to remotely monitor and control multiple vehicles simultaneously

Platform Control - Continued

Land Equal
• Provide ability for drivers to monitor speed, direction and status of their land vehicle
• Provide ability for drivers to control the vehicle's movement (speed, heading, orientation, status, etc.)
• Provide ability for drivers to monitor and control (to include tasking and retasking) the vehicle's on-board subsystems and payloads
• Provide on-board ability for the vehicle to recognize and report obstacles/potential collisions
• Provide ability for the vehicle to recognize and report on-board system anomalies

Land Be Ahead
• Provide ability for unmanned vehicle controllers to remotely monitor and control the vehicle's movement (speed, heading, orientation, altitude, status, etc.) (attributes include redundant, reliable, secure, etc.)
• Provide ability for unmanned vehicle controllers to remotely monitor and control (to include tasking and retasking) the vehicle's on-board subsystems and payloads
• Provide ability for the vehicle to respond by autonomous maneuvers to avoid obstacles/collisions
• Provide on-board ability for the vehicle to respond to on-board system anomalies (e.g. safing, self-healing, etc.)
• Provide on-board ability for the vehicle to recognize and report threats to and attacks on the vehicle
• Provide ability for unmanned vehicles to autonomously communicate with other unmanned vehicles (accomplish tasks such as crosslinking data/commands, networking, traveling in formation, acting in concert with one another, etc.)

Land Be Way Ahead
• Provide ability for drivers to monitor and respond to all relevant control, tasking/retasking, threat, and execution information
• Provide autonomous ability for the vehicle to take prompt defensive measures (may include on-board self-defense capabilities)
• Provide ability for unmanned vehicle controllers to remotely monitor and control multiple vehicles simultaneously

Platform Control – Continued

Sea **Equal**
• Provide ability for ship control team to monitor the speed, depth, bearing, and status of their ship or submarine
• Provide ability for ship control team to control the ship's or submarine's movement (speed, heading, orientation, depth, status, etc.)
• Provide ability for ship control team to monitor and control (to include tasking and retasking) the ship's or submarine's on-board subsystems and payloads
• Provide on-board ability for the vehicle to recognize and report obstacles/potential collisions
• Provide ability for the vehicle to recognize and report on-board system anomalies

Sea **Be Ahead**
• Provide ability for unmanned vehicle controllers to remotely monitor and control the vehicle's movement (speed, heading, orientation, altitude, status, etc.) (attributes include redundant, reliable, secure, etc.)
• Provide ability for unmanned vehicle controllers to remotely monitor and control (to include tasking and retasking) the vehicle's on-board subsystems and payloads
• Provide ability for the vehicle to respond by autonomous maneuvers to avoid obstacles/collisions
• Provide on-board ability for the vehicle to respond to on-board system anomalies (e.g. safing, self-healing, etc.)
• Provide on-board ability for the vehicle to recognize and report threats to and attacks on the vehicle
• Provide ability for unmanned vehicles to autonomously communicate with other unmanned vehicles (accomplish tasks such as crosslinking data/commands, networking, traveling in formation, acting in concert with one another, etc.)

Platform Control – Continued

Sea Be Way Ahead
• Provide ability for ship control team to monitor and respond to all relevant control, tasking/retasking, threat, and execution information
• Provide autonomous ability for the vehicle to take prompt defensive measures (may include on-board self-defense capabilities)
• Provide ability for unmanned vehicle controllers to remotely monitor and control multiple vehicles simultaneously

Space Equal
• Provide on-board ability for the spacecraft to recognize and report obstacles/potential collisions

Space Be Ahead
• Provide ability for controllers to remotely monitor and control the spacecraft's movement (pointing, orientation, rotation, altitude, status, etc.) (attributes include redundant, reliable, secure, etc.)
• Provide ability for controllers to remotely monitor and control (to include tasking and retasking) the spacecraft's on-board subsystems and payloads
• Provide ability for the spacecraft to, as needed, respond by autonomous maneuvers to avoid obstacles/collisions
• Provide ability for the spacecraft to recognize and report on-board system anomalies
• Provide on-board ability for the spacecraft to respond to on-board system anomalies (e.g. safing, self-healing, etc.)
• Provide on-board ability for the spacecraft to recognize and report threats to and attacks on the vehicle
• Provide ability for controllers to remotely monitor and control multiple spacecraft simultaneously
• Provide ability for spacecraft to autonomously communicate with other spacecraft (accomplish tasks such as crosslinking data/commands, networking, traveling in formation, acting in concert with one another, etc.)

Space Be Way Ahead
• Provide autonomous ability for the spacecraft to take prompt defensive measures (may include on-board self-defense capabilities)

APPENDIX B

CRITICAL TECHNOLOGIES FOR COMMAND AND CONTROL ORGANIZED BY BROAD INDUSTRIAL AREAS

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Collaboration Management	
Collaboration management tools set up a networked environment wherein field intelligence and pre-existing knowledge databases can easily be accessed, shared, and discussed among decision makers. Such an environment facilitates the information dissemination and analysis process between independent and dispersed stations.	
♦ Collaboration Intelligence Fusion Tool	
♦ Collaborative Data-Fusion Network	
♦ Collaborative Geographic Information Systems (GIS) Sharing Tool	
♦ Collaborative Plan Development Toolkit	
♦ Collaborative Virtual Workspace	
♦ Device Management Tool	
♦ Digital Library Integration Tool	
♦ Distributed Collaboration Environment	
♦ High-Security Collaborative Network / Backbone	
♦ Rapid File Diffusion	
♦ Shared Database Management Tool	
♦ Social Network Analysis (SNA) Tool	

Communications and Networking

These technologies optimize communication channels in terms of their data throughput rates, capacity, security, and mobility. Bandwidth enhancers and bandwidth sharing tools expand the content and detail of the information being exchanged, as well as its update frequency. Wireless technology allows a channel to be established anywhere while robust security measures keep the data on that channel private.

♦ 3rd Generation Wireless Device (UWCC – 3G)	♦ Digital Signal Processor
♦ 802.16-Compatible Device	♦ Drive-by-Wire
♦ Active Network Management Tool	♦ Encrypted Switches
♦ Adaptive Jitter Buffer	♦ Extremely High Frequency (EHF) Transmitter/Receiver
♦ Airborne Data Link	♦ Frequency Hopping Equipment
♦ Asset Preemption Tool	♦ Global System for Mobile Communications (GSM) Phones
♦ Automated Security Self-Evaluation Tool (ASSET)	♦ Handheld, Portable Satellite Phone
♦ Automatic Bandwidth Adjustment Tool	♦ High Bandwidth Conduit
♦ Automatic Fault Detection/Isolation/Correction Tool	♦ High Bandwidth Router
♦ Automatic Network Device Discovery and Configuration Tool	♦ Infrared Wireless Communications Controller
♦ Bandwidth Accelerator	♦ Intersatellite Links
♦ Bandwidth Compression Tool	♦ Intraflight Data Link (IFDL)
♦ Bandwidth Controller	♦ Laser Communications (Lasercom)
♦ Bandwidth on Demand Tool	♦ Link Monitor Software
♦ Beam Formation/Atmospheric Compensation Tool	♦ Long-Wavelength Radio Transmitter/Receiver
♦ Burst Communications Receiver/Transceiver	♦ LPI/LPD Imagery Link
♦ Channel Aggregation Tool	♦ Microwave Link
♦ Code Division Multiple Access (CDMA) Device	♦ Monitoring Tool
♦ Data Crosslink	♦ Multiband Multiplexers

