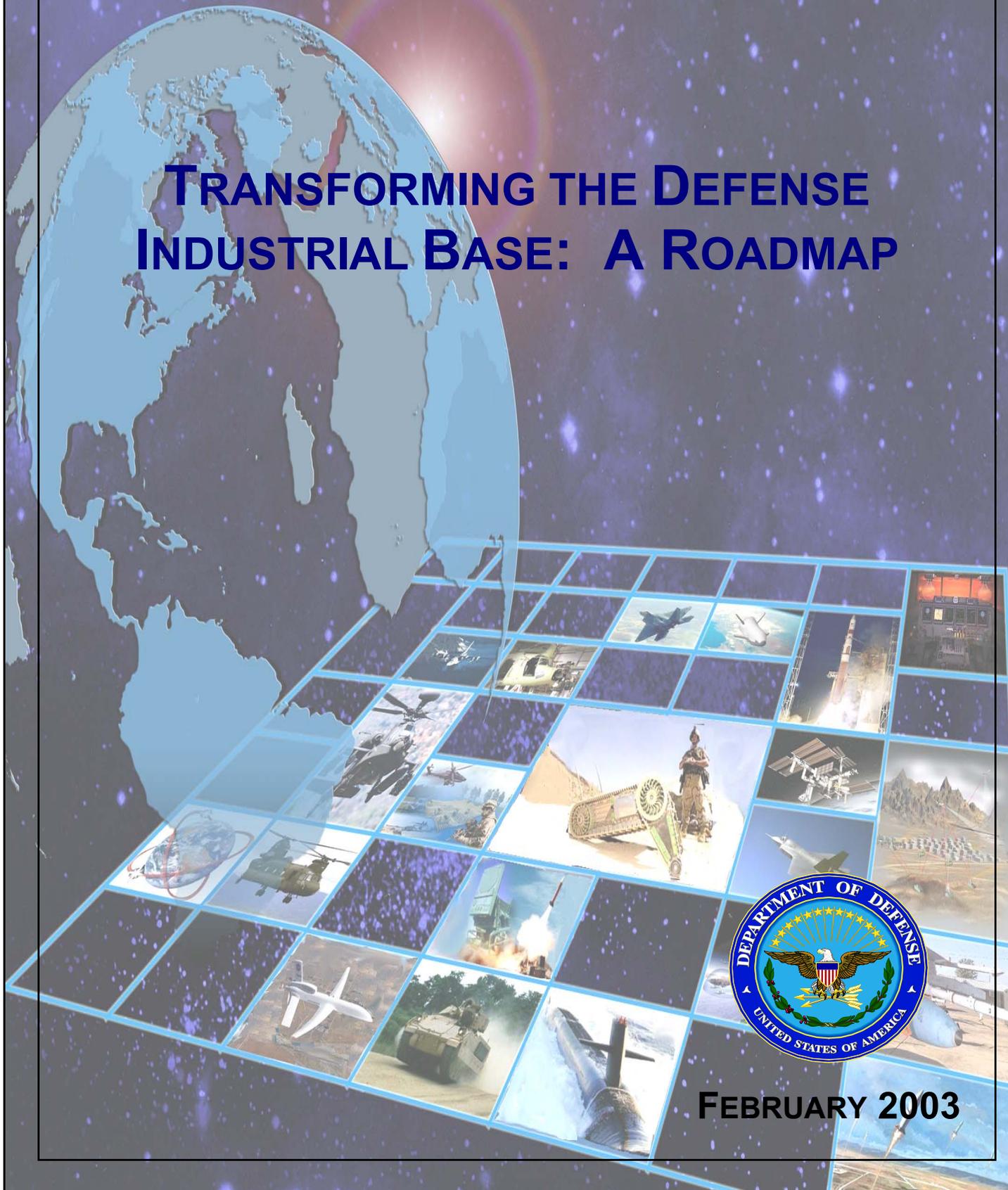


# TRANSFORMING THE DEFENSE INDUSTRIAL BASE: A ROADMAP



FEBRUARY 2003

# Report Documentation Page

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The team would especially like to acknowledge the contributions of the companies who provided us with data on a compressed timeframe. 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 DoD. Finally, we would like to thank our colleagues in the Office of the Secretary of Defense, the Services, and the Joint Staff who have helped shape this report through their comments and ideas. Inquiries regarding the report should be directed to Dawn Vehmeier at (703) 602-4322 or Michael Caccuitto at (703) 607-4065.

**TRANSFORMING THE DEFENSE  
INDUSTRIAL BASE: A ROADMAP**

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

**FEBRUARY 2003**

## STUDY OBJECTIVES

Build upon Secretary of Defense Rumsfeld's operational goals for transformation, lessons learned from OEF, requirements from JV 2020, and previous industrial base studies.

Create a compendium of representative emerging defense suppliers with transformational capabilities; highlight key representative technologies, best business practices, and products via case studies of selected companies.

Gain insight from legacy defense suppliers and the Defense Advanced Research Projects Agency to capture characteristics of the most important, most innovative, and fastest products.

Offer a roadmap for the defense industrial base to ensure that the warfighter of 2020 is supplied by an industrial base and processes that deliver transformational, network-centric weapon systems.

## FOREWORD

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This report sketches a roadmap to a transformed industrial base for legacy and emerging defense suppliers, as well as for senior leadership in the Department of Defense. It is built on case studies of 24 emerging defense suppliers who could grow to be tomorrow's defense giants. These are companies not unlike the Boeing of 28 employees in 1916. All have some business with the Department of Defense, but unlike today's giants, their annual revenues are often less than \$10 million and they are made up of dozens – not thousands – of employees. None of these companies wants to remain small, but all the companies in our case studies had difficulties finding their place in the defense enterprise and had experienced growing pains transitioning technologies they viewed as important to the Department and to transformation.

As a product of its time, this report is informed by the lessons learned in Operation Enduring Freedom about fielding systems quickly and combining them in new and different ways. It also heeds the Secretary's transformation mandate, attempting to make the emerging defense enterprise more transparent so that all companies – current and prospective, global and domestic, small and large – can better find their place in the United States defense enterprise and its decision-making processes.

Our military is moving toward a new doctrine – “effects-based operations.” To effectively support this, our business practices must also be effects-based. This report recommends that the Department consider:

- Viewing the industrial base as being composed of operational effects-based sectors that support transformational warfighting.
- Organizing its decision processes to optimize operational effects – not programs, platforms, or weapons systems.
- Evaluating technological and industrial capabilities and concerns within these sectors, including the investment and competitive issues necessary for informed, effective decision-making.

Against the backdrop of network-centric combat operations, the progress made by this Administration in its acquisition decisions and ongoing acquisition process and policy retooling initiatives will either prove a springboard to transformation – or will sanction the status quo. With this report, we are providing a notional construct that we believe will help emerging defense suppliers find their place in our transforming enterprise.

Our legacy suppliers will find tributes to the best of what they provided to us in the last century; the case studies of our emerging defense suppliers may help other emerging companies find their way. The investment community should find our compendium and the results of our follow-on study of critical capabilities to be published later this year useful guides to investing in transformation. Finally, this report may lead to enhanced decision-making for the Department.

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– CASE STUDIES OF SELECTED EMERGING DEFENSE SUPPLIERS

○ COMBAT SUPPORT

- ELUSYS THERAPEUTICS, INC.
- IROBOT, INC.
- NOMADICS, INC.
- OAKLEY, INC.
- SARCON MICROSYSTEMS, INC.

○ POWER PROJECTION

- AEROVIRONMENT, INC.
- AMPTEK INC.
- I2 TECHNOLOGIES, INC.

○ PRECISION ENGAGEMENT

- CARBON-CARBON ADVANCED TECHNOLOGIES, INC.
- FOAM MATRIX, INC.

○ HOMELAND & BASE PROTECTION

- COHERENT TECHNOLOGIES, INC.
- RIPTECH, INC.
- RSA SECURITY INC.
- SYSTEMS RESEARCH AND DEVELOPMENT (SRD)
- SYMANTEC CORPORATION
- VIISAGE TECHNOLOGY, INC.

○ INTEGRATED BATTLESPACE

- ACTUALITY SYSTEMS, INC.
- AIRFIBER, INC.
- DELTA INFORMATION SYSTEMS, INC.
- SABEUS PHOTONICS, INC.
- SRA INTERNATIONAL, INC.
- THE INSITU GROUP
- VANU, INC.
- ZAPLET, INC.

– SUMMARIES OF BEST PROGRAMS – BOEING, GENERAL DYNAMICS, LOCKHEED MARTIN, NORTHROP GRUMMAN, RAYTHEON, AND DARPA

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○ MOST IMPORTANT AND INNOVATIVE

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## EXECUTIVE SUMMARY

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### METHODOLOGY AND FINDINGS

For this study, we built upon Secretary Rumsfeld's six operational goals for transformation, requirements from Joint Vision 2020, lessons learned from Operation Enduring Freedom, and previous industrial base studies. We drew on recommendations from experts in the Department of Defense, industry, and the investment community to create

#### **Six Operational Goals for Transformation**

- *Protect homeland and bases*
- *Project power*
- *Deny sanctuary*
- *Protect information networks*
- *C4ISR interoperability*
- *Unhindered access to space*
  - *Secretary of Defense Donald H. Rumsfeld*

a compendium of representative emerging defense suppliers with transformational technologies and products.<sup>1</sup> We identified 24 companies' key technologies, products, and best business practices in case studies.<sup>2</sup> We also surveyed legacy defense suppliers and the Defense Advanced Research Projects Agency (DARPA) to capture key characteristics associated with programs and products judged to be among the organizations' most successful, most important and innovative, and fastest to field.<sup>3</sup> Finally, we spoke with five prominent companies who have substantially exited the defense business.<sup>4</sup>

The messages from emerging defense suppliers resonated strongly with lessons learned from legacy defense suppliers. They fell into six primary areas of concern:

- Insufficient visibility into the military enterprise
- Inadequate funding and advocacy for new technology transition
- Difficulty building a strong, interactive relationship with customers
- Cumbersome system design specifications
- Lengthy, laborious sales cycles
- Limited access to development and investment capital

The three recommendations offered for consideration in this report would provide emerging and legacy suppliers of interest to the Department more transparency into the programs and processes that constitute the military enterprise. Ongoing Department initiatives address many of these issues. Additionally, recasting the defense industrial landscape across operational effects-based sectors and organizing the Department's decision-making processes to optimize operational effects would improve supplier visibility into the military enterprise and help to more systematically secure "invention-to-weapon" technology transition funding. If programs were arrayed this way with corresponding management structures, emerging defense suppliers would be able to

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<sup>1</sup> Appendix A.

<sup>2</sup> Appendix B.

<sup>3</sup> Appendix B.

<sup>4</sup> Appendix C.

ascertain opportunities that cut across individual programs and platforms; and identify DoD and prime contractor points of contact with whom to engage. Conversely, senior DoD leaders would be better positioned to identify technology “gaps” affecting both individual and multiple programs. With such visibility, DoD leaders also would be positioned to advocate sufficient transition funding to “pull” the promising new technologies that would enhance operational effects for multiple defense systems. In this report, we will refer to this construct as the “Transformation Board” process.

We believe that this report provides an industrial base roadmap to Secretary Rumsfeld’s vision of transformation. If followed, the roadmap could position the Department to transform itself and its supplier base, and deliver innovative, network-centric weapons systems to the warfighter more expeditiously.

**RECOMMENDATION 1.**

The Department should view the industrial base as being notionally composed of five operational effects-based sectors: Combat Support, Power Projection, Precision Engagement, Homeland and Base Protection, and Integrated Battlespace. If we monitor the industry on this basis, and assess competition and capability issues on a similar basis, we will emphasize the essential functions of warfighting across the operational spectrum of engagement. This will alter the way we think about the required capabilities, the number of suppliers, and the frequency of competitions required to achieve increased capability. In monitoring the industrial base and in making investment decisions that shape it, the Department would be positioned to support the future more effectively.

***Operational Effects-Based Industrial Sectors***

- *Combat Support*
- *Power Projection*
- *Precision Engagement*
- *Homeland and Base Protection*
- *Integrated Battlespace*

**RECOMMENDATION 2.**

From program justification through budgeting and acquisition, the Department should organize its decision-making processes to optimize operational effects – an integrated view of force structure; not programs, platforms, or weapons systems. The current processes sometimes make it difficult to provide the forward thinking, strategic guidance necessary to field the interoperable, complementary, and transformational systems required for 21<sup>st</sup> century warfighting. An effects-based decision-making process would maximize the operational impact of the Department’s limited financial resources by minimizing operational overlaps among new and legacy defense systems.

***Operational effects-based decision-making will:***

- *Support the SECDEF’s mandate to institutionalize transformation;*
- *Transform the resource allocation and acquisition process; and*
- *Institutionalize industrial best business practices key to attracting systems-of-systems and innovative commercial solutions for the warfighter.*

This construct for a transformational acquisition and budgetary allocation process is organized to address decision-making in the five notional operational effects-based sectors. This approach offers a way ahead to maximize the operational impact of DoD's decisions on research and development and acquisition budgets.

***A Transformed Acquisition and Resource Allocation Process:***

- *Defense Planning Guidance provides mission precepts and allocates funding based on five operational effects sectors*
- *Enhanced JROC identifies and prioritizes programs for each of the sectors to respective JFCOM Component Commander for operational scrub*
- *Programs and elements are presented to Transformation Boards or similar structures by sector*
- *Transformation Board reviews programs and issues one Program Decision Memorandum on all programs in each sector*
- *Annual program reviews by Transformation Boards on a calendar-driven (perhaps April-August) schedule*

**RECOMMENDATION 3.**

DoD ought to analyze the results of a systematic assessment of critical technology requirements in each of these sectors. This would provide important investment guidance to senior Department decision-makers and the defense industrial base. Mapping these critical technology requirements against available sources of technology and the associated human capital would allow the Department to better understand the number of competitors and competitions required to shape the desired industrial base.

## THE CHALLENGE

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Ideas and products of emerging defense suppliers will be increasingly important for transformational warfare; and the defense industrial landscape of, say 2020, will be significantly different from today's because of the pace of change and the kinds of companies that make the new products. Our challenge is to match innovative capabilities and companies with the defense strategy, and provide beachheads and bridges – not barriers – to nurture them and draw them into defense.

### **NEW CONCEPTS DEMONSTRATED IN OPERATION ENDURING FREEDOM**

Against the backdrop of the Secretary's transformation mandate, the new concepts and legacy systems deployed in Operation Enduring Freedom demonstrated the value of transformational warfare. In this war, state-of-the-art and legacy products of the defense industrial base were matched with multi-dimensional, unconventional, and asymmetric tactics to produce a truly come-as-you-are war with a brand-new, transformational script.

Operation Enduring Freedom was a war unlike any our forces have previously fought. In 26 days, from 9/11 to the beginning of Operation Enduring Freedom on October 7, our forces adapted by using new systems just coming out of development, by converting legacy systems to new roles, and perhaps most importantly, by networking systems to create new capabilities – all of which were focused to optimize battlefield impact. In so doing, we demonstrated on the battlefield some of the most important precepts of the Secretary of Defense's transformation mandate.

*"These past two months have shown that an innovative doctrine and high-tech weaponry can shape and then dominate an unconventional conflict. This combination – real-time intelligence, local allied forces, special forces, and precision airpower – has really never been used before."*

*– President George W. Bush  
December 11, 2001*

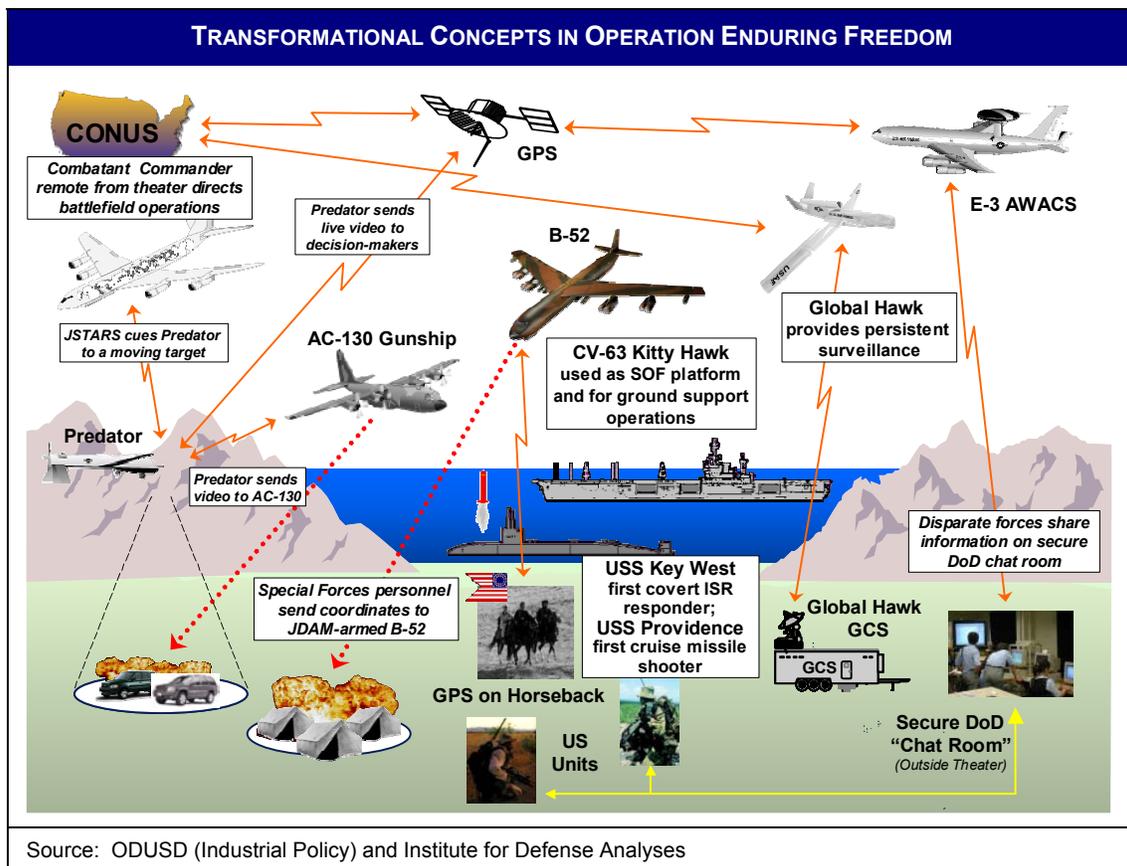
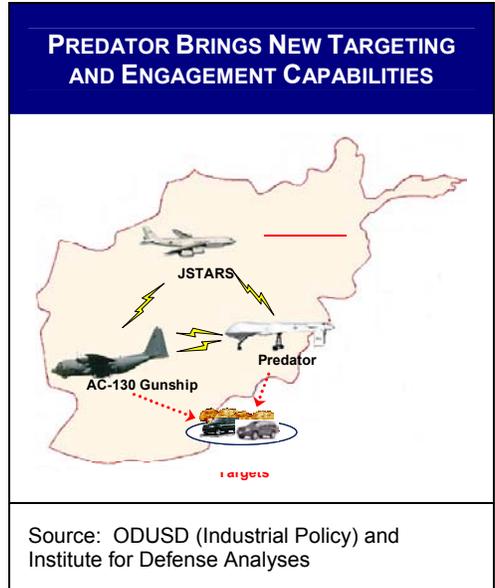
wartime field test, with no dress rehearsal. The system decreased the human footprint in theater by deploying from distant locations, and by remaining aloft for 24 hours without a pilot. Global Hawk provided persistent surveillance without risk to our warfighters, a critical new capability.

Although not an entirely new system, Predator brought new capability to the field. Predator flew lower than manned aircraft could safely fly to collect valuable imagery and transmit that imagery throughout the network. Predator also successfully employed weapons for the first time, and did so with a configuration that had seen limited testing, demonstrating the value of rapid technology insertion. While the loss of Predators in

operation has demonstrated the risks of this approach, the value of allied lives preserved and prisoners-of-war not captured is incalculable.

Predator was an important element of a network built “on the fly” that was able to find moving targets, track them, and kill them, while minimizing the exposure of our warfighters. Predator got cueing from the legacy Joint Surveillance Target Attack Radar System (JSTARS), and in turn, relayed low-altitude video to another legacy system, the AC-130 gunship for hand-off target engagement.

During Operation Enduring Freedom, the Services successfully employed network-centric concepts in communications, enabling linkages across various Service platforms. We saw Predator video transmitted to personnel in the field, and to the national command structure back home. Satellite communications and video links allowed commanders to be distant from the theater, while soldiers from disparate forces throughout the theater communicated via secure DoD “chat room,” coordinating activities, supporting bomb damage assessments, and reducing the chatter on limited tactical voice frequencies.



Several older weapons saw new life in transformed roles. The Kitty Hawk aircraft carrier, commissioned in 1961 as a weapon for the Cold War, saw service carrying Special Operations Forces to the new war and provided direct air support to forces on the ground. Surprisingly, the B-52, first deployed in 1955 as a strategic bomber, saw action in close air support – thanks to the Global Positioning System operated by special forces soldiers on horseback and the Joint Direct Attack Munition.

Operation Enduring Freedom had the characteristics we expect of future conflict. It came at a time we didn't anticipate, in a place we had not prepared to fight, and was conducted in a manner invented on the fly. Some of the most important successes of Operation Enduring Freedom were those of our defense industrial base: Global Hawk brought into operation before formally entering production; Predator armed 9 months after approval; the cave-busting GBU-28 developed in 6 months; and the Phraselator providing synthetic translation services in four languages, four months after the program was approved.

*"I don't have any problem writing iRobot, saying 'I'm sorry your robot died, can we get another?' That's a lot easier letter to write than to a father or mother."*

*– Colonel Bruce Jette, the U.S. Army's pointman on robot deployment, who accompanied the first \$45,000 iRobot "PackBots" into the field in Afghanistan  
January 22, 2003*

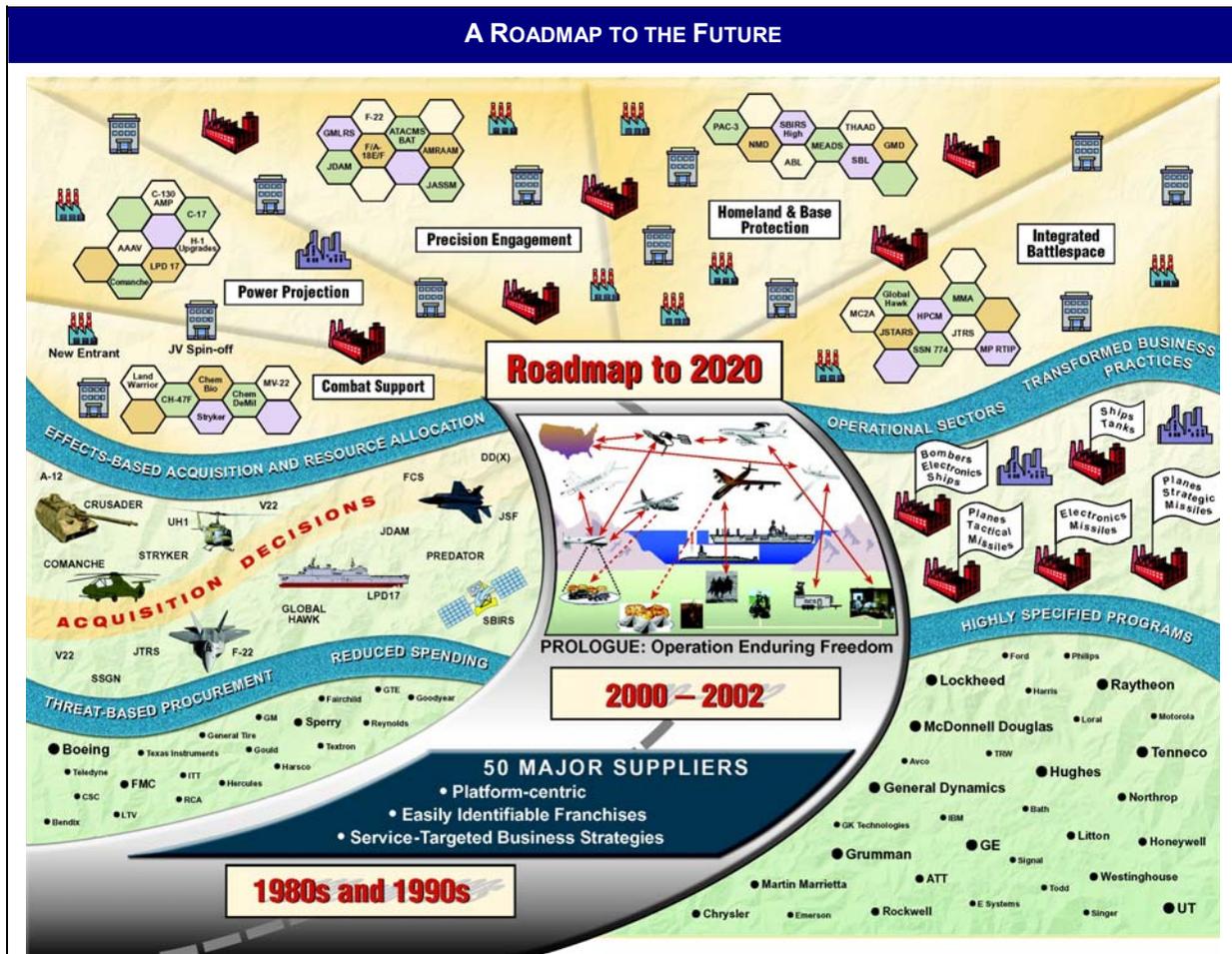
Operation Enduring Freedom required transformed warfighting concepts and capabilities. It reinforced the fact that speed is life on the battlefield and in deploying systems to the battlefield. Transformed DoD business practices would support the transformed warfighter. They would: (1) shape and access an innovative industrial base focused on operational effects; (2) make acquisition and budgeting decisions in a net-centric context; and (3) inject new technology rapidly into weapons systems.

## **A ROADMAP TO THE FUTURE**

It is the challenge of today's policymakers to help shape an industrial base that will supply 21st century warriors as effectively as it has prior generations of American men and women in uniform. As the chart on the next page shows, the defense industrial base of today is a distillate of its prior form.

The backdrop against which this Administration began making budgetary and weapons system acquisition decisions included three key features: a number of large programs still on the drawing board as long as 20 years after inception; a highly consolidated defense industrial base; and the realities of warfighting in the 21<sup>st</sup> century as punctuated by Operation Enduring Freedom. Recognizing that the futuristic weapons systems required for 2020 and beyond will not be forged overnight, the Department moved programs essential to next generation warfighting from development into production. As the Department completes its review and restructuring of current programs, some may be discontinued, no longer relevant to the Secretary's transformational goals.

What were roughly 50 major defense suppliers in the 1980s have become five highly consolidated, cross-Service, cross-platform prime contractors. As such, they are uniquely suited to provide us with system-of-systems approaches to requirements. Some people are concerned about this allegedly excessive narrowing of the defense industrial base. We believe that consolidation was a normal market response to reduced demand, driven by the post-Cold War defense budget drawdown of the 1990s.



Source: ODUSD (Industrial Policy), Institute for Defense Analyses, and E.B. Phillips

However, we think that this “narrowing” may reverse itself as new companies join the base in response to futuristic warfare concepts. We envision that the defense suppliers of tomorrow may organize around operational, effects-based industrial sectors similar to the Secretary’s transformation goals. The five sectors on the roadmap chart above would provide for full-spectrum dominance: Combat Support, Power Projection, Precision Engagement, Homeland & Base Protection, and Integrated Battlespace.

***Operational Effects-Based Industrial Sectors***

- *Combat Support*
- *Power Projection*
- *Precision Engagement*
- *Homeland and Base Protection*
- *Integrated Battlespace*

***Six Operational Goals for Transformation***

- *Protect homeland and bases*
- *Project power*
- *Deny sanctuary*
- *Protect information networks*
- *C4ISR interoperability*
- *Unhindered access to space*

To support Secretary Rumsfeld's six operational transformation goals, the Department could use operational effects-based acquisition decision processes, supported by associated assessments, and underpinned by industrial best-business practices to achieve a transformed DoD acquisition and budgeting process that productively engages the best American industry has to offer for the warfighter.

## INDUSTRIAL STRUCTURE

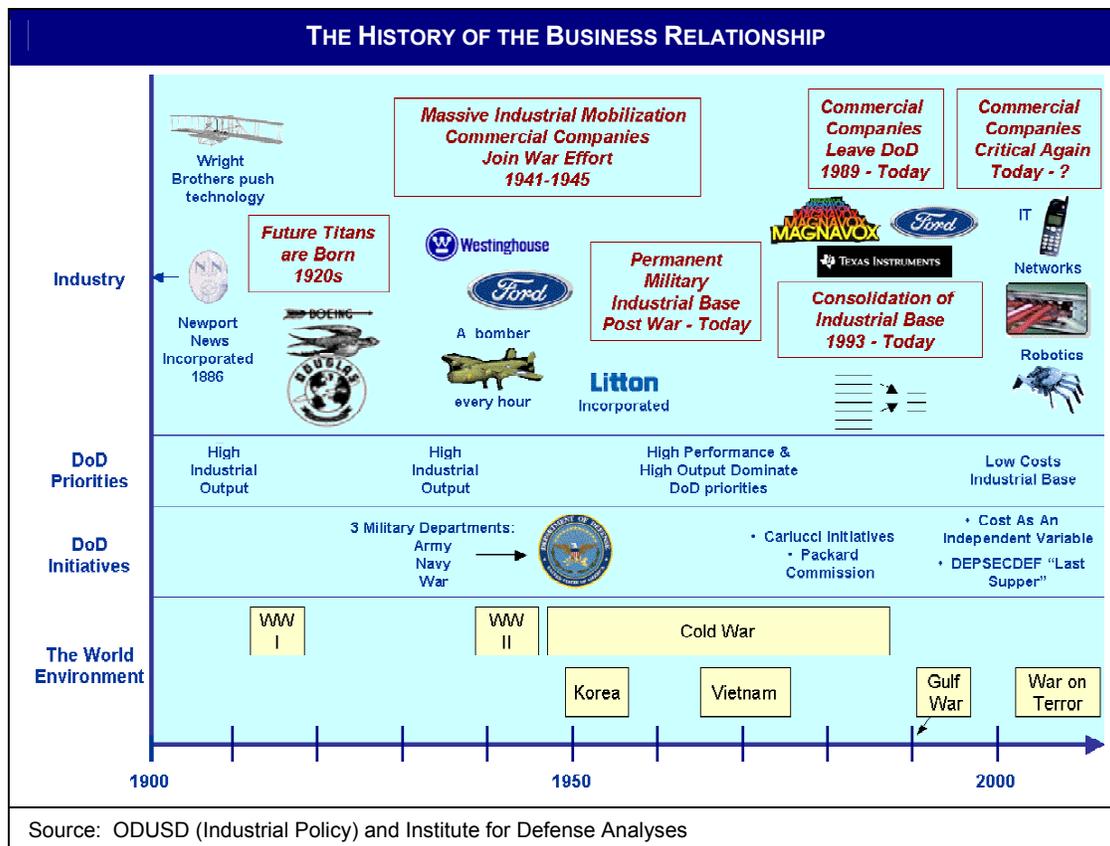
### Findings and Conclusions:

- *Competitive pressures have shaped a more concentrated defense industrial base, with “industry giants” well positioned to provide transformational, network-centric system-of-system solutions*
- *Emerging defense suppliers will make important contributions to the battlefield of the future*
- *DoD should stop considering the defense industry only as ship-builders, aircraft makers, and spacecraft integrators, and begin to think of it instead as providers of required operational effects*

### Recommendation:

- *The Department should view the industrial base as being composed of operational effects-based sectors, monitor the industry on this basis, and assess competition and capability issues on a similar basis*

Competitive pressures of the market place have shaped the current smaller, more concentrated defense industrial base. As shown in the chart below, consolidation spanning less than ten years fused and fundamentally changed an industry nearly a century in the making. However, we believe that today’s opportunities for investors and companies are no less promising than those offered decades ago when the defense giants of today were just beginning to take form.