Communications and Networking – Continued	
♦ Multi-band Transmitter/Receiver	♦ Tactical Data Link
♦ Multi-Hop, Multi-Band, Multi-Mode, Multi-Function Jam Resistant Radio	♦ Thermal Noise Detector
♦ Multiple Protocol Label Switching (MPLS) Tool	♦ Threshold Assignment Tool
♦ Network Controller Radio	♦ Time Division Multiple Access (TDMA) Device
♦ Noise Cancellation Tool	♦ Traffic Monitoring Equipment
♦ Optical Cross Connect Switch	♦ Transmission Termination Tool
♦ Optical Waveform Synthesis	♦ Transmitter/Receiver
♦ Packet Size Variation Handling Tool	♦ Ultra-Wideband Device
♦ Portable Wireless Network Card	♦ Undersea Master Communications Node
♦ Public Key Infrastructure (PKI) Interoperability Tool	♦ Universal Mobile Telecommunications Device
♦ Public Key Infrastructure (PKI) Software	♦ VERSAmodule Eurocard (VME) Bus Communications Controller
♦ Radio Frequency Identifier	♦ Very High Frequency (VHF) Transmitter/Receiver
♦ Resonant Optical Modulator	♦ Very Low Frequency (VLF) Transmitter/Receiver
♦ Routing Algorithms	♦ Virtual Network Modeling and Simulation Tool
♦ Satellite Data Link	♦ Virtual Private Network (VPN) Tool
♦ Secure VPNs	♦ Wavelength Division Multiplexing Tool
♦ Short-Range Transmitter/Receiver	♦ Wideband Code Division Multiple Access (CDMA) Device
♦ Signal Hopping Transmitter/Receiver	♦ Wideband Satellite Communications Transmitter/Receiver
♦ Signal Modulator	♦ Wireless Control Loop Technology
♦ Smart Card	♦ Wireless Fidelity (Wi-Fi) Device
♦ Software-Programmable Radio	♦ Wireless Hub
♦ Sonar Communications Transmitter/Receiver	♦ Wireless Router
♦ Speech Signal Digital Enhancement Tool	

Computers

Computer technologies develop information processing hardware that is fast, efficient, durable, and deployable. With information coming from an increasing number of battlefield sensors, more sophisticated processing hardware is necessary to receive, sort, and analyze the data. Increased processing capability expands the scope of information synthesis and reduces the burden on human decision makers.

- Airborne Tactical Mission Computer
- Hardened Components
- High-capacity On-board Satellite Data Processor
- Intelligent Network Interface Card (NIC)
- Miniaturized High-Capacity Low-Power Memory
- Miniaturized Low-Power Processor
- Multi-function Processors
- Next Generation Command and Control Personal Computer (C2PC)
- On-board Mission Processor
- On-board Multi-Level Secure Mission Processor
- Optical Processor
- Super Computing Processor
- Wearable Computer

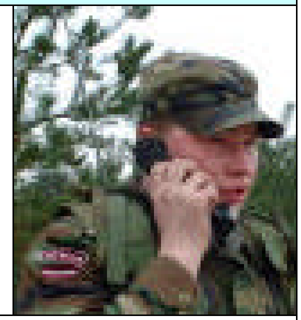
Data Management

In order to utilize the large volumes of data intrinsic to modern battlefield awareness, information must be securely saved and rapidly accessed. This requires hardware storage media to house the data and software to track, retrieve, and exploit the database information.

♦ Activities Tracking Information Database	♦ Machine Readable Cataloguing (MARC) Tool
♦ Authentication Device	♦ Massive Data Storage Device
♦ Authorization Management and Advanced Access Control Models (AM&AACM)	♦ Master Air Attack Plan (MAAP) Tool
♦ Automated Data, Information & Information Request Tagging	♦ Message Processing Tool
♦ Compliance Management Software	♦ Miniaturized Mass Storage Device
♦ Consistent Data Playback Tool	♦ Non-volatile RAM
♦ Cryptographic Module Validation Program (CMVP)	♦ Object Oriented Database
♦ Data Conversion Tool	♦ Optical Storage Device
♦ Data Import/Export Tool	♦ Parallel Data Processing/Data Reduction Software
♦ Data Mining Software	♦ Pattern Recognition Software
♦ Data Synchronization Tool	♦ Real-Time Data Handling/Storage Tool
♦ Data Warehouse	♦ Relational Database
♦ Database Application Development Toolkit	♦ Secure Database Replicator
♦ Distributed Geospatial Meta Database	♦ Secure Portable Data Storage Device
♦ Document Tagging Tool	♦ Social Software Analytics
♦ Dynamic Database Fusion Tool	♦ Spatial Indexing Software
♦ High-Capacity On-board Satellite Data Storage	♦ Temporal Indexing Software
♦ High-Volume Imagery Database	♦ Topicgraphical Indexing Software
♦ Image Tagging Tool	♦ Traffic Management Software
♦ Intelligent Data Retrieval Tool	♦ Web-enabled Timeline Analysis System (WebTAS)
♦ Knowledge Management Software	

Decision Support

Decision support comes from a large list of resources ranging from gathered intelligence to current and future 3D weather patterns. Using software, hardware, and algorithms along with simulations and modeling creates a very valuable resource for decision making.



♦ 2D/3D Modeling Software	♦ Expert Systems
♦ 3D Image Technology	♦ Future State Prediction Model
♦ 4D Temporal Modeling	♦ Heuristic Models
♦ Adaptive Belief Engine (ABEL)	♦ High Fidelity Human Performance Model
♦ Adversary Modeling	♦ Human and Mission Centered Decision Aid Tool
♦ Atmospheric Modeling	♦ Influence Analysis Simulator
♦ Automated Decision Aid Tool	♦ Intelligent Agent
♦ Automated Information Fusion and Correlation Tool	♦ Machine Learning Algorithm
♦ Bayesian Variable/Resolution Modeling Tool	♦ Multi/source Decision Support Software
♦ Behavioral Modeling	♦ Network Link/Node Analysis Software
♦ Biometrics Modeling	♦ Network/System Mapping
♦ Cognitive Modeling	♦ Neural Networks
♦ Cognitive Reasoning Toolkit	♦ Operational Analysis Tool
♦ Combat Maneuver Model	♦ Pattern Recognition Algorithms
♦ Computational Modeling Tool	♦ Perceptually Optimized Audio Signal Processing and Presentation Tool
♦ Course of Action (COA) Analysis Tool	♦ Portable Intelligent Maintenance Aid Tool
♦ Course of Action (COA) Generation Software	♦ Predictive Analysis Tool
♦ Cynefin Model	♦ Risk Analysis and Modeling Tool
♦ Database Modeling Tool	♦ Sensemaking Model
♦ Digital Elevation Model	♦ Signal Outage Forecasting Tool
♦ Embedded Decision Aid Tool	♦ Simultaneous Localization and Mapping (SLAM) Tools
♦ Embedded Simulation Tool	♦ Social/Economic/Cultural Modeling Software
♦ Enterprise Reporting Tool	♦ Taxonomy Development Software
♦ Environmental Modeling	♦ Transport and Dispersion Modeling Tool

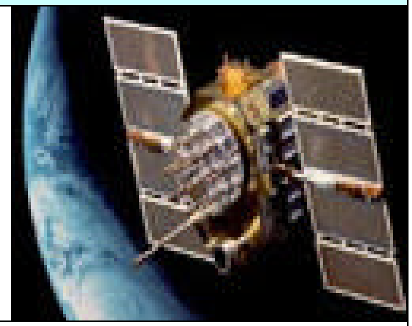
Displays

Displays utilize several different methods including plasma, laser projection, and liquid crystal to show both real and virtual pictures/motion video. Along with powerful software and hardware, displays can portray a clear picture of an environment or a battlefield to both a different place and time around the world to military personnel.