## HISTORICAL PERSPECTIVE

Among the ten largest companies in the mid-1980s were familiar, strong franchise firms: McDonnell Douglas, General Dynamics, Rockwell, Lockheed, Northrop, Grumman, and the Boeing Company. These and other venerable “nameplates” were readily associated with famous platforms: Lockheed with Skunk Works and its many space, strategic and aircraft systems; Grumman, progenitor of naval aviation, with the F-14, E-2, A-6, and EA-6B; McDonnell Douglas with the new F/A-18, C-17 and missile programs; and Northrop cutting its teeth on the futuristic B-2, appearing to encroach on Lockheed’s position in stealth. Among them all, General Dynamics had perhaps the most expansive footprint, with platform presence in all major combat arenas, from submarines to space systems.

### **Top Ten Defense Suppliers of 1985**

- *McDonnell Douglas*
- *General Dynamics*
- *Rockwell*
- *General Electric*
- *Boeing*
- *Lockheed*
- *United Technologies*
- *Hughes*
- *Raytheon*
- *Grumman*

Together the top ten firms garnered over 34 percent of all DoD prime contract awards – \$75 billion in FY02 terms. A further 28 percent of direct DoD revenues were widely distributed among an additional 40 firms. This sub-tier base maintained hierarchical subcontractor relationships with prime contractors generally characterized by well-established “teaming” relationships.

However, revolutionary innovations in military technology traditionally came from these second-tier or niche firms, organizations that frequently went on to dominate that market. These monumental leaps were infrequently developed by the top firms of their time. Furthermore, this paradigm – major innovation originating in second-tier or niche firms – has been observed frequently in many other industries as well.

As the chart on the following page shows, by the early 1990s, many of the commercial firms in sub-tier defense niches left or dramatically reduced their presence in defense-specific product markets. Others, such as Westinghouse and Texas Instruments, divested defense activities to focus on non-defense core businesses. Companies such as General Electric divested defense-specific businesses because the defense market environment of decreasing budgets and slim profit margins did not support growth-oriented market dominance objectives to be the number one or number two player in a given market.<sup>5</sup>

This exit of these largely commercial firms from the defense industry precipitated a wave of mergers and acquisitions beginning in the 1990s. Contraction of the industry, most visible at the top-tier, proceeded in lockstep with the 51 percent decline in DoD research and development (R&D) and procurement funding from 1985 to 1998.

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<sup>5</sup> See company “exit stories” in Appendix C.

**SAMPLING OF "NAMEPLATES" THAT REDUCED/ELIMINATED DEFENSE PRESENCE**

Parent Company	Military Business Divestiture	Military Products	Acquirer	Year Acquired
	Aerospace Division	Satellites, radar and sonar systems, simulation systems, communications systems, government technical services, and other aerospace and defense systems		1992
	IBM Federal Systems	Systems integration and complex aerospace solutions (Skylab, AWACS, submarine sonar, FAA air control )	<b>LORAL</b>	1994
	Ford Aerospace	Tactical missiles and satellites	<b>LORAL</b>	1990
<b>LORAL</b>	Defense operations	Communications and radiation-hardened spacecraft components, Sidewinder missile, airborne radar warning		1996
	Defense and electronic systems division	Advanced radar systems, airspace management, and marine and space systems		1996
	Lucent Advanced Technology Systems	Undersea surveillance systems, signal processing defense systems, vibration control systems and related technologies	<b>GENERAL DYNAMICS</b>	1997
<b>MAGNAVOX</b>	Magnavox Electronic Systems	Satellite communications products, signals intelligence electronic combat situational awareness and combat identification systems	<b>HUGHES</b>	1995
	Chrysler Tech. Airborne	Aircraft modification and defense electronics	<b>Raytheon</b>	1996
	Defense Systems and Electronics Division	Guided missiles, electro-optical systems, and defense electronics equipment	<b>Raytheon</b>	1997
	<b>HUGHES</b> Defense	Airborne and ground-based radars, ground, air and ship-launched missiles, tactical communications, and training simulators and services, Air Traffic Control systems	<b>Raytheon</b>	1997

Source: ODUSD (Industrial Policy) and First Equity

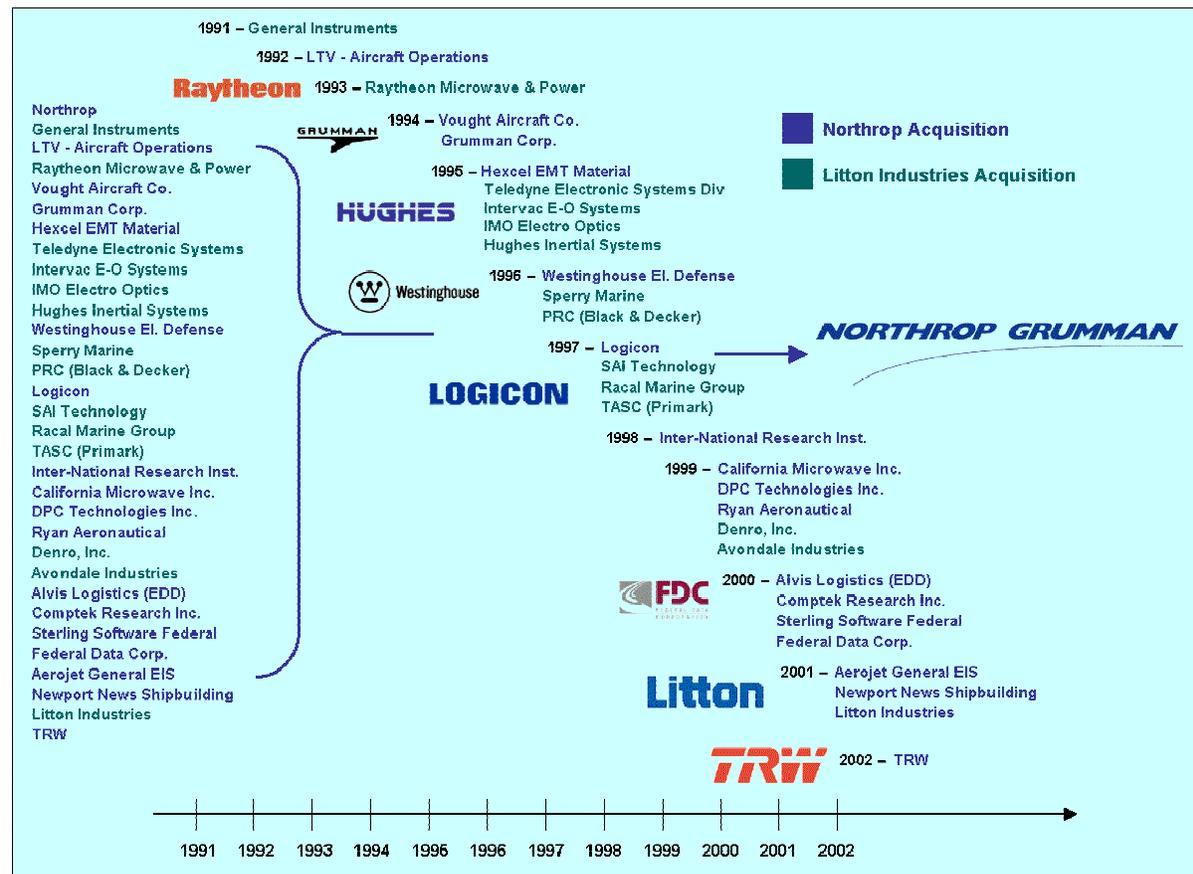
By the end of 2001, the five largest defense firms received the same percentage of DoD prime contracts by value as the top ten suppliers received in 1985. Therefore, Lockheed Martin, Boeing, Raytheon, General Dynamics, and Northrop Grumman, the largest five in 2001, are as dominant in the defense market, on a relative basis, as the largest ten were in 1985.

**TODAY'S ENVIRONMENT**

The company known today as Northrop Grumman is an excellent and highly representative case study of this consolidation. The chart on the next page illustrates the coming together of an array of industry nameplates – Grumman, Westinghouse, Logicon – consummated with the acquisition of Litton, Newport News Shipbuilding, and TRW to produce today's defense giant.

Northrop Grumman's dramatic growth and restructuring throughout the 1990s also resulted in an increase in direct DoD contract awards. Both as a percentage of overall DoD prime contracts, and in real FY02 dollar terms, Northrop's defense presence has multiplied over five-fold.

## THE EVOLUTION OF NORTHROP GRUMMAN<sup>6</sup>



Source: ODUSD (Industrial Policy) and First Equity

## THE DEFENSE INDUSTRY OF THE FUTURE

We believe that the current industrial landscape is a watershed and that transformation will spawn dozens of new entrants to the global defense industrial base. The development of the future industrial landscape undoubtedly will have its own surprises.

After 9/11 at Ground Zero, for example, two of the first responders from the defense industry were from very different corporate entities. Raytheon's thermal imaging rescue systems were used by one group of first responders. Other robotic searchers used on site were made by iRobot, a company recently better known for toys and robotic vacuum cleaners. Raytheon is a company of tens of thousands of employees and \$16.9 billion in revenues; iRobot is a relatively nascent company of roughly one hundred employees and one-thousandth the revenues of Raytheon.

Our confidence in the likely contributions of emerging defense suppliers such as iRobot is rooted in the early history of today's defense industrial base. In 1918, the Loughhead

<sup>6</sup> See Appendix D for similar charts for Lockheed Martin, The Boeing Company, General Dynamics, and Raytheon.

Flying Boat made its first flight and the fledgling Loughhead Aircraft Manufacturing Company made its first military sale: the Curtiss HS-2L Flying Boat to the U.S. Navy. This company, Lockheed, went on to produce such revolutionary airplanes as the SR-71 Blackbird, F-117 Night Hawk, F-22 Raptor and the F-35 Joint Strike Fighter, becoming the largest defense firm in the world. In much the same way, we expect many small, innovative firms to join the defense industrial base and grow into tomorrow's defense giants.

*"I worry about the technology base in this country. The degree of competition is declining in the defense industry. The longer the large defense contractors deal with the Defense Department, the more they become like the Defense Department – and I don't say that as a compliment. They get big and slow and sluggish and bureaucratic. 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. Delay helps the big companies, because they've got all the lawyers and all the lobbyists and all the people in Washington. Smaller companies don't have the time to do all of that. That means that government tends not to have the kind of interaction with the creativity and innovation that exists in our society."*

– Secretary of Defense Donald H. Rumsfeld  
November 18, 2002

We envision three major sources of new and innovative companies that will be household names by 2020. First, we believe that most of the legacy defense suppliers have well understood the transformation mandate, and will change with the times. One of the ways that they could change is by acquiring emerging defense suppliers or by expanding their product offerings. Their corporate names may be the same in 2020, but likely their operating divisions will have different names. They will be joined by lower-tier firms that grow to be prime contractors.

The second source of new companies in the corporate landscape of 2020 will be those companies – perhaps like iRobot, or those innovative, emerging defense suppliers now in joint ventures with primes – that achieve critical mass on their own. Perhaps the surfboard manufacturer Foam Matrix, who entered the defense market to make wings for Lockheed's Joint Air-to-Surface Standoff Missile and now produces the wings for the Air Force's unmanned combat aerial vehicle in a joint venture with Boeing, will find enough markets to become a prime composite structures manufacturer on its own.

And third, there will be commercial companies or divisions of companies that form around defense requirements. These could be the pharmaceutical companies that present themselves to the challenges of chemical biological warfare and associated vaccination programs. Or they could be entertainment companies like Westinghouse in the mid-1930s, whose radio broadcasting skills the government thought may be applicable to the development of radar. Today's entertainment companies might, for example, apply their ability in visualization to the battlefield of tomorrow.

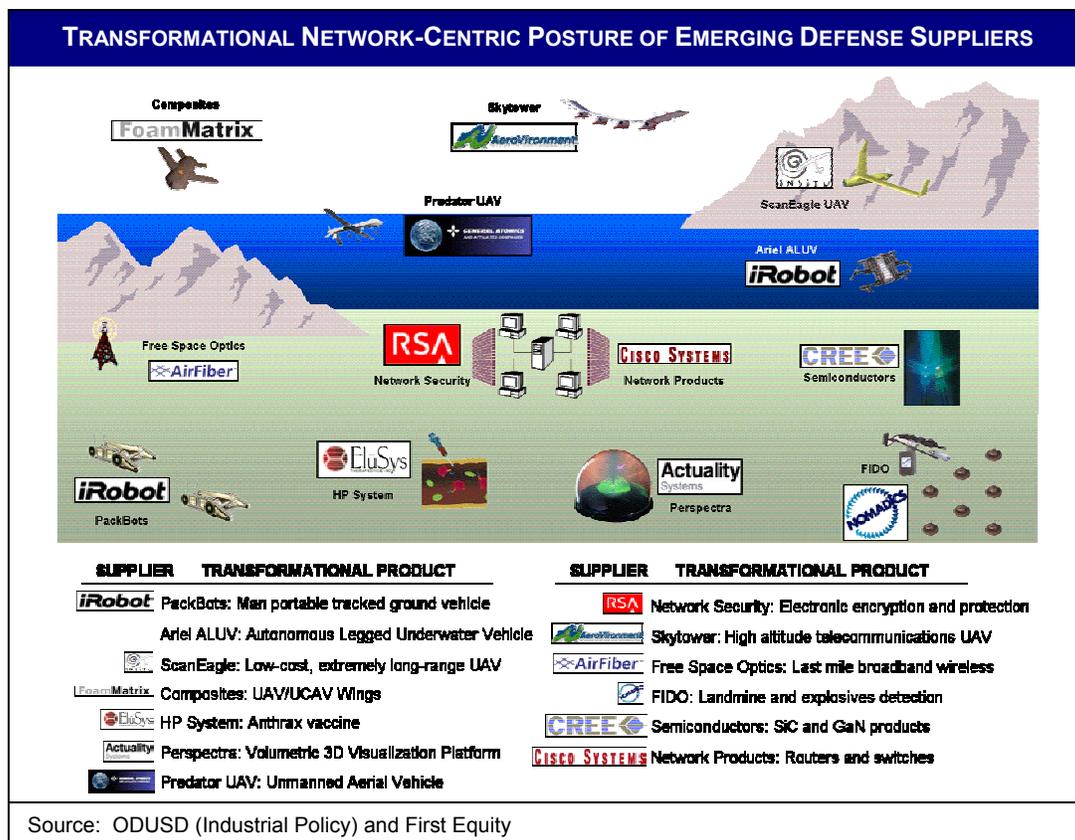
To capture the key industrial dynamics of this watershed between legacy defense suppliers and those that transformation will spawn, we collected information from three groups of companies: emerging defense suppliers (primarily smaller, based on

employment and revenue), legacy defense suppliers, and former defense suppliers (mostly commercial) that have left the industry. All of the emerging defense suppliers evaluated for this study offer either products or enabling technologies that will help satisfy the goals of the Secretary of Defense.

We asked of the legacy defense suppliers which of their programs were most outstanding and why; of the firms that exited the defense industry why they left; and of the new entrants what they can offer DoD and how we can best engage them.

This study builds on the results of an earlier study, conducted between February and June 2002.<sup>7</sup> That earlier study focused on five innovative emerging defense suppliers (Cisco, Cree, General Atomics, Sun Microsystems, and TriQuint). These firms echoed many of the same concerns expressed by our traditional suppliers.