♦ 3D Audio Display	♦ Immersive Display Tool
♦ 3D Display	♦ Laser Projection Device
♦ Animation Software	♦ Lightweight 3D Plasma Display
♦ Auditory Displays	♦ Liquid Crystal Displays (LCD)
♦ Cave Automatic Virtual Environment (CAVE)	♦ Moving Map Tactical Display System
♦ Configurable Display	♦ Multi/INT Visualization Tool
♦ Digital Light Projection (DLP) Displays	♦ Multi/View Display Tool
♦ Display Enhancement Processing Tool	♦ Rapid Terrain Visualization Tool
♦ Electronic Ink Display	♦ Real and Virtual Environment (RAVE)
♦ Flexible Polymer Display	♦ Real/time Synthetic Imager
♦ Haptic Display	♦ Spatial Light Modulator
♦ Heads/Down Display	♦ Streaming Video Viewer
♦ Heads/Up Display	♦ Synthetic Vision Device
♦ Helmet Mounted Display (HMDs)	♦ Tactical Portable Display
♦ Holographic Video Projection and Display	♦ Virtual Retinal Display
♦ Immersive Display Middleware	

Location and Identification

Locating and identifying both friendly and adversarial targets is a critical task. With major help from GPS and various tagging techniques, including infrared tagging, targets can be located, identified, and tracked. As next generation identification devices are refined, locating and identifying targets will become faster and more accurate.



- Automated Location and Identification Information Processing
- Common Georegistration Tool
- Geospatial Intelligence Visualization Tool
- GPS Signal Receiver
- GPS-based Precise Orbit Determination (POD) Device
- Infrared Tagging
- Next-Generation Secure Identification Friend or Foe (IFF) Device
- Personnel Tagging
- Signal-Target Geolocation and Mapping Tool

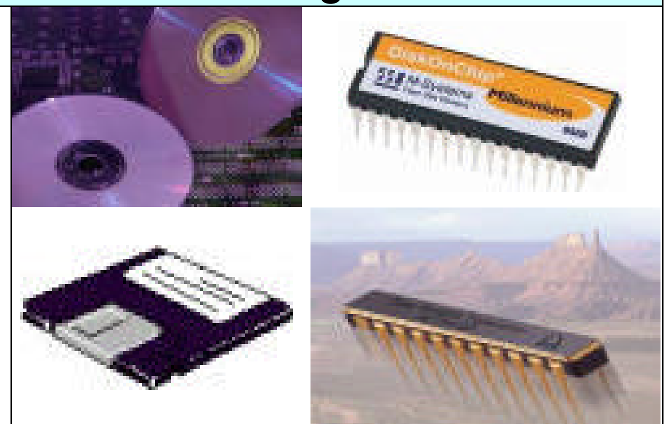
Power Generation and Storage

Power in one form or another is what drives all forms of electrical and mechanical tools. Power can be transported in any of several forms including electrical energy in batteries, ranging in size from smaller than a watch battery to larger than a standard car battery, and potential mechanical energy stored in the form of fuel.

- Fuel Cell
- Hybrid-Electric Drive
- Micro-Scale Fuel Cell
- Nano-Composite Solar Cell
- Next Generation Space Battery
- Next Generation Terrestrial Battery
- Solar Cells

Software Encryption and Tasking

Software is a vital component to all electronic equipment. Using materials such as silicon and data compression techniques we are able to store more and more information in smaller and smaller devices. Software can be transported through hardware or can be updated wirelessly for tremendous flexibility.



♦ Asymmetric (Public Key/Private Key) Cryptography Tool	♦ Double and Triple Wrapper
♦ Audio Compression	♦ Enterprise Intelligence Software
♦ Audio-Video Combination and Editing Tool	♦ Geographic Information System Software
♦ Automated Sensor Cross-cueing Tool	♦ Image Compression
♦ Automated Sensor Cueing Tool	♦ MLS Security Tools
♦ Automatic Language Translation Tool	♦ Over-the-Air Rekeying (OTAR) Device
♦ Common Encryption Tool	♦ Speech Technology Integration Tool
♦ Cyclic Code Shift Keying (CCSK)	♦ Symmetric Cryptography Tool
♦ Data Compression	♦ Text Comparison Utility
♦ Distributed Collaborative Smart Agent	♦ Video Compression
♦ Control Tool	

Unmanned Vehicle

Unmanned vehicles, at generally a lower cost than conventional vehicles, gather enormous amounts of valuable data. Unmanned airplanes, for example, can fly higher, further, and longer than an aircraft with a human pilot using automated programs and tools, which allows military personnel to stay out of harms way.

♦ Automated Path Planning Tool	♦ Multiple, Simultaneous Vehicle Control Tools
♦ Alternative Energy Sources	♦ Object-Based Task Level Controller
♦ Automated Resource Scheduling Tool	♦ Object-Resolved Control Tools
♦ Automated Tasking Tool	♦ Pilot-Centered, Virtual Mock-Up Cockpit
♦ Autonomous Satellite Control Software	♦ Quiet/Silent Propulsion Engine
♦ Autonomous Vehicle Control Software	♦ Satellite Cluster Control Software/Tool
♦ Cluster-Constellation Control Device	♦ Space Qualified Radiation Hardened Processor
♦ Control Moment Gyro	♦ Speech Computer Control Tool
♦ Dynamic Programming Tool	♦ Subsurface Control Tool
♦ Electric Ion Propulsion Device	♦ Telemetry, Tracking, and Control (TT&C) - Central Control Transmitter/Receiver
♦ Gyroscope	♦ Telemetry, Tracking, and Control (TT&C) - Control Algorithm
♦ Low-Observable Engine	♦ Turbofan Engine
♦ Low-Observable Structures	♦ Vertical Take-off/Landing Thrust-Vectoring Engine
♦ Model-Based Reactive Self-Configuration Tool	

APPENDIX C

COMPENDIUM OF ASSESSED TECHNOLOGY COMPANIES AND RESEARCH INSTITUTIONS

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

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Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Collaboration Management - Collaborative Intelligence Fusion Tool					
Alcatel (Alsthom Group)	1985	Paris, France	60,486	15,731.0	www.alcatel.com
ALPHATECH, Inc.	1979	Arlington, VA	200	40.0	www.alphatech.com
BTG's Defense Intelligence Business Group	-	Fairfax, VA	-	-	web.btg.com
General Dynamics Advanced Information Systems	1952	Arlington, VA	67,600	16,617.0	www.gd-ais.com
QinetiQ, Ltd.	2001	Hampshire, UK	9,000	1,399.1	www.qinetiq.com
Swedish Defense Research Agency's FOI Stockholm Information Fusion Group	1986	Stockholm, Sweden	1,300	136.0	www.foa.se
Collaboration Management - Collaborative Virtual Workspace					
CACI International, Inc.	1962	Arlington, VA	7,500	843.1	www.caci.com
Citrix Systems, Inc.	1989	Fort Lauderdale, FL	1,885	588.6	www.citrix.com
Collaborative Laboratories for Europe (CIBIT): De Utrecht; Aspen Enterprises, Ltd.; Learning Futures	1988	Netherlands, Brent Knoll, U.K., Abersychan, Wales	70	n.a.	www.cibit.com www.aspen.uk.com www.learningfutures.ndirect.uk
MatrixOne, Inc.	1983	Westford, MA	450	109.4	www.matrixone.com
metalayer AG	1999	Zurich-Kloten, Switzerland	32	-	www.metalayer.com
Silverline Technologies, Ltd.	1997	Warwick, UK	22	3.6	www.silverline.com
Communications and Networking - Bandwidth Accelerator					
AirZip	2000	Berkshire, U.K.	10	0.7	www.airzip.com
Expand	1998	Roseland, NJ	40	4.0	www.expand.com
Flashnetworks	1996	Amsterdam, The Netherlands	80	-	www.flashnetworks.com
InterWAVE Communications Int'l, Ltd.	1994	Menlo Park, CA	195	30.0	www.iwv.com
Venturi Wireless	1996	Sunnyvale, CA	39	-	www.venturiwireless.com
Communications and Networking - Data Link - Airborne Data Link					
BAE Systems	1977	Bristol, U.K.	68,400	14,911.2	www.baesystems.com
BES Systems, Ltd.	1998	Givataim, Israel	20	3.0	www.bes.co.il
General Dynamics United Kingdom, Ltd.	1952	Oakdale, South Wales, U.K.	67,600	16,617.0	www.generaldynamics.uk.com
Harris Corporation	1895	Melbourne, FL	10,200	2,092.7	www.harris.com

[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 include: Hoover's, AMADEUS (Analyse MAjor Databases from EUropean Sources), open source internet research, and telephone polling.

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Communications and Networking - Data Link - Airborne Data Link (continued)					
L-3 Communications (Communications Systems - West Division)	1997	Salt Lake City, UT	38,700	5,061.6	www.l-3.com/csw
The Aero Telemetry Corporation	-	Huntington Beach, CA	-	-	www.aerotelemetry.com
Communications and Networking - Data Link - Airborne Data Link - Field Programmable Gate Array					
Altera Corporation	1983	San Jose, CA	2,000	827.2	www.altera.com
Atmel Corporation	1984	San Jose, CA	7,900	1,330.6	www.atmel.com
Faraday Technology Corporation	1993	Hsinchu, Taiwan	462	96.2	www.faraday-tech.com
Toshiba Design & Manufacturing Service Corporation	1965	Tokyo, Japan	165,776	47,191.8	www.toshiba.com
Xilinx	1984	San Jose, CA	2,612	1,397.8	www.xilinx.com
Communications and Networking - Data Link - Airborne Data Link - Software-Definable Transceiver					
Allamat Electonic, Ltd.	-	Dobris, Czech Republic	-	-	www.allamat.cz
AMI Semiconductor Belgium BVBA	1966	Oudenaarde, Belgium	2,569	454.2	www.amis.com
MicroStrain, Inc.	1986	Burlington, VT	20	3.0	www.microstrain.com
Motorola	1953	Phoenix, AZ	88,000	27,058.0	www.motorola.com
Rohde & Schwarz GmbH & Co KG	1933	Munich, Germany	5,885	992.6	www.rsd.de
Silicon Laboratories, Inc.	1996	Austin, TX	486	325.3	www.silabs.com
Communications and Networking - Data Link - Intraflight Data Link (IFDL)					
Northrop Grumman	1929	Los Angeles, CA	123,000	26,200.0	www.northgrum.com
Symetrics Industries, LLC	1962	Melbourne, FL	70	18.0	www.symetrics.com
Communications and Networking - Optical Communications - Intersatellite Links					
Ball Aerospace Technologies Corporation	1956	Broomfield, CO	2,505	491.2	www.ball.com
Matra Marconi Space[2]	1990	Germany	3,670	-	www.matra-marconi-space.com
Northrop Grumman	1929	Redondo Beach, CA	123,000	26,200.0	www.northgrum.com
Oerlikon-Contraves Group	1936	Zurich, Switzerland	7,435	1,919.5	www.oerlikoncontraves.com
SINTEF	1950	Trondheim., Norway	1,700	-	www.sintef.no
Solid State Laser Communications in Space (SOLACOS)[3]	1922	Friedrichshafon, Germany	>100,000	25,110.8	www.eads.net

[2] Matra Marconi Space merged with EADS in 2003.
[3] German government funded project at Dornier Gmbh, (subsidy of EADS)

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Communications and Networking - Optical Communications - Laser Communications (Lasercom)					
Australian Centre for Space Photonics	1973	Australia	-	n.a.	www.aao.gov.au/lasers
Ball Aerospace Technologies Corporation	1956	Boulder, CO	2,505	491.2	www.ballaerospace.com
European Space Agency	1975	Paris, France	1,920	n.a.	www.esa.int
Los Alamos National Laboratory	1943	Los Alamos, NM	10,700	n.a.	www.lanl.gov/worldview.com
National Institute of Information and Communications Technology (formerly Communications Research Laboratory)	1952	Koganei, Tokyo, Japan	427	n.a.	www.nict.go.jp/overview/index.html
Northrop Grumman Radio Systems	1929	San Diego, CA	9,300	2,800.0	www.st.northropgrumman.com
Solid State Laser Communications in Space (SOLACOS)[3]	1922	Friedrichshafon, Germany	>100,000	25,110.8	-
Communications and Networking - Optical Communications - Wavelength Division Multiplexing (WDM) Tool					
Australian Fibre Works, Pty, Ltd.	2001	Victoria, Australia	-	-	www.ausfibreworks.com
CIENA Corporation	1992	Linthicum, MD	1,816	283.1	www.ciena.com
Cisco Systems, Inc.	1984	San Jose, CA	34,000	18,878.0	www.cisco.com
Fiber Optic Network Technology Company	1996	Surrey, B.C., Canada	5	n.a.	www.fontcanada.com
Lucent Technologies	1996	Murray Hill, NJ	34,500	8,500.0	www.lucent.com
OPTRONICS Technologies S.A.	1990	Athens, Hellas, Greece	-	-	www.optronics.gr
Communications and Networking - Radios - Multi-Hop, Multi-Band, Multi-Mode, Multi-Function Jam-Resistant Radio					
Harris RF Communications	1895	Rochester, NY	10,200	2,092.7	www.rfcomm.harris.com
RAFAEL Armament Development Authority	1948	Tel Aviv, Israel	6	2.0	www.rafael.co.il
Raytheon	1922	Fullerton, CA	78,000	18,109.0	www.raytheon.com
Rockwell Collins	1933	Cedar Rapids, IA	14,500	2,500.0	www.rockwellcollins.com
Rohde & Schwarz GmbH & Co KG	1933	Munich, Germany	5,885	992.6	www.rohdeandschwarz.com
Communications and Networking - Radios - Multi-Hop, Multi-Band, Multi-Mode, Multi-Function Jam-Resistant Radio - Adaptive Transceiver					
DICOM	1993	Uherské Hradište, Czech Republic	200	7.8	www.dicom.cz
General Dynamics Decision Systems	1952	Falls Church, VA	67,600	16,617.0	www.gd-decisionsystems.com
Harris RF Communications	1895	Rochester, NY	10,200	2,092.7	www.rfcomm.harris.com