The chart below is illustrative of the products from emerging defense suppliers participating in both the earlier and current study. While not meant to be definitive, this illustration shows how some of the technologies of emerging defense suppliers could be incorporated and used by the military.



One thing we know for sure based on all of our industrial studies, particularly this one focused on emerging transformational companies: all companies within the defense

<sup>7</sup> A summary of Phase I can be found in Appendix H.

industrial base of 2020, regardless of size, type, location or socio-economic category, must be able to function as nimbly as the warfighters of Operation Enduring Freedom, and extend the transformational trends that have emerged in 2002. Much as the warfighters in Afghanistan often exchanged sensor-shooter roles to achieve optimum operational effect, we expect prime and sub-tier companies to reverse roles when doing so increases win probability. Such behavior will ensure that innovation from the lower tiers will be leveraged in the design and development of new systems. We also expect that some of the innovative, emerging defense companies of today, perhaps like General Atomics with its Predator, will achieve and retain high profile, market leading positions or even grow into the defense giants of tomorrow.

## **CONCLUSIONS**

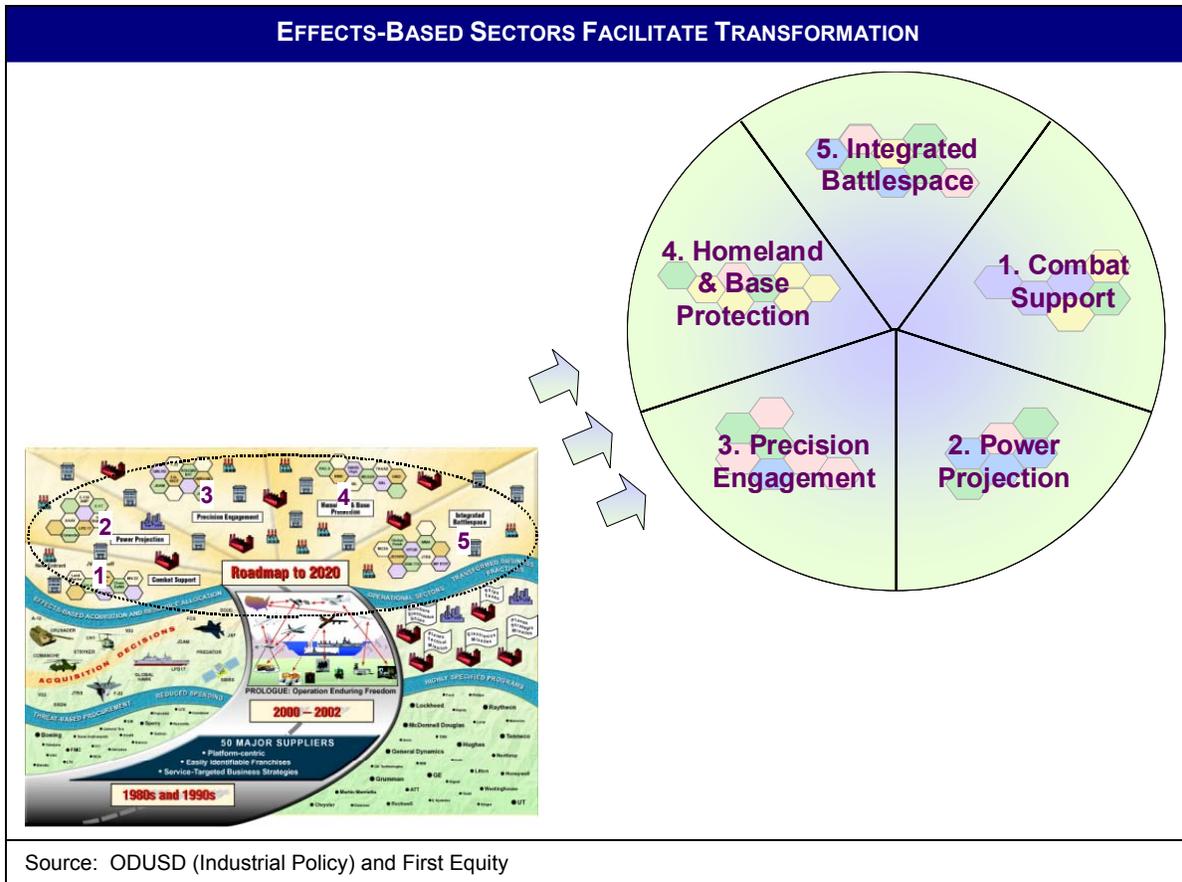
The challenge of today's DoD policy makers is to help shape an industrial base that will supply 21<sup>st</sup> century warfighters as effectively as it has prior generations of American men and women in uniform. The DoD must "inspire" the roadmap. Without such a roadmap, we run the risk – after expending considerable time and money – of reaching the wrong destination.

The battlefield of the future will be very different, and the companies building the systems occupying that battlefield also will be different. The way the Department thinks of the industrial base should be different as well. We should stop characterizing industry as ship-builders, aircraft makers, and spacecraft integrators, and think of them instead as providers of the required operational effects. Warfighting in the 21<sup>st</sup> century requires the best equipped and supported troops; the ability to quickly project power around the globe; a lethal and precise engagement capability; safe bases and a safe homeland; and a robust, flexible and powerful integrated battlespace.

This way of thinking is not revolutionary. The largest legacy defense suppliers already think this way. Spurred by consolidation, they've transitioned from platform specialists to integrators of capabilities. Some have taken the next step; they've organized their enterprises by outcomes rather than platforms. The most successful smaller companies have always thought this way. They find homes for the skills they have, and build skills that are needed, without regard to labels like air or ground, Army or Navy.

By thinking of the industrial landscape in operational effects-based sectors, the Department could better emphasize the essential functions of warfighting, without restrictive subcategories like sealift or strike aircraft. Unencumbered by these restrictions, DoD could more easily think of broader solution sets, and a broader field of solution providers. Looking to the future, we could more readily think of loitering unmanned aerial vehicles competing with space-based communications relays. Directed energy weapons could compete with bombs. Hypersonic strike aircraft could compete with aircraft carriers.

To arrive at the proposed five operational effects-based industrial sectors, we surveyed (and in some cases merged) Joint Staff Mission Areas and Joint Warfighting



Capabilities Assessments and arranged the sectors in the order of the operational employment spectrum from the particular to the more general. In conceptualizing the networks of systems that would populate operational effects-based sectors, we reviewed all FY03 major defense acquisition programs and placed them in the sector in which we deemed the operational effect most important. Many systems have capabilities that warrant their assignment to several categories. To operate efficiently, the process would demand that they each be placed in a “lead sector,” but their contributions to other sectors should be evaluated in all reviews and analyses.

- The *Combat Support* sector includes functions that equip our troops and move them in theater. The Land Warrior program resides here, as do the V-22 and utility helicopters. Chemical and biological detectors also fit into this sector.
- The *Power Projection* sector brings the fight to the enemy wherever that may be. Airlift programs such as the C-17 and the C-5 re-engine program belong in this sector, as do sealift and many logistics functions.

- *Precision Engagement* puts weapons on targets. Strike aircraft such as the Joint Strike Fighter, F/A-22, and F/A-18 reside in this sector, as do the munitions programs that arm them.
- *Homeland and Base Protection* includes the functions that keep deployed troops and our homeland safe, and which have recently become ever more important. Missile defense functions fit into this sector.
- *Integrated Battlespace* includes many of the most critical capabilities of network-centric warfare. This is where networks of sensors will be connected to give the U.S. military un-matched situational awareness, and where our combatants will communicate as never before. Sensor programs clearly belong in this sector, but aircraft carriers and other multi-sensor platforms belong here too. Although they have many functions, these assets are dominant nodes in command, control, communications, computers, intelligence, surveillance, and reconnaissance networks. To maintain their value in the network-centric future, these high-value platforms must be designed and procured with interoperability and network compatibility foremost in mind. The placement of high-value, sensor-rich platforms such as those in battle groups in this sector should also allow for easier identification of expensive redundancy.

These sector categories and the programs assigned to them are notional. They are explicitly intended to evolve as requirements, capabilities, and our understanding of warfare evolve. Nonetheless, this operational effects-based structure would serve from the beginning as a construct to alter the way we think about building military capabilities. Looking across the sectors would allow DoD decision-makers to identify capabilities gaps, overlapping functions, and potential trade-offs among sectors. It may be that Combat Support is relatively under-populated, an observation that might lead us to investigate whether we are effectively supporting the “tip of the spear.” We will note that aircraft carriers and long-range bombers have overlapping functions in Power Projection, Integrated Battlespace, and Precision Engagement, and seek to minimize unnecessary redundancy. We would be constantly reminded of how choices affect multiple sectors. When ground-based precision engagement choices create a lighter force, demand on the adjacent sector of Power Projection should be reduced. When unmanned vehicles replace manned functions in Precision Engagement, Combat Support requirements should decrease.

Effects-based sectors also would change the way we think about the industrial base and the way that base views the defense enterprise. Companies will be able to readily identify programs related to each other in capability or connectivity, and which might offer multiple application opportunities for a new technology. Firms will see where capability or technology gaps exist, and which gaps they might be able to fill. And particularly important for innovative, aggressive non-defense companies, the effects-based construct would make the functions of warfare and the procurement activities that support them more connected and clear.

This would alter the way the Department thinks about the required number of suppliers, and the areas where it needs increased capability. In monitoring the industrial base, and in making the investment decisions that shape it in this way, the Department would be positioned to move from the status quo and support the future.

### **RECOMMENDATION**

The Department should consider viewing the industrial base as being composed of operational effects-based sectors, monitoring the industry on this basis, and assessing competition and capability issues on a similar basis. In addition to organizing the military enterprise along net-centric, transformational lines for our own purposes, in so doing we will also be more clearly projecting the composition and purpose of the military enterprise to suppliers.

## ACQUISITION EXCELLENCE IN BUSINESS PRACTICES

### Findings and Conclusions

- Many of the deficiencies in DoD acquisition policies cited by emerging and legacy defense suppliers are similar
- These deficiencies impede DoD's ability to deliver superior operational capabilities to the battlefield

### Recommendation

- The Department should restructure its internal R&D and acquisition planning, programming, and budgeting processes

The Department of Defense has fielded the most technologically innovative, capable, and responsive defense weapons systems in the world. Today's program managers continue to do so in an uncertain security environment requiring fewer new platforms and more transformational, network-centric defense solutions. Future success necessitates profound changes in DoD's internal policies and processes and in the external business practices with which we engage industry. These changes will be instrumental in helping meet the transformational warfighting requirements of the future – now from three primary sources of transformational capabilities: transformed legacy defense suppliers, innovative new firms or spin-offs, and commercial companies.

### ***Transforming the Department of Defense***

*"We must transform not only our armed forces, but also the Department that serves them by encouraging a culture of creativity and intelligent risk taking. We must promote a more entrepreneurial approach to developing military capabilities, one that encourages people to be proactive, not reactive, to behave somewhat less like bureaucrats..."*

*– Secretary of Defense Donald H. Rumsfeld  
January 31, 2002*

## **LESSONS LEARNED FROM EMERGING DEFENSE SUPPLIERS AND BEST PROGRAMS**

In this study, we interviewed 24 emerging defense suppliers to learn how they do business, both commercially and with DoD.<sup>8</sup> These companies averaged 621 employees, \$160 million in annual revenues, and have been in existence on average 13 years. Nearly half of these, however, had annual revenues of less than \$10 million. Of the emerging defense suppliers interviewed, involvement in the defense market spans the entire spectrum. As measured by the percentage of total revenue related to defense work, firms' defense participation ranges from zero (in the cases of a pre-revenue start-up and a commercial company trying to break into the defense market) to 100 percent (in the cases of a previously commercial supplier currently pursuing only defense opportunities and a sole-source manufacturer of a niche defense product).

<sup>8</sup> Complete case studies for these 24 companies can be found in Appendix B.

**TWENTY FOUR CASE STUDIES OF EMERGING DEFENSE SUPPLIERS**

Company Name	Annual Sales		Location	Enabling Technologies
	Total (\$ Millions)	Defense <sup>1</sup> (%)		
<b>Combat Support</b>				
EluSys Therapeutics	\$2.0	100%	Pine Brook, NJ	Anthrax Vaccine
iRobot	n.a.	n.a.	Somerville, MA	Intelligent robotics
Nomadics	7.0	80%	Stillwater, OK	Advanced sensors
Oakley	476.9	n.a.	Foothill Ranch, CA	Human form accessories
Sarcon Microsystems	0.0	0%	Knoxville, TN	Infrared sensors
<b>Power Projection</b>				
Aerovironment	50.0	50%	Monrovia, CA	Energy systems and UAVs
Amptek	7.0	5%	Bedford, MA	Space instrumentation
i2 Technologies	986.0	15% <sup>2</sup>	Dallas, TX	Logistics software
<b>Precision Engagement</b>				
C-CAT	2.0	50%	Fort Worth, TX	Carbon-carbon components
Foam Matrix	4.0	100%	Inglewood, CA	Net molded structures
<b>Homeland and Base Protection</b>				
Coherent Technologies	19.2	52%	Lafayette, CO	Laser radar technologies
Riptech	45.0	10%	Alexandria, VA	Managed security services
RSA Security	282.7	10%	Bedford, MA	Network security products
SRD	7.5	50%	Las Vegas, NV	Fraud prevention software
Symantec Corp	1,160.0	n.a.	Cupertino, CA	Network security products
Viisage Technology	30.5	10%	Littleton, MA	Biometrics technologies
<b>Integrated Battlespace</b>				
Actuality Systems	1.0	65%	Burlington, MA	3D visualization technology
AirFiber	n.a.	n.a.	San Diego, CA	Wireless equipment
Delta Information Systems	7.0	40%	Horsham, PA	Communications equipment
Sabeus Photonics	2.0	0%	Chatsworth, CA	Sensor technologies
SRA International	361.0	95%	Fairfax, VA	IT systems and consulting
The Insitu Group	2.0	65%	Bingen, WA	Long-range UAVs
Vanu	n.a.	50%	Cambridge, MA	Software radio
Zaplet	1.0	67%	Redwood Shores, CA	Collaborative software

<sup>1</sup> When military and civil government sales aggregated, most relevant government sales figure presented

<sup>2</sup> Next year's target for new licensing revenue

n.a. = not available

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

Source: Emerging defense suppliers interviews

During our discussions, these suppliers made recommendations as to how to improve the Department's relationship with its emerging supplier base in order to enhance its capacity to acquire leading edge, revolutionary technologies. The most common and most significant of these are distributed across the various stages of the product lifecycle and encapsulated in the table on the next page.

<b>EMERGING DEFENSE SUPPLIERS' RECOMMENDATIONS FOR BEST BUSINESS PRACTICES</b>	
<b>Market Identification</b>	Communicate military needs more effectively Assist innovative companies in navigating military command structure Foster interactive relationships between customers and suppliers Reduce redundancy in military sales efforts
<b>Allocation of R&amp;D Capital</b>	Conduct application-focused research to meet user needs Involve end-user in research process
<b>Concept Development</b>	Decrease use of cumbersome system design requirements Be receptive to high-risk and innovative concepts
<b>Contract Negotiation</b>	Fund all stages of a technology's lifecycle Increase direct DoD involvement with second and third tier suppliers Centralize and simplify contracting to speed development Reduce systems bundling
<b>Product Development</b>	Connect developer to user more directly in acquisition process
<b>Product Testing</b>	Standardize technological requirements
<b>Product Delivery</b>	Increase direct DoD involvement with second and third tier suppliers Provide incentives for primes to work with innovators more often
<b>Life Cycle Support</b>	Provide channel to allow suppliers to directly support their technologies
<b>Contract Administration</b>	Streamline and simplify initial and follow-on contracting to speed development Use more small, long-term contracts Centralize decision-making capabilities along technological lines Promote cross-agency collaboration
<b>Intellectual Property</b>	Protect companies' intellectual property while assuring military usage rights
<b>Foreign Sales</b>	Monitor export regulation enforcement to prevent unnecessary export restriction
Source: Emerging defense suppliers interviews	

In addition to discussions with emerging defense suppliers, we sought insights from legacy defense suppliers and DARPA<sup>9</sup> to help us identify what currently “works” – innovative and effective ways of delivering critical weapons systems to the warfighter. To get a complete effects-based picture, we asked them to characterize their fastest to field, most important and innovative, and overall most successful programs.<sup>10</sup>

<sup>9</sup> See DARPA description in Appendix G.

<sup>10</sup> Full program summaries can be found in Appendix B.

The messages from emerging defense suppliers resonated strongly with lessons learned from legacy defense suppliers. The messages heard from both fell into six primary areas of concern:<sup>11</sup>

- Insufficient visibility into the military enterprise
- Inadequate funding and advocacy for new technology transition
- Difficulty building a strong, interactive relationship with customers
- Cumbersome system design specifications
- Lengthy, laborious sales cycles
- Limited access to development and investment capital

The latter three concerns, particularly, have surfaced in a multitude of previous reviews. The Department has addressed them in the past, with mixed success; and continues to seek effective solutions today. In October 2002, the Department canceled its existing acquisition policy documents. Replacement policies, now being finalized, are intended to create an acquisition environment that fosters efficiency, flexibility, creativity, and innovation. The new policies would:

- Give the program manager more authority and freedom by minimizing regulatory requirements, removing prescriptive practices, and tailoring the timing and scope of milestone decision reviews;
- Encourage the use of performance-based acquisition and sustainment strategies by stating contractual requirements in performance terms; and only using military specifications and standards to address Government-unique requirements; and
- Emphasize evolutionary acquisition as the preferred strategy and spiral development as the preferred vehicle to execute that strategy. This approach would facilitate reduced cycle times and deliver military capabilities to the warfighter more rapidly than in the past.

Improving access to development and investment capital poses a difficult challenge. Emerging defense suppliers frequently face hurdles in raising money for military research and development and project opportunities. Capital markets are extremely tight (as evidenced by the significant reduction in the number of initial public offerings since 2000) and venture-financing opportunities similarly have declined. These problems are compounded in defense markets because potential investors do not view the risk-reward ratio as sufficiently attractive. To address this problem, the Army, Office of Force Transformation, and the Director of Defense Research and Engineering have established separate venture capital initiatives. These sorts of initiatives to fund and gain access to innovative commercial sector firms and apply their technologies to meet defense needs should be institutionalized in the recast investment process to provide transition funding to programs across the five operational effects-based sectors.

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<sup>11</sup> See Appendix B for a more detailed discussion of these issues.

Over time, we could address key aspects common to these issues by recasting the defense industrial landscape across operational effects-based sectors and organizing the Department's decision-making processes to optimize operational effects within those

**Six Primary Areas of Concern:**

- *Insufficient visibility into the military enterprise*
- *Inadequate funding and advocacy for new technology transition*
- *Difficulty building a strong, interactive relationship with customers*
- *Cumbersome system design specifications*
- *Lengthy, laborious sales cycles*
- *Limited access to development and investment capital*

sectors. This would improve supplier visibility into the military enterprise and help to more systematically secure "invention-to-weapon" technology transition funding. Emerging defense suppliers would be able to ascertain opportunities that cut across individual programs and platforms; and identify DoD and prime contractor points of contact with whom to engage. Most importantly, senior DoD leaders would be better positioned to identify technology "gaps" affecting both individual and multiple programs. With such visibility, DoD leaders also would be positioned to advocate sufficient transition funding to "pull" the promising new technologies that would enhance operational effects for multiple defense systems.

The Department's recent moves away from encouraging prime contractor total system performance responsibility and the bundling of smaller contracts should strengthen DoD-supplier relationships by permitting more direct communication with emerging defense suppliers and making it easier for such firms to compete for and win DoD contracts.

*"Total System Performance Responsibility is dead. It was a bad idea to start with. It's a bad idea today, and we're not going to allow it to live any longer."*

– Air Force Secretary James Roche  
May 14, 2002

It is also possible that a reinvigorated Department relationship with preeminent engineering and manufacturing universities could assist in the "clearing house" function cited by a number of the companies in our case studies. Universities specifically tasked for each of the operational effects-based sectors and provided requirements insight by the Department could assist innovative companies – and investors – in conducting application-focused research and help with technology transition.

## **CONCLUSIONS**

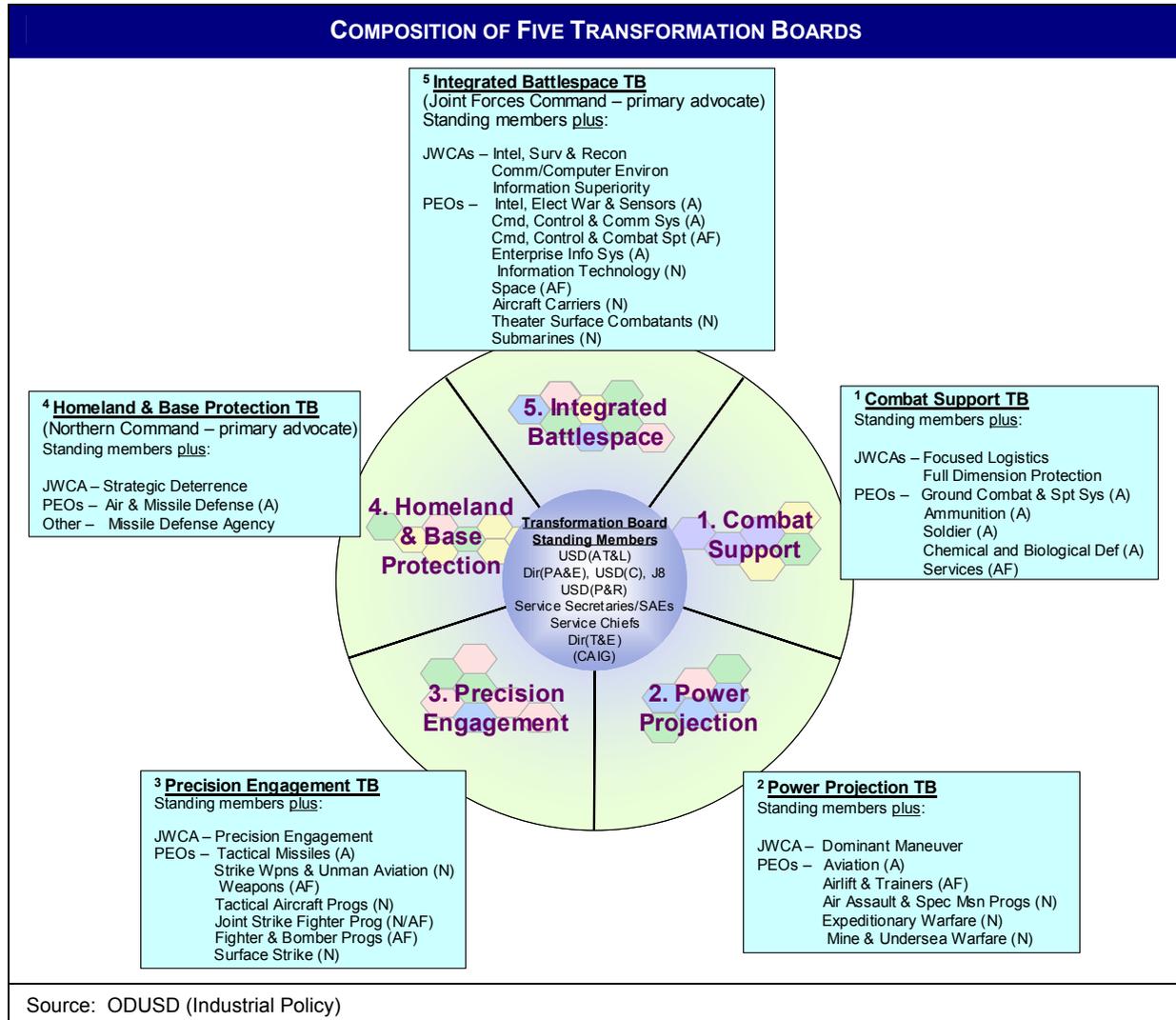
Restructuring DoD's internal investment, budgeting, and acquisition processes to place them in an operational effects-based context would:

- Support the SECDEF's mandate to institutionalize transformation;
- Transform the resource allocation and acquisition process; and
- Institutionalize industrial best business practices key to attracting systems-of-systems and innovative commercial solutions for the warfighter.

The construct described below suggests a model with which this recommendation could be implemented.

## THE TRANSFORMATION BOARD STRUCTURE

In this effects-based acquisition and resource allocation process model, the envisioned Transformation Boards for each of the operational effects-based sectors would facilitate cross-Service, network-centric, strategic planning and decisions within each operational segment.



Each of the Transformation Boards would have both standing and sector-specific members. The standing board members would be essentially the same as the current Defense Acquisition Board members as shown at the center of the graphic above. The proposed Transformation Board structure would provide equity for all current process shareholders. The Service Acquisition Executives would remain as stewards/architects of programs and key advocates.

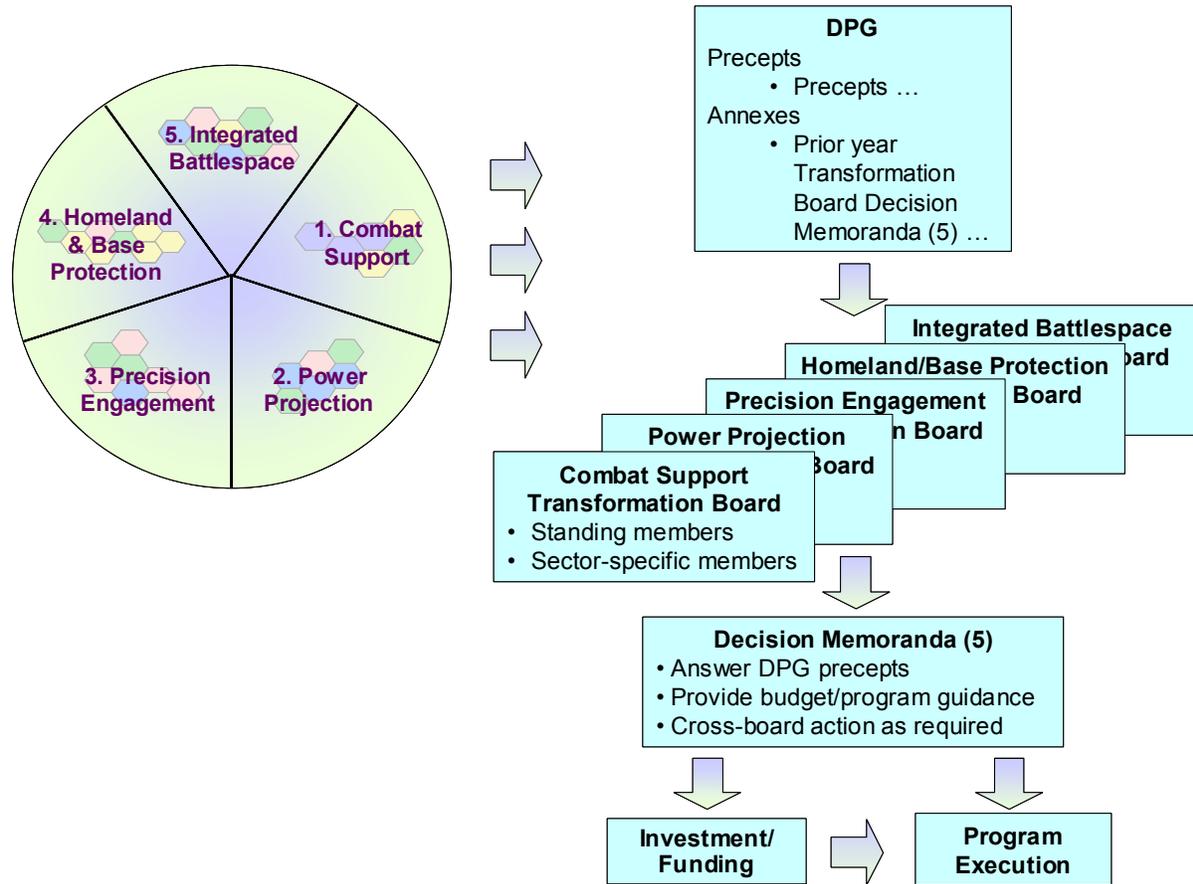
However, the Service Chiefs have been added as standing members of the Transformation Boards, recognizing that the unit of the “last tactical mile” is the soldier, sailor, marine, or airman. The Services must retain responsibility for personnel, training, maintenance, and readiness – and if we are successful in reducing program cycle times, their direct participation in decisions would allow them to more directly implement those requirements. Full participation by the Service Chiefs, Secretaries, and Acquisition Executives would also make them accountable to the Department’s transformation mandate, provide funding discipline, and provide for program implementation and execution.

The standing board member structure allows senior DoD leaders to act as harvesters of technology across all sectors as programs are reviewed, ensuring every Board links programmatic and budget decisions to achieving the Secretary’s operational goals for transformation. They also would monitor performance on key performance parameters important to joint operations such as operation-wide integration, flexible synchronization, mobility, sustainability, lethality, and survivability. In addition, as security requirements change, the precepts communicated to the boards in the Defense Planning Guidance would change to reflect the most important, overarching needs of the Secretary and of the warfighter.

## **THE TRANSFORMATION BOARDS**

In addition to the standing board members, each operational effects-based Transformation Board would include senior warfighting and acquisition leaders from the Joint Staff and Services most knowledgeable in the pertinent program and joint warfare concept areas. Two of the Transformation Boards have obvious primary advocates. For instance, the Homeland & Base Protection Transformation Board could be supported by Northern Command whose mission is homeland defense and civil support. The Integrated Battlespace Transformation Board could be supported by Joint Forces Command whose mission is to serve as a “force provider” to the geographical commands - providing trained and ready forces to deploy rapidly and conduct sustained operations worldwide.

**SECDEF PRIORITIES STRUCTURED ALONG OPERATIONAL EFFECTS-BASED SECTORS PROVIDES CONTEXT FOR TRANSFORMATIONAL DECISION-MAKING**



Source: ODUSD (Industrial Policy)

The Transformation Boards would provide funding and program implementation guidance for the programs in their purview, identify gaps or overlaps among programs for which they are responsible, and function as innovation and capability sponsors as critical capability shortfalls and innovative solutions are identified.

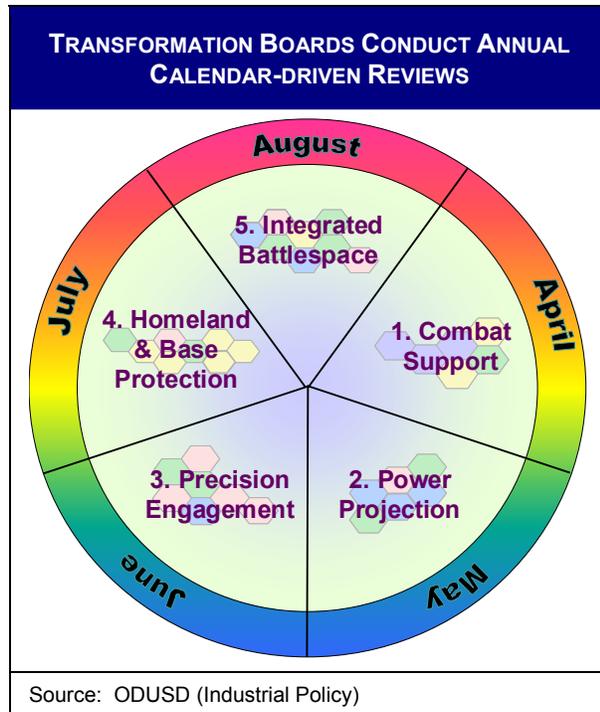
**PROCESS ENVISIONED**

Transformation guidance would come from the top in the form of annual Defense Planning Guidance (DPG) that would clearly state the Secretary's mission precepts and also allocate funding based on the operational effects sectors. An enhanced Joint Requirements

*"Instead of four services working as best they can to see their way to the future and then trying to cobble together what their acquisitions bring to the battlefield, you've got an understood, validated warfighting concept that the Services have all worked on together."*

– Marine Corps General Peter Pace, Vice Chairman of the Joint Chiefs of Staff, regarding the top-down JCS procurement approach  
January 27, 2003

Oversight Council, or similar body, would identify and prioritize programs (including current programs, new desired capabilities, and capability gaps) for each sector and present the prioritized programs to the appropriate Component Commander of the Joint Forces Command for a warfighter assessment.