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Communications and Networking - Radios - Multi-Hop, Multi-Band, Multi-Mode, Multi-Function Jam-Resistant Radio - Adaptive Transceiver (continued)					
Motorola	1953	Schaumberg, IL	88,000	27,058.0	www.motorolla.com
Rohde & Schwarz GmbH & Co KG	1933	Munich, Germany	5,885	992.6	www.rohdeandschwarz.com
Spectrum Signal Processing, Inc.	1987	Burnaby, B.C., Canada	136	19.6	www.spectrumsignal.com
Communications and Networking - Radios - Multi-Hop, Multi-Band, Multi-Mode, Multi-Function Jam-Resistant Radio - Antenna					
Antenova	1999	Cambridge, U.K.	26	-	www.antenova.com
France Telecom	1988	Paris, France	218,500	56,500.0	www.francetelecom.com/en/
Lucent Technologies	1996	Murray Hill, NJ	34,500	8,500.0	www.lucent.com
Nokia	1967	Espoo, Finland	37,031	51,359.0	www.nokia.com
Nortel Networks	1895	Brampton, Ontario, Canada	25,000	9.8	www.nortelnetworks.com
Northrop Grumman	1929	Los Angeles, CA	123,000	26,200.0	www.northgrum.com
Racal Antennas	1960	Southampton, U.K.	93	27.0	www.racal-antennas.com
Skycross, Inc.	2000	Melbourne, FL	18	2.0	www.skycross.com
STMicroelectronics	1987	Geneva, Switzerland	45,700	7,238.2	www.st.com
Texas Instruments and Advanced Bionics, Inc.	1938	Dallas, TX	34,154	9,834.0	www.ti.com
Thales Communication	1900	West Sussex, UK	9,000	20,293.1	www.thales-communications.com/communications/home_uk.html
Communications and Networking – Radios - Software-Programmable Radio					
BAE Systems North America	1977	Wayne, NJ	68,400	14,911.2	www.na.baesystems.com
European Aeronautic Defense & Space Company	2000	Munich, Germany	103,967	25,110.8	www.eads.com
ITT Aerospace	1974	White Plains, NY	39,000	5,626.6	www.acd.itt.com
Rohde & Schwarz GmbH & Co KG	1933	Munich, Germany	5,885	992.6	www.rohde-schwarz.com
Sony CSL, Inc.	1988	Tokyo, Japan	29	n.a.	www.csl.sony.co.jp
The Boeing Company	1916	Anaheim, CA	157,000	50,485.0	www.boeing.com/defense-space
Communications and Networking - Radios - Software-Programmable Radio - Adaptive Computing System-on-Chip					
Elixent	2000	Bristol, U.K.	40	-	www.elixent.com
Hitachi, Ltd.	1910	Tokyo, Japan	320,528	69,343.0	www.hitachi.com
Intel, Inc.	1968	Santa Clara, CA	78,000	30,141.0	www.intel.com

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Communications and Networking - Radios - Software-Programmable Radio - Adaptive Computing System-on-Chip (continued)					
Interuniversity Microelectronics Center	1984	Leuven, Belgium	1,272	134.0	www.imec.be
Motorola	1953	Schaumburg, IL	88,000	27,058.0	www.motorola.com
Quicksilver Technology	1998	San Jose, CA	65	-	www.qstech.com
Communications and Networking - Wireless Network - 3rd Generation Wireless Device (UWCC-3G)					
Hutchison 3G U.K., Ltd.	2000	Maidenhead, U.K.	1,700	11,400.0	www.three.co.uk
Lucent Technologies	1996	Richardson, TX	34,500	8,500.0	www.lucent.com
Motorola	1953	Schaumburg, IL	88,000	27,058.0	www.motorola.com
Nokia	1967	Espoo, Finland	37,031	51,359.0	www.nokia.com
Nortel Networks	1895	Richardson, TX	36,960	9.8	www.nortelnetworks.com
Sony Ericsson	2001	London, U.K.	55	32.4	www.sonyericsson.com
Communications and Networking - Wireless Network - 802.16-Compatible Device					
Airspan Networks, Inc.	1998	Boca Raton, FL	227	30.7	www.airspan.com
Alvarion, Ltd.	2001	Tel Aviv, Israel	579	127.2	www.alvarion.com
Aperto Networks	1999	Milpitas, CA	80	-	www.apertonet.com
Nokia	1967	Espoo, Finland	37,031	51,359.0	www.nokia.com
Wi-LAN, Inc.	1992	Calgary, Alberta, Canada	120	14.8	www.Wi-LAN.com
Communications and Networking – Wireless Network - Ultra-Wideband Device					
Multispectral Solutions, Inc.	1989	Germantown, MD	26	3.5	www.multispectral.com
Pulse~LINK™, Inc.	2000	Carlsbad, CA	36	-	www.pulselink.net
Wisair, Ltd.	2001	Tel-Aviv, Israel	26	-	www.wisair.com
Freescale Semiconductor, Inc.	1953	Austin, TX	22,000	4,900	www.freescale.com
Computers - Hardened Components					
Actel Europe	1985	Surrey, U.K.	500	146.0	www.actel.com
Alcatel	1985	Paris, France	60,486	15,731.0	www.alcatel.com
BAE Systems North America	1977	Manassas, VA	68,400	14,911.2	www.baesystems.com
Harrris Corporation	1895	Melbourne, FL	10,200	2,092.7	www.govcomm.harris.com
Honeywell's Solid State Electronics Center	1965	Plymouth, MN	550	-	www.ssec.honeywell.com
Maxwell Technologies	1965	San Diego, CA	184	45.0	www.maxwell.com
STMicroelectronics	1987	Geneva, Switzerland	45,700	7,238.2	www.st.com

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Computers – Hardened Components - Novel Shielding Materials					
Applied Coating Technologies, Ltd.	2000	Midlands, U.K.	-	-	www.applicoat.com
Maxwell Technologies	1965	San Diego, CA	184	45.0	www.maxwell.com
Rittal, Ltd.	1972	Heerborn, Germany	10,000	1,680.0	www.rittal.de
Shielded Components	-	Christ Church, New Zealand	-	-	www.shieldedcomponents.co.nz
Sigma Technologies International, Inc.	1992	Tucson, AZ	35	10.0	www.sigmalabs.com
Triton Systems, Inc.	1922	Chelmsford, MA	80	12.0	www.tritonsys.com
Computers - Miniaturized High-Capacity Low-Power Memory					
Hitachi, Ltd.	1910	Tokyo, Japan	320,528	69,343.0	www.hitachi.com
IBM	1885	Armonk, NY	255,157	89,131.0	www.ibm.com
Intel, Inc.	1968	Santa Clara, CA	78,000	30,141.0	www.intel.com
NEC Corporation	1899	Tokyo, Japan	145,807	39,788.4	www.nec.com
Network Appliance, Inc	1992	Sunnyvale, CA	2,400	892.0	www.netapp.com
Toshiba Corporation	1965	Tokyo, Japan	165,776	47,191.8	www.toshiba.com
Computers - Miniaturized High-Capacity Low-Power Memory - MEMS Integrated Circuit (IC)					
Hewlett Packard	1939	Palo Alto, CA	142,000	73,061.0	www.hpl.hp.com
IBM	1885	Armonk, NY	255,157	89,131.0	www.ibm.com
MEMSIC	1999	Jiangsu, China	70	-	www.memsic.com
Nanochip, Inc.	1996	Oakland, CA	23	3.5	www.nanochip.com
Samsung Electronics Co., Ltd.	1938	South Korea	175,000	33.8	www.samsung.com
Tower Semiconductor, Ltd.	1993	Migdal Haemek, Israel	1,265	61.4	www.towersemi.com
Computers – Portable Device – Command and Control - Wearable Computer					
Hitachi, Ltd.	1910	Tokyo, Japan	320,528	69,343.0	www.hitachi.com
Infineon Technologies	1999	Munich, Germany	32,308	7,167.0	www.infineon.com
Ingineo	2001	France	-	-	www.ingineo.net
Microvision, Inc.	1993	Bothell, WA	180	14.7	www.mvis.com
ViA, Inc.[4]	-	Bensalem, PA	n.a.	-	www.via-pc.com
Xybernaut	1990	Fairfax, VA	91	11.0	www.xybernaut.com
Computers – Processors - Miniaturized Low-Power Processor					
Dspfactory, Ltd.	1998	Ontario, Canada	76	22.8	www.dspfactory.com
EM Microelectronic	1975	Marin, Switzerland	350	-	www.emmicroelectronic.com
Southwest Research Institute	1947	San Antonio, TX	2,800	-	www.swri.edu

[4] Via, Inc. was purchased by Infologix in 2004.

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Computers – Processors - Miniaturized Low-Power Processor (continued)					
MIPS Technologies, Inc.	1998	Mountain View, CA	149	39.1	www.mips.com
NEC Electronics Corporation	2002	Tokyo, Japan	24,500	7,815.8	www.necel.com
Texas Instruments and Advanced Bionics, Inc.	1938	Dallas, TX	34,154	9,834.0	www.ti.com
Computers – Processors - Super Computing Processor					
Advanced Micro Devices	1969	Sunnyvale, CA	14,300	3,519.2	www.amd.com
ClusterVision	2002	AL Hoofddorp, Netherlands	15	5.4	www.clustervision.com
Cray	1972	Seattle, WA	900	237.0	www.cray.com
Hitachi, Ltd.	1910	Tokyo, Japan	320,528	69,343.0	www.hitachi.com
NEC Corporation	1899	Tokyo, Japan	145,807	39,788.4	www.nec.com
RackSaver, Inc.	1996	San Diego, CA	262	48.0	www.racksaver.com
Computers – Processors – Super Computing Processor - Optical Interconnects					
Albany Nanotech	1993	Albany, NY	30	125.0	www.albanynanotech.org
BinOptics Corporation	2000	Ithaca, NY	20	1.5	www.binoptics.com
BTG	1949	London, U.K	197	49.6	www.btgplc.com
Hitachi, Ltd.	1910	Tokyo, Japan	320,528	69,343.0	www.hitachi.com
IBM, Corning, Department of Energy, and the National Nuclear Security Administration	2003	Various	-	n.a.	www.fibers.org
Quadrics	1996	Bristol, U.K. and Roma, Italy	45	21.6	www.quadrics.com
Computers – Processors – Super Computing Processor - Quantum Computing					
IBM Almaden Research Corporation	1885	San Jose, CA	255,157	89,131.0	www.almaden.ibm.com
id Quantique	2001	Geneva, Switzerland	3	n.a.	www.idquantique.com
Los Alamos National Laboratory	1943	Los Alamos, NM	10,700	n.a.	www.lanl.gov/worldview.com
MagiQtech	1999	New York, NY	27	-	www.magiqtech.com
RIKEN	1917	Wako, Japan	693	-	www.riken.go.jp
Wave Systems, Inc.	1999	Vancouver, Canada	14	-	www.dwavesys.com
Data Management – Data Storage - Miniaturized Mass-Storage Device					
Cornice, Inc.	2000	Longmont, CO	105	-	www.corniceco.com
Forward Solutions, Inc.[5]	2003	San Ramon, CA	18	0.1	www.forwardsolutions.info

[5] Forward Solutions, Inc. is owned by PowerHouse Technologies Group, Inc.

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Data Management – Data Storage - Miniaturized Mass-Storage Device (continued)					
GS Magicstor, Inc.	2002	Guiyang, China	1,500	-	www.gs-magicstor.com
Iomega Corporation	1980	San Diego, CA	590	391.3	www.iomega.com
M-Systems	1989	Kfar Saba, Israel	311	130.1	www.m-sys.com
Toshiba	1965	Tokyo, Japan	165,776	47,191.8	www.toshiba.com
Data Management – Data Storage – Miniaturized Mass-Storage Device - Compact Holographic Memory					
Aprilis, Inc.	1999	Maynard, MA	27	4.4	www.aprilisinc.com
Data Storage Institute	1992	Singapore, Republic of Singapore	250	0.8	www.dsi.a-star.edu.sg
InPhase Technologies	2000	Longmont, CO	51	3.5	www.inphase-technologies.com
Manhattan Scientifics, Inc.	1997	Plano, TX	2	-	www.Mhtx.com
NTT Corporation	1999	Tokyo, Japan	7,450	10,104.0	www.ntt.com
Polight Technologies	2000	Cambridge, U.K.	19	5.8	www.Polight.com
Data Management – Data Storage – Miniaturized Mass-Storage Device - Nano-Electromechanical System (NEMS)					
Hitachi Global Storage Technologies	2003	Tokyo, Japan	21,000	4,200.0	www.hgst.com
IBM Zurich Research Laboratory	1885	Zurich, Switzerland	255,157	89,131.0	www.zurich.ibm.com
Nanochip, Inc.	1996	Fremont, CA	8	-	www.nanochip.com
NanoCo Technologies	2001	Manchester, U.K.	2	-	www.nanoco.biz
Nanosys, Inc.	2001	Palo Alto, CA	38	n.a.	www.nanosysinc.com
Oxonica	1998	Oxfordshire, U.K.	29	212.4	www.oxonica.com
Data Management – Database – Dynamic Database Fusion Tool					
Advanced System Architectures, Ltd.	1984	Bentley, U.K.	40	3.7	www.asa.co.uk
General Dynamics Advanced Information Systems	1952	Arlington, VA	67,600	16,617.0	www.gd-ais.com
Knowledge Based Systems, Inc.	1988	College Station, TX	100	6.0	www.kbsi.com
Silver Bullet Solutions	1996	San Diego, CA	15	2.0	www.silverbulletinc.com
Sonardyne	1971	Yateley, Hampshire, U.K.	155	2.4	www.sonardyne.com
Thales Systems	1892	Ottawa, Ontario, Canada	62,000	12,700.0	www.thalesgroup.com
Decision Support - Course of Action (COA) Generation Software					
Army Research Laboratory	1992	Adelphi, MD	2,000	n.a.	www.arl.army.mil