Once they have determined the array of programs that meet the Secretary's guidance for a particular operational effects-based sector, the assigned program managers would be responsible for structuring, managing, and briefing these programs in their respective operational effects-based context to the appropriate Transformation Board. While programs would continue to be managed on a milestone basis, Transformation Boards would generally conduct program reviews annually (in lieu of at program milestones). A calendar-driven schedule (perhaps April-August) would provide timely feeds to the budget and the following year's DPG process. Annual reviews would optimize synergies across sectors – particularly early in transformation – but may not always be necessary.

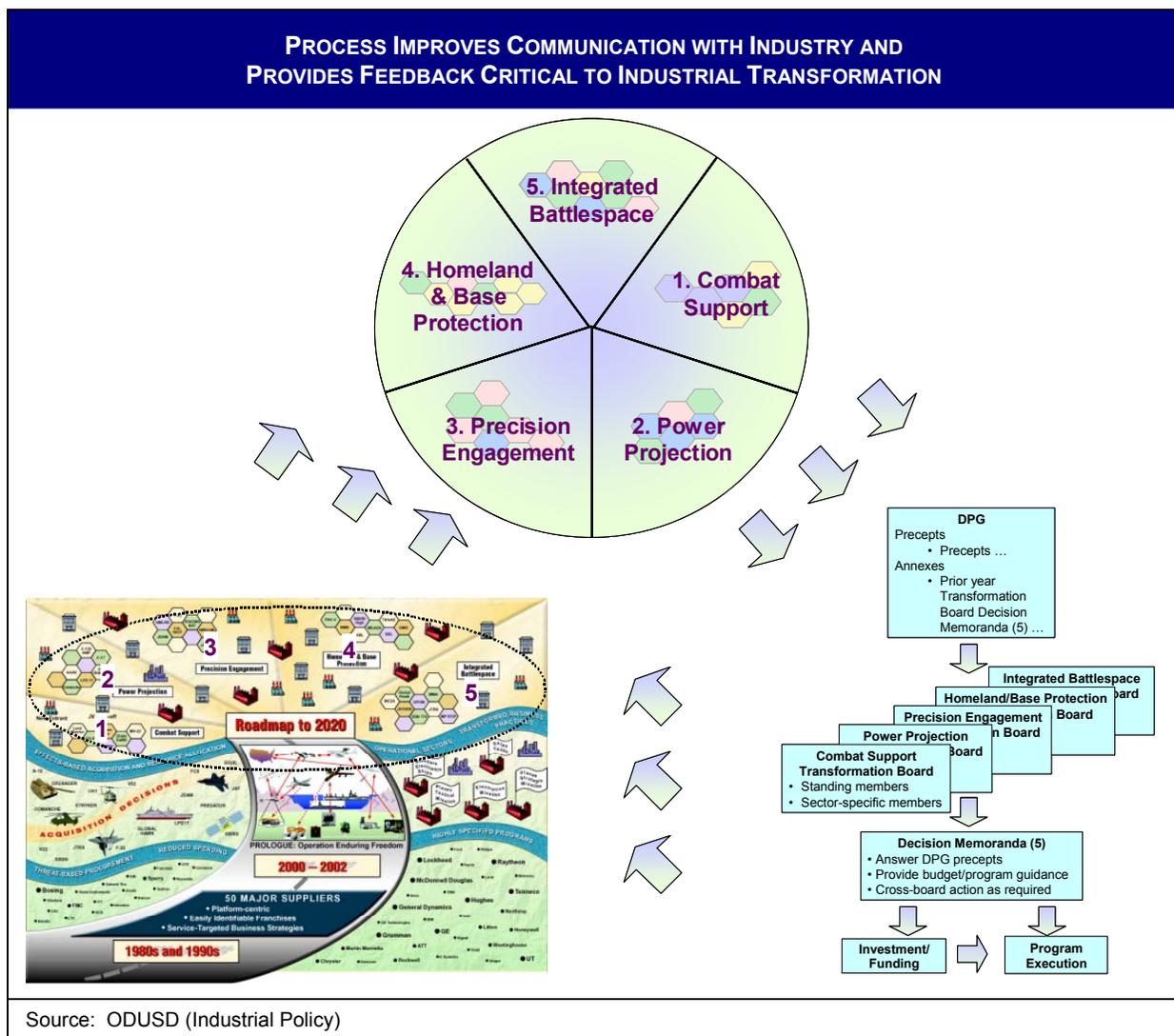
At the end of these sector reviews, each Board would issue a single, binding acquisition and funding decision memorandum for its sector addressing programmatic issues and budget/funding decisions for each program. As necessary, these decision memoranda would also include tasking for cross-sector issues to be resolved. Each year's investment deliberations would be interactive across sectors and would build on the previous years' Transformation Board reviews.

This fusion of functions of the Joint Chiefs of Staff as envisioned in the Goldwater Nichols Act with such an operational effects-based investment and program implementation process would provide a sound basis for re-engineering the requirement/acquisition/resource process and structure. Some legislative changes may be required.

Perhaps most importantly, top to bottom, all participants – government and industry program teams, emerging and legacy suppliers, and key decision-makers – would operate within the newly described context. Budget and operational trade-offs would be easier to reconcile and capability gaps and overlaps would be more readily identifiable by sector. In addition to improving DoD's strategic thinking and processes, the Transformation Board construct also would foster participant learning and the application of innovative techniques and technologies across all sectors.

The Transformation Board process would contribute to reduced cycle times by fostering cleaner, cross-Service strategic planning and decision-making. It would force the cross-program learning and consistent oversight so important to successful joint programs, limit iterative funding and oversight burdens, and help reduce the need for program stretches and course changes.

The effects-based focus of the Transformation Boards also would encourage spiral development and testing. Depending on circumstances, three basic forms of testing could be employed: (1) classical testing as enumerated in existing guidance, (2) focused joint experimentation to analyze proposed capabilities, and (3) battlefield testing. The involvement of the Joint Staff and Combatant Commanders would be key to the latter two testing options.



Transformation Board pressure could be focused to create performance-based specifications in the context of operational effects and transformational goals. Both emerging companies and representatives from successful legacy programs identified performance-based specifications as powerful enablers.

Recognizing that this structure should be more transparent to industry, the five operational effects-based Boards could evolve to sponsor the development of critical technologies and provide the funding and advocacy required to effectively “pull” new technologies into weapons systems. This would be the place to institutionalize the numerous “venture capital” funding initiatives spawning in the Department and potentially, provide representation for the university enablers as well.

Suppliers and potential suppliers would learn to use this more transparent system for transformation advocacy and the Transformation Boards would evaluate new capabilities (and capabilities gaps) on an annual basis. Finally, the Boards would improve supplier visibility into the defense enterprise by presenting DoD’s goals, strategies, and funding plans in an integrated, network-centric context. This would help potential suppliers learn DoD’s objectives and plans, and how emerging products could fit into those objectives and plans. Several emerging defense suppliers examined our proposed operational effects-based sector structure and found that it “makes sense” and provides emerging defense suppliers “significant insight” into the Department and relevant programs.

Perhaps most importantly, the Transformation Boards would be able to nurture creative and successful program management that emphasizes program manager knowledge of, and compatibility with, other programs within and across operational sectors. The Transformation Boards also would be able to provide a management structure that encourages reasonable risk-taking in pursuit of optimized operational effects. The schedule discipline embedded in this approach would focus the program manager’s attention on process matters for only the period of his sector’s reviews. For the balance of the year, he would be free to manage his program and source the best technology solutions available in industry.

This construct for process change has not been developed in a vacuum. Over the last year, the weapon system decision reviews have struggled to provide a more operational effects-based context. The Defense Planning Guidance provided early evidence of key tenets of this approach, and the corresponding decision document, the Program Decision Memorandum, provides many of the essential elements envisioned for the Transformation Board decision memoranda. The Department has also been in the process of retooling its program elements to reduce platform focus. The Joint Staff has produced a strawman Joint Capstone Concept to deconflict and coordinate Service forces into a fully integrated capabilities-based force. The Under Secretary of Defense for Acquisition, Technology, and Logistics restructured his Defense Systems organization to better focus on capabilities-based acquisition. The staff of the Secretary of the Navy has been reorganized to focus on mission rather than platform areas. Similarly, the Air Force has shifted from program reviews to a review process centered

on warfighting capabilities and effects. The revisions to the 5000-series acquisition regulations and the corresponding Joint Staff Requirements Generation System currently underway are surely a recognition that Department business practices must change. And finally, with the reorganization of the House Armed Services Committee subcommittee structure, our colleagues in the legislative branch are also changing with the times.

## **RECOMMENDATION**

From program justification through budgeting and acquisition, DoD should organize its decision-making processes to optimize operational effects – not programs, platforms, and weapon systems. Once an effects-based acquisition and budgetary process is put into place, effects-based procurement and contracting practices will follow.

If the Department is successful in designing an enhanced decision-making process, programming and budgeting acquisition decisions would be based on an integrated view of force structure focused on operational effects. The current processes sometimes make it difficult for senior DoD leaders to provide the forward thinking, strategic guidance necessary to field the interoperable, complementary, and transformational systems required for 21<sup>st</sup> century warfighting. Sometimes, current processes also hinder DoD's ability to effectively leverage limited financial resources for an optimal operational mix between emerging and legacy defense systems.

The chart on page 32 details a notional construct of our proposed investment, budgeting, and acquisition process model organized to address decision-making in the five operational effects-based sectors. The proposed construct presents an opportunity to review complex programs in a manner that crystallizes interrelationships within a given program as well as with other programs in the same or complementary operational effects-based sectors.

An important benefit to this approach is in providing better monitoring of the competitive landscape of the defense industry. Since all programs within a sector would be evaluated essentially simultaneously, DoD leaders would be positioned to identify those contractors providing multiple programs or major subsystems in a given sector. This would provide senior Department decision-makers real-time assessments of all programs contributing to system of systems solutions. Such reviews conducted in this way would provide ongoing assessments of the extent to which contractors with substantial vertical and horizontal capabilities are offering internal solutions at the expense of better external solutions. If necessary, DoD then could require acquisition strategy changes to ensure competition-driven innovation.

Finally, defense suppliers – particularly emerging defense suppliers – would benefit significantly from this operational effects-based arrangement of programs because program interfaces would become more visible. The Transformation Boards would, in turn, provide insight into how these programs are managed. Suppliers would be able to ascertain opportunities that cut across individual programs and platforms; and identify

DoD and prime contractor points of contact with whom to engage. When suppliers are afforded more visibility into DoD's goals, strategies, and funding plans, they are better able to marshal their unique industrial and technological capabilities and offer innovative solutions to a myriad of defense requirements.

# TRANSFORMATION ACQUISITION AND RESOURCE ALLOCATION STRUCTURE AND PROCESS

**Key:**  
 ● = Army    ● = Air Force  
 ● = Navy    ● = DoD  
 Color coding of PEOs denotes potential overlaps

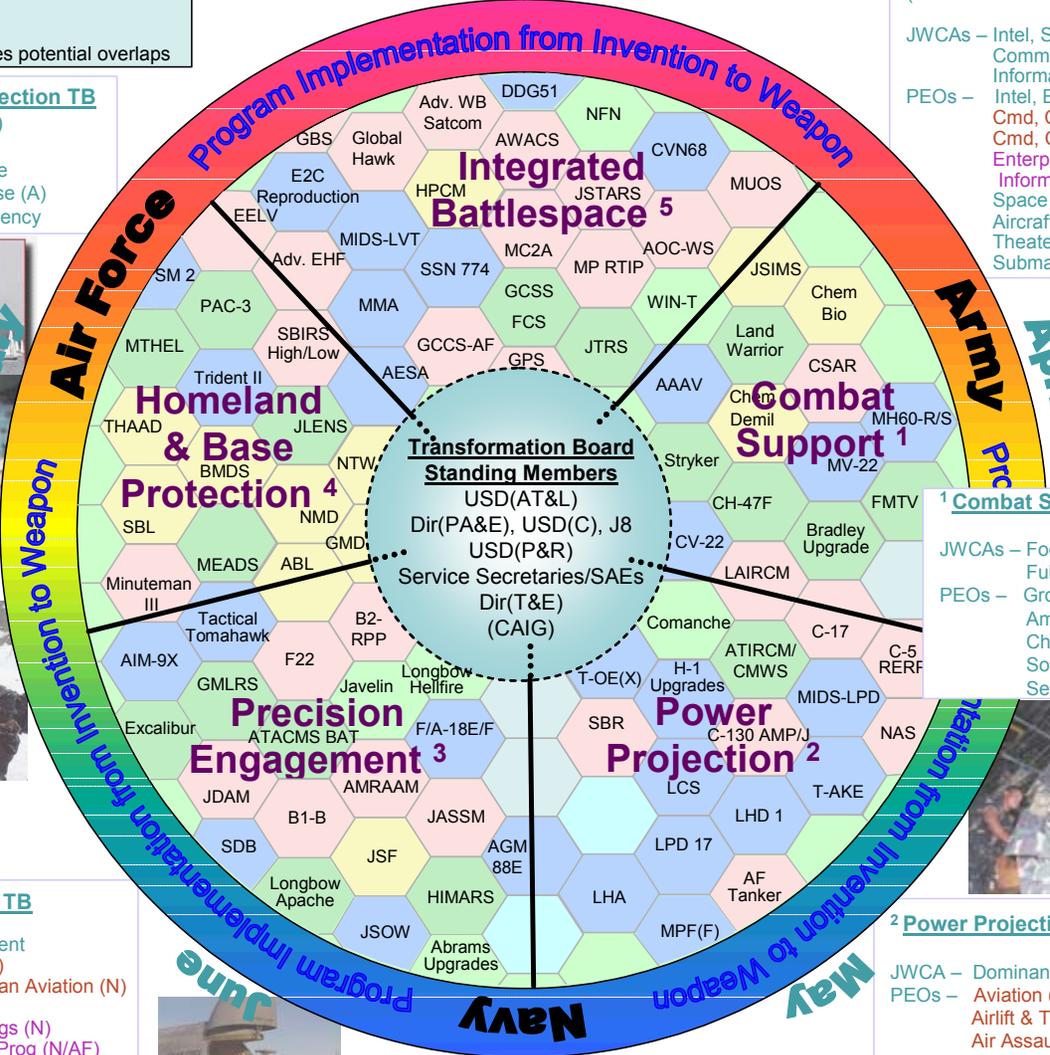
**4 Homeland & Base Protection TB**  
 (Northern Command lead)  
 JWCA – Strategic Deterrence  
 PEOs – Air & Missile Defense (A)  
 Other – Missile Defense Agency



**3 Precision Engagement TB**  
 JWCA – Precision Engagement  
 PEOs – Tactical Missiles (A)  
 Strike Wpns & Unman Aviation (N)  
 Weapons (AF)  
 Tactical Aircraft Progs (N)  
 Joint Strike Fighter Prog (N/AF)  
 Fighter & Bomber Progs (AF)  
 Surface Strike (N)



**August**



**5 Integrated Battlespace TB**  
 (Joint Forces Command lead)  
 JWCA – Intel, Surv & Recon  
 Comm/Computer Environ  
 Information Superiority  
 PEOs – Intel, Elect War & Sensors (A)  
 Cmd, Control & Comm Sys (A)  
 Cmd, Control & Combat Spt (AF)  
 Enterprise Info Sys (A)  
 Information Technology (N)  
 Space (AF)  
 Aircraft Carriers (N)  
 Theater Surface Combatants (N)  
 Submarines (N)



**1 Combat Support TB**  
 JWCA – Focused Logistics  
 Full Dimension Protection  
 PEOs – Ground Combat & Spt Sys (A)  
 Ammunition (A)  
 Chemical & Biological Def (A)  
 Soldier (A)  
 Services (AF)



**2 Power Projection TB**  
 JWCA – Dominant Maneuver  
 PEOs – Aviation (A)  
 Airlift & Trainers (AF)  
 Air Assault & Spec Msn Progs (N)  
 Expeditionary Warfare (N)  
 Mine & Undersea Warfare (N)

Source: ODUSD (Industrial Policy)

## THE WAY AHEAD

### Findings and Conclusions

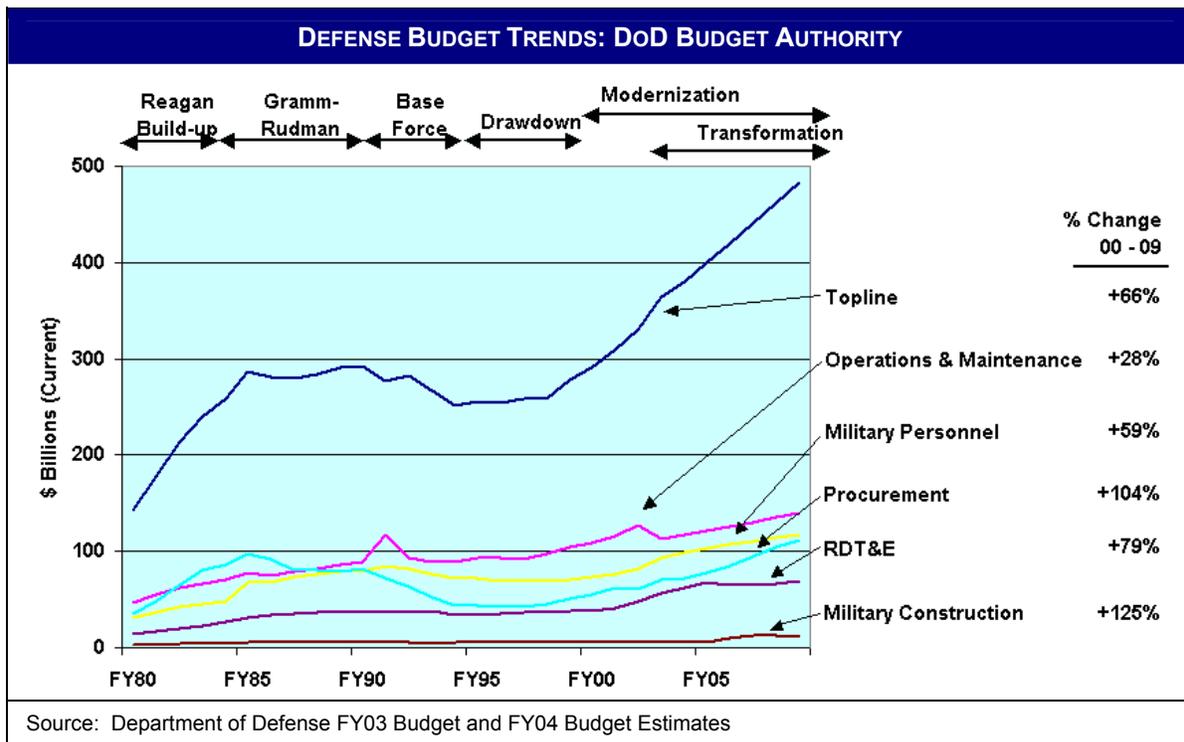
- We must know what to procure for future generations of warfighters mapped in the same five operational effects-based sectors
- Such critical technology assessments will identify capability and technology shortfalls to focus Department and industry investment and human capital development to the required capabilities
- Such assessments will be useful in assessing the number of sources and frequency of competitions required for critical technologies.

### Recommendation

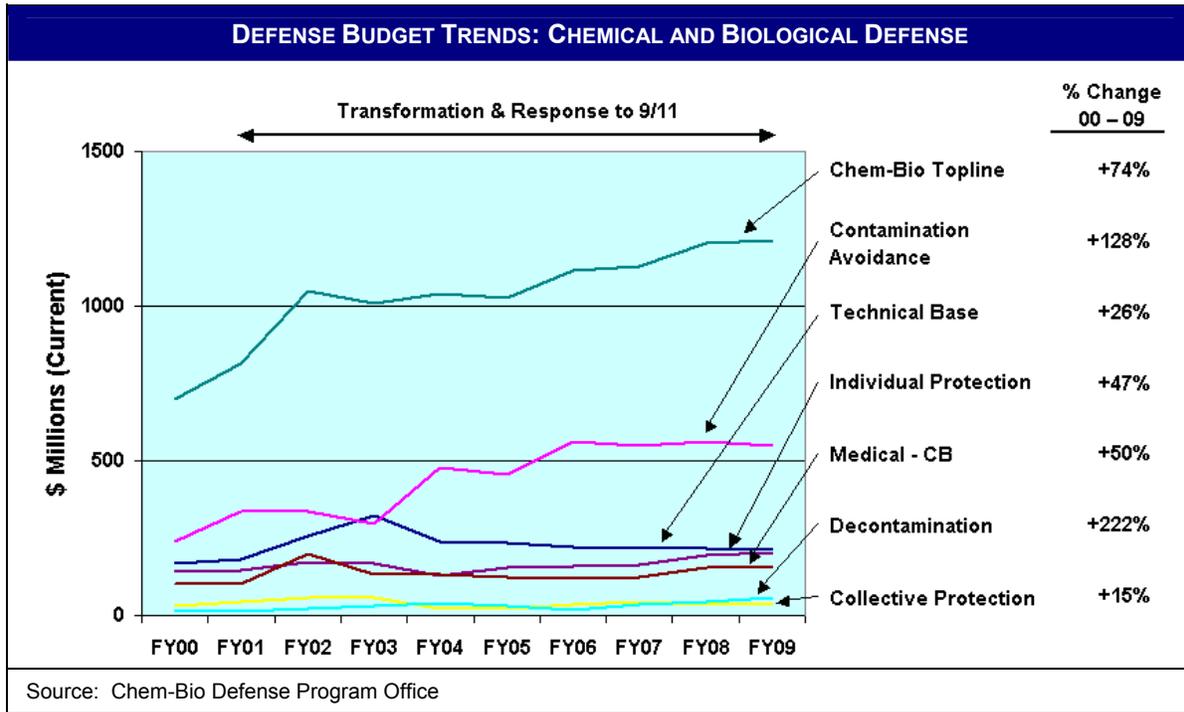
- The Department should conduct industrial assessments – focused on operational effects-based sectors – in order to provide DoD decision-makers an industrial base investment roadmap to the future

## INVESTING IN TRANSFORMATIONAL TECHNOLOGIES

Probably the most important thing that the Department can do to improve and develop innovative technologies is to provide robust funding. The chart below illustrates that the FY04 \$379.6 billion defense budget increases defense spending by approximately four percent over FY03, with R&D and procurement accounts each increasing on the order of six percent over FY03.



The tools for transformational warfare and thus the keys to preserving U.S. preeminence in innovation will be forged in the next several years of R&D spending as well as in discretionary spending allocated for transformational capabilities, such as the over one billion dollars allocated in the FY04 budget for unmanned aerial vehicles. The overall upward budget trends bode well for the defense industry.



In fact, spending for transformational technologies will grow faster than the aggregate defense budget, as evidenced by a greater projected growth in defense expenditures for chemical and biological defense technologies through 2009. This new focus on transformational warfighting requirements will continue to provide more business opportunities for legacy defense suppliers and also will attract emerging suppliers to the defense market.

### **SOURCING TRANSFORMATIONAL TECHNOLOGIES**

The “how” of transformation will be a product of improved processes and robust funding. The “what” will be less clear unless we systematically study existing and required capabilities across the same five operational effects-based sectors we use for investment and acquisition decision-making.

In our recent space study co-sponsored with the National Reconnaissance Office, we developed a systematic methodology useful for this endeavor. This methodology identifies and assesses the technologies within a defense sector critical to the warfighter’s needed capabilities. The resulting picture shows the Department where to focus attention and highlights weaknesses and gaps in industrial technical maturity.

This enables us to shape the transformation of the industrial base by mapping critically required capabilities against which to direct Department and industrial investment strategies.

The critical technologies assessment of our space study begins with identification of capability leadership goals as shown on the next page. This analysis shows us, from left to right, which capabilities should be readily available in the global industrial base and which are more rare. This grid is also useful in mapping which capabilities require more competitors – and more frequent competitions.

Underlying this assessment is the understanding that where global capabilities are more robust, products can be acquired in the global marketplace at competitive prices, thus requiring fewer domestic suppliers. As defense solutions become rarer and the technologies of interest more critical to the warfighter – the far right column of the chart – the Department must stimulate competitions and multiple sources to achieve the required innovation. We believe that singular among all factors, competition induces innovation. Timely, well-spaced competitions for systems that “push the envelope” are the industrial equivalent to “writing it all down” when one compiles a term paper or takes an exam in school. The opportunity to bid on contracts is the only way industry can “strut its stuff” and government customers can learn most about technology available in the defense industrial base.

Using this same methodology, assessments of each of the proposed operational effects-based industry sectors would enable the Department to direct future investments to maximize limited financial resources, directly feed critical technology requirements to the Transformation Boards, and provide guidance to industry on DoD’s goals and strategies.

**U.S. SPACE LEADERSHIP GOALS: AN EXAMPLE**  
(WHERE THE U.S. SHOULD BE AHEAD IN CAPABILITIES)

Mission Area	DEGREE OF LEADERSHIP			
	Open Market	Equal or Better	Be Ahead	Be Way Ahead
Space Control			Current Counterspace, Situational Awareness	Next Gen Counterspace, Situational Awareness
Position, Nav, Timing	Civil Uses		National Security Uses	*
Missile Warning		Shared Warning	Warning	Missile Defense Related
Intelligence, Surveillance, Reconnaissance			Commercial Imagery	Nat'l Security Imagery, SIGINT, Persistent Surveillance
Environmental Sensing	Commercial Uses	Civil Uses	National Security Uses	*
Communications	Civil and Commercial Common Uses	National Security Common Uses	Hardened, Secure	Agile, Low Prob Intercept, Unlimited Bandwidth
Force Application			Through Space	From Space
Satellite (Sat) Operations	Civil and Commercial Common Sat Command and Control (C2)	National Security Common Sat (C2)	Nat'l Sec Unique Sat C2, On-Orbit Maintenance, Sat Power Supplies	Autonomous Ops, Miniaturization, Sat Cluster C2
Space Transportation		Expendable Launch Vehicles	Space Shuttle, Propulsion in Space	Next Generation Reusable Vehicles, On-Orbit Vehicles
Space, Science, and Exploration		Deep Space, Interplanetary, Manned	*	*

**Critical Technology**

\* National Space policy states that we will share space science, exploration technology, and other civilian applications of space technology with the rest of the world. Thus, goals to put us ahead of the rest of the world in these areas have not been established.

Source: Space Research and Development Industrial Base Study Phase Two Final Report (Booz-Allen & Hamilton)

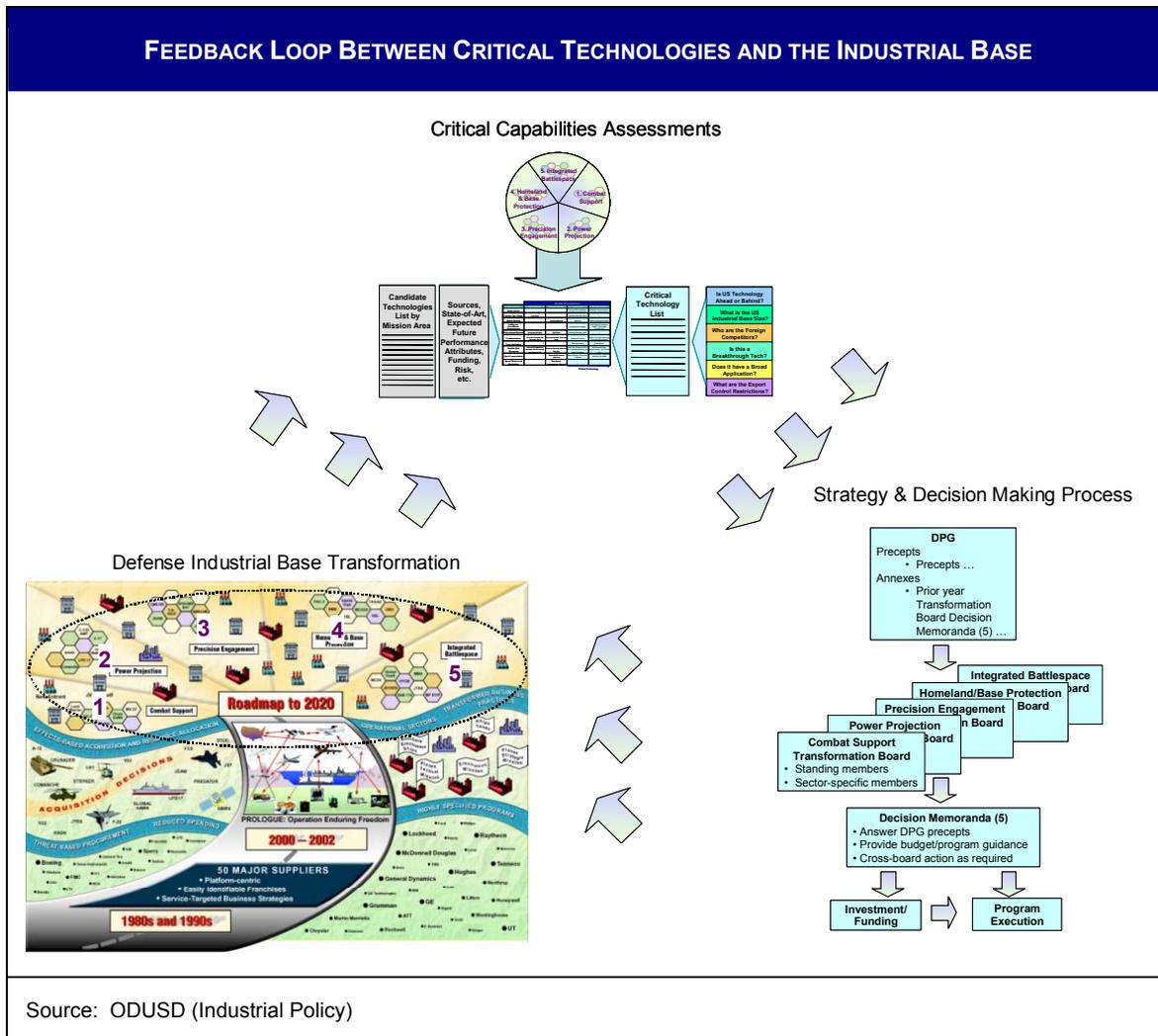
## **CONCLUSIONS**

The Department has historically conducted industrial assessments to identify and evaluate those industrial and technological capabilities needed to meet current and future defense requirements. It has used the results of these decisions to make informed budget, acquisition, and logistics decisions.