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Decision Support - Course of Action (COA) Generation Software (continued)					
U.S Army Communications-Electronics Command	1962	Monmouth County, NJ	-	n.a.	www.monmouth.army.mil/cecom
University of Chicago, Argonne National Lab	1942	Argonne, IL	4,000	n.a.	www.anl.gov
Displays - Helmet-Mounted Displays (HMDs)					
BAE Systems Avionics	1977	Bristol, U.K.	68,400	14,911.2	www.baesystems-avionics.com
CAE	1947	Toronto, Ontario, Canada	5,500	750.0	www.cae.ca
Microvision, Inc.	1993	Bothell, WA	180	14.7	www.mvis.com
Rockwell Collins	1933	Cedar Rapids, IA	14,500	2,500.0	www.rockwellcollins.com
Thales Avionics	1940	Massey Cedex, France	4,219	1,051.2	www.thales-avionics.com
Vision Systems International, LLC	1996	San Jose, CA	30	45.0	www.vsi-hmcs.com
Displays – Helmet-Mounted Display (HMDs) - Head-Tracking Display					
InterSense	1996	Burlington, MA	23	3.7	www.isense.com
Polhemus	1969	Colchester, VT	26	5.0	www.polhemus.com
VR Depot	1996	Santa Cruz, CA	1	0.2	www.vrdepot.com
Displays – Helmet-Mounted Displays (HMDs) - Retinal Display					
Holoverse, Inc.	1991	Yarmouth Port, MA	40	3.3	www.holoverse.com
Microvision, Inc.	1993	Bothell, WA	180	14.7	www.mvis.com
Displays – Immersive Displays - Cave Automatic Virtual Environment (CAVE)					
Barco N.V.	1934	Kortrijk, Belgium	4,117	701.2	www.barco.com
Engineering Research Center, Mississippi State University	1990	Mississippi State, MS	-	n.a.	www.erc.msstate.edu
Fakespace Systems, Inc.	1988	Marshalltown, IA	100	25.0	www.fakespacesystems.com
Georgia Tech Virtual Environments Group	1885	Atlanta, GA	12	n.a.	www.cc.gatech.edu/gvu/virtual
National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign	1986	Champaign, IL	500	-	www.ncsa.uiuc.edu
National Research Council Canada Virtual Environment Technologies Centre	1999	Ottawa, Ontario, Canada	4,000	150.0	http://www.nrc-cnrc.gc.ca
partnership: Institut Image in Chalon sur Saône and Ecole Nationale Supérieure d'Arts et Métiers	1997	Chalon-sur-Saone, France	38	n.a.	www.ai.cluny.ensam.fr
Sense8	1992	San Rafael, CA	35	10.0	www.sense8.com

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Displays – Immersive Displays - Cave Automatic Virtual Environment (CAVE) (continued)					
Softimage Company	1986	Montreal, Canada	300	-	www.softimage.com
VizTek, Inc.	2001	Iowa City, IA	6	0.5	www.viz-tek.com
VRCO	1996	VA Beach, VA	20	1.5	www.vrco.com
Displays – Immersive Displays – Cave Automatic Virtual Environment (CAVE) - Stereoscopic Eyewear					
Barco N.V.	1934	Kortrijk, Belgium	4,117	701.2	www.barco.com
eDimensional, Inc.	2000	West Palm, FL	10	0.2	www.edimensional.com
i-Art Corporation	1996	Taipei Hsien, Taiwan	-	-	www.iart3d.com
Inition, Ltd.	2001	London, U.K.	10	1.2	www.inition.co.uk
StereoGraphics Corporation	1982	San Rafael, CA	25	2.6	www.stereographics.com
VR Depot	1996	Summerlin, NV	1	0.2	www.vrdepot.com
Displays – Immersive Displays – Cave Automatic Virtual Environment (CAVE) - Stereoscopic Projection					
Barco N.V.	1934	Kortrijk, Belgium	4,117	701.2	www.barco.com
Christie Digital Systems	1979	Cypress, CA	300	150.0	www.christiedigital.com
Digital IMAGE	-	Overath, Germany	-	-	www.digital-image.de
Fakespace Systems, Inc.	1988	Marshalltown, IA	100	25.0	www.fakespacesystems.com
Stereoscopic Image Systems, Ltd.	1999	Hampshire, U.K.	-	-	www.stereoimagesystems.co.uk
Vrex, Inc.	1993	Elmsford, NY	12	1.3	www.vrex.com
Location and Identification – Combat ID - Next Generation Secure Identification Friend or Foe (IFF) Device					
BAE Systems North America	1977	Wayne, NJ	68,400	14,911.2	www.cnir.na.baesystems.com
European Aeronautic Defense & Space Company	2000	Munich, Germany	103,967	25,110.8	www.eads.com
General Dynamics Decision Systems	1952	Scottsdale, AZ	67,600	16,617.0	www.gd-decisionsystems.com
Northrop Grumman	1929	Woodland Hills, CA	123,000	26,200.0	www.nsd.es.northropgrumman.com
Raytheon Systems Ltd.	1998	London, U.K.	40	630.0	www.raytheon.co.uk
Tokimec	1988	Tokyo, Japan	1,300	392.0	www.tokimec.co.jp
Location and Identification – Combat ID – Next Generation Secure Identification Friend or Foe (IFF) Device - Laser Interrogator					
European Aeronautic Defense & Space Company	2000	Munich, Germany	103,967	25,110.8	www.eads.com
General Dynamics Decision Systems	1952	Scottsdale, AZ	67,600	16,617.0	www.gd-decisionsystems.com

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Location and Identification – Combat ID – Next Generation Secure Identification Friend or Foe (IFF) Device - Laser Interrogator (continued)					
Luy Broadband Technology	1997	Beijing, China	20	-	www.luy-tech.com
Micron Optics	1990	Atlanta, GA	30	4.5	www.micronoptics.com
Raytheon	1922	Waltham, MA	78,000	18,109.0	www.raytheon.com
Raytheon Systems, Ltd.	1998	London, U.K.	40	630.0	www.raytheon.co.uk
Power – Power Generation - Micro-Scale Fuel Cell					
Adaptive Materials, Inc.	1999	Ann Arbor, MI	6	0.4	www.adaptivematerials.com
Ball Aerospace Corp.	1956	Boulder, CO	2,505	491.2	www.ball.com/aerospace
Casio Computer Co., Ltd.	1957	Tokyo, Japan	11,481	3,767.1	world.casio.com
Protonex	2000	Southborough, MA	15	1.0	www.protonex.com
QinetiQ, Ltd.	2001	Hampshire, U.K.	9,000	1,399.1	www.qinetiq.com
Toshiba	1965	Tokyo, Japan	165,776	47,191.8	www.toshiba.co.jp
Power - Micro-Scale Fuel Cell - Catalytic Micro-Combustor					
Tohoku University	1907	Sendai, Japan	-	n.a.	http://www.mems.mech.tohoku.ac.jp/index_e.html
University College London	1826	London, U.K.	27	n.a.	www.chemeng.ucl.ac.uk
University of California at Berkeley	1962	Berkeley, CA	26	n.a.	http://www-microlab.eecs.berkeley.edu/
University of Southern California	1880	Los Angeles, CA	10	n.a.	http://mems.usc.edu/
University of Tokyo	1877	Tokyo, Japan	-	n.a.	www.mech.t.u-tokyo.ac.jp
Washington State University	1999	Pullman, WA	25	n.a.	www.mems.wsu.edu
Power – Power Generation – Micro-Scale Fuel Cell - Micro-Reformers					
DoE Pacific Northwest National Laboratory	1965	Richland, WA	3,865	851.8	www.pnl.gov
Fraunhofer Institute	1949	Munchen, Germany	12,700	n.a.	www.fraunhofer.de
Institute for Micromachining	1988	Villingen-Schwenningen, Germany	80	n.a.	www.hsg-imit.de
Lehigh University	1865	Bethlehem, PA	-	n.a.	www.lehigh.edu
Oregon State University	1867	Corvallis, OR	17	n.a.	www.mecs.oregonstate.edu
Power – Power Generation - Nano-Composite Solar Cell					
Matsushita Electric Works, Ltd.	1918	Osaka, Japan	15,302	1.3	www.mew.co.jp
Nanosys, Inc.	2001	Palo Alto, CA	38	n.a.	www.nanosysinc.com
Swiss Federal Institute of Technology	1963	Zurch, Switzerland	-	n.a.	www.ethz.ch/index_EN

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Power – Power Generation – Nano-Composite Solar Cell - Inorganic Semiconductor Nanorods					
Matsushita Electric Works, Ltd.	1918	Osaka, Japan	15,302	1.3	www.mew.co.jp
Nanosys, Inc.	2001	Palo Alto, CA	38	-	www.nanosysinc.com
Power – Power Storage - Next Generation Battery					
Arotech Corp./Electric Fuel Batteries Co.	1991	Auburn, AL	219	17.3	www.electric-fuel.com
Moltech Corporation	2002	Shanghai, China	42	8.0	www.moltech.com
NEC Corporation - Tokin	1938	Miyagi, Japan	1,600	10.6	www.nec-tokin.com
Power Paper, Inc.	1997	Petah Tikva, Israel	50	-	www.powerpaper.com
Zinc Matrix Power, Inc.	1997	Santa Barbara, CA	25	3.5	www.zmp.com
Power – Power Storage – Next Generation Battery - Lithium-Ion Polymer (LiP)					
Amperex Technology, Ltd.	1999	Tsuen Wan, N.T., Hong Kong	4,000	-	www.atlbattery.com
Electrovaya	1983	Ontario, Canada	175	4.3	www.electrovaya.com
Lithium Technology Corp.	1994	Plymouth Meeting, PA	45	0.2	www.lithiumtech.com
Ness Corp.	1999	Kyonggi-Do, South Korea	-	-	www.ness.co.kr
Ultralife Batteries, Inc.	1991	Newark, NY	935	79.5	www.ulbi.com
Valence Technology, Inc.	1989	Henderson, NV	95	2.6	www.valence.com
Power – Power Storage – Next Generation Battery - Nickel-Metal Hydride (NiMH) Battery					
Energizer Battery Company, Inc.	1886	St. Louis, MO	14,602	2,232.5	www.energizer.com
Ovonic Battery Co./Texaco Ovonic Battery Systems	2001	Troy, MI	179	7.0	www.txobattery.com
Rayovac Corporation	1906	Madison, WI	5,000	922.1	www.rayovac.com
SAFT	1991	Bagnolet, France	4,000	642.0	www.saftbatteries.com
Sanyo Electric Co., Ltd.	1947	Osaka, Japan	16,167	18,949.0	www.sanyo.co.jp
Yuasa-Delta Technology, Inc.	1994	Hsinchu, Taiwan, ROC	51	38.0	www.ydt.com
Power – Power Storage – Next Generation Battery - Oxyride Battery					
Matsushita Battery Industrial Co., Ltd.	1979	Osaka, Japan	26,700	180.0	www.mbi.panasonic.co.jp
Software – Encryption - Over-the-Air Rekeying (OTAR) Device					
Aeroflex, Inc.	1937	Plainview, NY	2,600	291.8	www.aeroflex.com
Motorola	1953	Schaumberg, IL	88,000	27.058.0	www.motorola.com
Raytheon	1922	Waltham, MA	78,000	18,109.0	www.raytheon.com
Rohde & Schwarz GmbH & Co KG	1933	Munich, Germany	5,885	992.6	www.rohde-schwarz.com

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Software – Tasking - Automated Sensor Cross-cueing Tool					
General Dynamics Advanced Information Systems	1952	Arlington, VA	67,600	16,617.0	www.gd-ais.com
Northrop Grumman	1929	Los Angeles, CA	123,000	26,200.0	www.northropgrum.com
Raytheon	1922	Waltham, MA	78,000	18,109.0	www.raytheon.com
Software – Tasking - Automatic Sensor Cueing Tool					
Raytheon	1922	Waltham, MA	78,000	18,109.0	www.raytheon.com
The MITRE Corporation	1958	Washington, DC	5,000	740.0	www.mitre.org
Titan Corporation, Aerospace Electronics Division	1981	San Diego, CA	11,500	1,775.0	www.titan.com
Uninhabited Vehicle – Control - Autonomous Vehicle Control Software					
Helsinki University	1640	Helsinki, Finland	7,300	n.a.	www.helsinki.fi/university
Northrop Grumman	1929	Los Angeles, CA	123,000	26,200.0	www.northropgrumman.com
Princeton Satellite Systems	1992	Princeton, NJ	6	1.0	www.psatellite.com
The Boeing Company	1916	Chicago, IL	157,000	50,485.0	www.boeing.com
University of Sydney	1850	Sydney, Australia	-	n.a.	www.usyd.edu.au
Uninhabited Vehicle – Control - Speech Computer Control Tool					
Edinburgh University of Scotland's Human Communication Research Center	1989	Edinburgh, Scotland	40	n.a.	www.hcrc.ed.ac.uk
Institute for Human and Machine Cognition	1990	Pensacola, FL	115	n.a.	www.ihmc.us
Linköping University	1975	Sweden	-	n.a.	www.liu.se/en/
Micro Analysis & Design	1984	Boulder, CO	85	25.2	www.maad.com
MITs Library for Information and Decision Systems	1939	Cambridge, MA	-	n.a.	http://web.mit.edu/communications/dev/catalogue/overv.chap6-lids.shtml
Stanford University's Center for the Study of Language and Information	1983	Stanford, CA	13	n.a.	www-csli.stanford.edu
Uninhabited Vehicle – Control - Swarming Control Tools					
Altarum	2001	Ann Arbor, MI	360	50.0	www.altarum.org
Carnegie Mellon University Robotics Institute	1979	Pittsburgh, PA	403	-	www.ri.cmu.edu
Icosystem Corporation	2000	Cambridge, MA	15	1.0	www.icosystem.com

Technology Suppliers[1]					
Company Name	**Est.**	**Location**	**Employees**	**Sales (US$M)**	**Website**
Uninhabited Vehicle – Control - Swarming Control tools (continued)					
Navy Center for Applied Research in Artificial Intelligence Computational Group	1982	Washington, DC	-	n.a.	www.aic.nrl.navy.mil
University of Southern California Research Robotics Group	1880	Los Angeles, CA	-	n.a.	www-robotics.usc.edu
University of Washington Computer Science Department	1861	Seattle, WA	-	n.a	www.cs.washington.edu
Uninhabited Vehicle - Satellite Control - Autonomous Satellite Control Software					
Air Force Research Laboratory	1997	Dayton, OH	5,300	n.a.	www.afrl.af.mil
Ames Research Center	1939	Moffitt Field, CA	2,000	n.a.	www.ic.arc.nasa.gov
Georgia Tech	1885	Atlanta, GA	1,000	n.a.	www.gatech.edu
Concordia University	1903	Portland, OR	-	n.a.	www.cu-portland.edu
Interface and Control Systems, Inc	1988	Melbourne, FL	50	4.5	www.interfacecontrol.com
Science Systems, Ltd.	1980	Bristol, U.K.	450	122.4	www.scisys.co.uk
Uninhabited Vehicle – Satellite Control - Cluster/Constellation Control Software					
CAE	1947	Toronto, Ontario, Canada	5,500	750.0	www.cae.com
Deimos Space S.L.	2001	Madrid, Spain	25	70.0	www.deimos-space.com
Interface and Control Systems, Inc.	1988	Columbia, MD	50	4.5	www.interfacecontrol.com
Princeton Satellite Systems, Inc.	1992	Princeton, NJ	6	1.0	www.psatellite.com
Science Systems, Ltd.	1980	Bristol, U.K.	450	122.4	www.scisys.co.uk
Stottler Henke Associates	1988	San Mateo, CA	34	5.7	www.shai.com