Heretofore, the Department has not conducted a systematic evaluation of the ability of the defense industrial base to develop and provide transformational, network-centric, operational effects-based warfighting capabilities. To enable informed and effective decision-making, it should perform such assessments. The Department should address – for each operational effects-based industry sector – enabling technologies, human capital, funding constraints and opportunities, and the competition and acquisition strategies that would permit the Department to leverage all of its resources to shape a transformed defense industrial base for the 21<sup>st</sup> century.



This information would help decision-makers sustain and nurture key suppliers and the human resources needed for the future, identify capability gaps to be filled, target new transformational technologies, and structure competitions to advance state-of-the-art technologies for future defense applications. Perhaps of special interest, the results of our assessment of the nascent Homeland & Base Protection sector could help identify key suppliers and new technologies with the potential capability to help lay the groundwork from an industrial base perspective for both the DoD Homeland Security office and the new Homeland Security Department.



Once all sector studies have been completed, the Department will have validated the Roadmap to 2020 we posited earlier in this report. These sector studies will, in time, provide direct feed to the Defense Planning Guidance and the Transformation Board process envisioned to ensure that the future generations of warfighters have the tools required to fight in the network-centric context envisioned by the Secretary of Defense's transformation mandate. They will also be an invaluable resource for emerging and legacy defense suppliers looking to focus their research and investment strategies to best support future warfighters.

## AFTERWORD

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This report was inspired by the excellence that our defense industrial base has delivered to generations of warfighters over the last century. The combination of Secretary of Defense Rumsfeld's transformation mandate, the ingenuity of our men and women in Operation Enduring Freedom, and the imagination and dedication available in some of the companies struggling to emerge as defense suppliers have all been important motivating factors in giving us the courage to recommend substantial changes in the way the Department conducts its business with industry.

We are also mindful that these recommendations are but outlines of the roadmap that will allow us to provide the best that American industry has to offer future generations of warfighters. But as we set on this course together, there is one time-honored principle which should inform the planning of our financial and industrial resources: the requirements of our men and women in uniform. They will be the first judges and proof of our success.

## BIBLIOGRAPHY

---

- Allen-Mills, Tony. "Robots to Lead U.S. Battle in Baghdad." *London Sunday Times* 11 Aug. 2002.
- Arkin, William, M. "Dressed and Equipped to Kill" *Los Angeles Times* 4 Aug. 2002.
- Baden, Colin and Erick Posten. Telephone interview. 10 Oct. 2002.
- Baratz, Alan, et al. Telephone interview. 21 Oct. 2002.
- Bates, Jason. "NIMA Upgrades Map Software." *Defense News* 26 Aug. – 1 Sep. 2002.
- Bawden, Scott. "Call to Action" *Undersea Warfare* Summer 2002.
- Biesecker, Calvin. "Report Eyes Key Issues Facing Small Companies in Defense Supply Chain." *Defense Daily* 9 Oct. 2002.
- Boeing. "Program Summary: Evolved Expendable Launch Vehicle (EELV) /Delta IV." 2002.
- . "Program Summary: Joint Direct Attack Munition (JDAM)." 2002.
- . "Program Summary: The Super Hornet." 2002.
- Book, Elizabeth G. "Competition Gets Under Way for Objective Force Warrior." *National Defense* May 2002: 32-33.
- Bose, Vanu. Telephone interview. 15 Oct. 2002.
- Bowe, Christopher. "Big Names In Defense Face Tough Choices." *Financial Times* 25 Nov. 2002.
- Bradt, Gary et al. Telephone interview. 15 Nov. 2002.
- Brown, Malina. "Cebrowski: Transformation Should Initially Skip Acquisition Realm." *Inside the Navy* 25 Nov. 2002: 2.
- Buechner, Maryanne. "Coolest Inventions 2002." *Time* 18 Nov. 2002: 73-98.
- Byrnes, Gerald and Bob Schmidt. Telephone interview. 15 Nov. 2002.
- Cast, Mike. "'Smart' Instruments Enhance Army's Testing Capabilities." *National Defense* May 2002: 38-39.
- Cebrowski, Arthur. "New Rules, New Era Pentagon Must Embrace Information Age" *Defense News* 21-27 Oct. 2002.
- Clark, Colin. "The 9/11 Effect." *Defense News* 9 Sep. 2002.
- Conver, Tim. Telephone interview. 3 Oct. 2002.
- Cox, Matthew. "Afghanistan-Bound Troops To Get New Gear." *Army Times* 13 Nov. 2002.
- Crawley, Vince. "Changing Of The Guard." *Army Times* 25 Nov. 2002: 23.
- Cumming, Colin, et al. Telephone interview. 3 Oct. 2002.
- de Fusco, Andre', et al. Telephone interview. 12 Nov. 2002.
- DARPA. "Program Summary: Phraselator." 2002.
- . "Program Summary: Control of Agent Based Systems." 2002.
- . "Program Summary: Global Hawk." 2002.
- Dembeck, Chet. "Army Lines Up Private-Sector Partnerships." *Federal Times* 26 Aug. 2002: 3.
- Despeignes, Peronet. "Number of US Patent Applications Set To Drop." *Financial Times* 9 Sep. 2002.
- "Diversa Awarded Department Of Energy Grant Through Genomes TO Life Program." *PR Newswire* 23 July 2002.

Dombrowski, Peter J. Military Transformation and the Defense Industry After Next: The Defense Industrial Implications of Network-Centric Warfare. Center for Naval Warfare Studies US Naval War College, Sep. 2002.

Eisman, Dale. "Rumsfeld Gives Endorsement To New Aircraft Carrier Design." The Virginian-Pilot 5 Nov. 2002.

Erwin, Sandra I. "'Persistent' Intelligence Feeds Benefit Air Combat Planners." National Defense October 2002: 20-21.

Favalora, Gregg and Cameron Lewis. Telephone interview. 1 Oct. 2002.

Feder, Barnaby, J. "Shape Memory Alloy May be Ready for Market." The New York Times 22 July, 2002.

Fineman, Mark. "War, The Mother of Inventions." Los Angeles Times 17 July, 2002: 1.

Forman, Ross. "Training to go High Tech." Chicago Tribune 29, Oct. 2002.

Frazier, Thomas P. "Department of Defense Profit Policy and Capital Investment in the Military Aircraft Industry." Review of Economics and Statistics August (1992): 394-403.

GAO. Contract Management: DoD's Profit Policy Provision to Stimulate Innovation Needs Clarification. GAO-01-801 July 2001.

---. Acquisition Reform: DoD's Guidance on Using Section 845 Agreements Could Be Improved. GAO/NSIAD-00-33 April 2000.

---. Defense Trade: Weaknesses Exist in DoD Foreign Subcontract Data. GAO/NSIAD-99-8 November 1998.

---. Defense Industry Consolidation: Competitive Effects of Mergers and Acquisitions. GAO/T-NSIAD-98-112 March 1998.

---. Defense Industry: Trends in DoD Spending, Industrial Productivity, and Competition. GAO/PEMD 97-3 January 1997.

---. Federal Research: DoD's Small Business Innovation Research Program. GAO/RCED-97-122 April 1997.

---. Industrial Base: Assessing the Risk of DoD's Foreign Dependence. GAO/NSIAD-94-104 April 1994.

Gardner, Alan. "They Might Be Giants." IEEE Spectrum Sep. 2002: 43-48.

General Dynamics. "Program Summary: Stryker." 2002.

---. "Program Summary: SSGN." 2002.

---. "Program Summary: Automated Deep Operations Coordination System (ADOCS)." 2002.

Gertz, Bill. "Inside the Ring." Washington Times 2 Aug. 2002: 7.

Glanz, William. "Tracking Terrorists." Washington Times 1 Aug. 2002: C8.

Goure, Daniel. "Stryker Drives to Future." Defense News 21-27 Oct. 2002: 27.

Graham, Bradley. "Out-Of-The-Box Thinking At Pentagon." Washington Post 2 Dec. 2002: 19.

Grant, Rebecca. "An Air War Like No Other." Air Force Magazine Nov. 2002.

Greiner, Helen. Telephone interview. 9 Oct. 2002.

Harbiston, John R. U.S. Defense Industry Under Siege – An Agenda for Change. Booz-Allen & Hamilton March 2002.

Harper, Jennifer. "Now Here's A 3-Year-Old Sandwich to Die For." Washington Times 30 Oct. 2002: 1.

Heebner, David, et al. Telephone interview. 21 Jan. 2003.

Henry, Shannon. "A Captain Searches For His Next Ship." *Washington Post* 12 Aug. 2002: E11.

---. "In-Q-Tel, Investing in Intrigue." *Washington Post* 1 July, 2002: E01.

Ives, Jack. Telephone interview. 16 Oct. 2002.

Johnson, Nicholas. "Venture Capitalists Steer Away From the IPO Road." *Washington Post* 19 Nov. 2002.

Jones, Gregg. "Home-Front Technology Furnished Key Bomb for Persian Gulf War." *Dallas Morning News*.

Jonson, Nick. "Sept. 11 Attacks Changed Defense Spending Patterns, Public Perceptions." *Aerospace Daily* 11 Sep. 2002.

Kaufman, Gail and Ratnam. "The Search for an Affordable UAV." *Defense News* 2-8 Sep. 2002: 1.

Keeter, Hunter. "Acquisition Reform Requires Legislative Change, Navy Says." 18 Oct. 2002.

---. "Navy Six Months from Refining Industry Roles in LCS Concept." *Defense Daily* 17 July, 2002.

---. "Rumsfeld: War Against Terror Provides 'Impetus' For Transformation." *Defense Daily* 21 Aug. 2002: 6-8.

---. "Cambone: New Capabilities-Focus Not Just Rhetoric, But Programs Shape Budget."

Kelley, Maryellen R. *In From the Cold: Prospects for Conversion of the Defense Industrial Base* Science-Vol. 268 April 1995.

Kennedy, Harold. "Naval Transformation Gets Boost From War on Terror." *National Defense* 1 Dec. 2002: 30.

Kennedy, Paul. "Power and Terror." *Financial Times* 2 Sep. 2002. <<http://www.ft.com>>

Kerber, Ross. "Pentagon's Call For Help Brings Few Contracts." *Boston Globe* 29 July, 2002.

Kozaryn, Linda D. "Demystifying 'Transformation'." *American Forces Information Service* 14 Aug. 2002.

Kreitman, Darryl, et al. Telephone interview. 9 Dec. 2002.

L3 Communications. "L-3 Communications Selected as Team Member for the Transformational Development of Advanced Satellite Communications Systems." *L-3 Press Release* 9 Oct 2002.

Landers, Amanda. "Boeing Chooses Chicago as Center of New Corporate Architecture." 10 May 2001. <[http://www.boeing.com/news/releases/2001/q2/news\\_release\\_010510a.html](http://www.boeing.com/news/releases/2001/q2/news_release_010510a.html)>.

Landry, Julie. "Top 10 Innovators." *Red Herring* Sep. 2002: 39, 42-43, 46, 48, 50-54.

Liang, John. "Pentagon Transformation Causes Examination of 'Less-Traditional' Supplier Base." *Inside Defense* 20 Feb. 2002. <<http://www.insidedefense.com>>.

Lockheed Martin. "Program Summary: Deepwater." 2002.

---. "Program Summary: Atlas V/Evolved Expendable Launch Vehicle." 2002.

---. "Program Summary: F-117 Night Hawk." 2002.

Loeb, Vernon. "For The US Military, A Transforming View From The Maginot Line." *Washington Post* 6 Oct. 2002.

---. "Billions, and It Can't Make Change." *Washington Post* 13 Sep. 2002.

McCarthy, Ellen. "Firm Goes With The Flow To Put Sensor On Market." *Washington Post* 19 Aug. 2002. <<http://www.washingtonpost.com>>.

McGarry, Thomas, WM. "Looking for Charlie the Tuna." *Unmanned Systems* May/June 2002.

McGrovy, Evans and Monaghan. "Robotic Warfare Leaves Terrorists No Hiding Place." *London Times* 6 Nov. 2002

Magnuson, Stew. "Space Businesses Get Lesson In Ways of Venture Capitalists." SpaceNews 24 June, 2002.

Marshall, Matt. "CIA Searching Out Technologies To Boost National Security." Silicon Valley 17 Nov. 2002. <<http://siliconvalley.com>>.

Merle, Renae. "Boeing Moves to Get More Federal Work." *The Washington Post* 11 July, 2002: E3  
 ---. "Contractors' Mergers Hit New Highs." *Washington Post* 16 Dec.2002: E5.

Michaels, Brett, et al. Personal interview. 18 Oct. 2002.

Moniz, Dave. "Afghanistan's Lessons Shaping New Military." *USA Today* 8 Oct. 2002: 13.  
 ---. "Stealths Would Play Crucial Role in Early Hours Of a War With Iraq." *USA Today* 21 Nov. 2002: 11.

Montgomery, Dave. "War Could Feature New U.S. Arsenal." Fort Worth Star Telegram 29 Sep. 2002: 1.

Morris, Jefferson. "Transformation Office To Partner With Venture Capital Firms." Aerospace Daily 30 Sep. 2002.

Mulholland, David. "US DoD Looks TO Speed UP Defence Industry Changes." Jane's Defense Weekly 6 Nov. 2002.

Muradian, Vago. "Questions but No Answers." Defense News 29 July, 2002.

Nelson, Robert, et. al. Telephone interview. 7 Jan. 2003.

Nichols, Bill. "No-Fly Zones Likely To Trigger Invasion." *USA Today* 21 Nov. 2002: 11.

Noonan, Michael P. "Form, Function, and U.S. Defense Transformation." Foreign Policy Research Institute 8 Nov. 2002.

Northrop Grumman. "Program Summary: Global Hawk." 2002.  
 ---. "Program Summary: Affordable Moving Surface Target Engagement (AMSTE)." 2002.  
 ---. "Program Summary: E-2C Advanced Hawkeye Radar Modernization Program (RMP)." 2002.

Nystrom, Dennis, et al. Telephone interview. 24 Oct. 2002.

Odeen, Philip. Preserving a Healthy and Competitive U.S. Defense Industry To Ensure Our Future National Security Defense Science Board Task Force November 2002.

Opall-Rome, Barbara. "Israeli Firm Adds A New Layer to Virtual Training." DefenseNews 19-25 Aug. 2002: 17.  
 ---. "Brig. Gen. Shmuel Yachin." Defense News 19-25 Aug. 2002: 22.

Pantazis, John, et al. Telephone interview. 18 Nov. 2002.

Perrine, Don, et al. Telephone interview. 22 Oct. 2002.

Peterson, Molly M. "Defense Agency Makes On Homeland Technologies." GovExec.com 21 Aug. 2002. <<http://www.govexec.com>>.

Plummer, Anne. "Don Rumsfeld Talks Guns and Butter." Fortune 18 Nov. 2002: 143.

Pugliese, David. "Canadian Firm Works on U.S. Defense Shield." *Ottawa Citizen* 31 October, 2002: 7.

Ratnam, Gopal. "US Coast Guard Tailors Modernization To Meet Future Budget Battles." DefenseNews 1-7 July, 2002: 3-4.  
 ---. "U.S. Defense Patents Lack Protection." Defense News 14-20 Oct. 2002.  
 ---. "How Europe Can Close The Gap." DefenseNews 1, 4.  
 ---. "Pentagon Seeks To Widen Supplier Base To Meet New Goals." DefenseNews 21-27 Oct. 2002: 64.

---. "Industry Giants Scrambled for Solutions." Defense News 9 Sep. 2002.

---. "Boeing Lands On Feet With UAV Unit." Defense News 26 Nov.-1 Dec. 2001: 16.

Raytheon. "Program Summary: Adverse Weather GBU-15 Enchantment Program (EGBU-15)." 2002.

---. "Program Summary: DD (X)." 2002.

---. "Program Summary: Advanced Medium Range Air to Air Missile (AMRAAM)." 2002.

Revely, Paul, et al. Personal interview. 17 Oct. 2002.

Ricci, Larry. "Case Study: DARPA TO Kabul In 126 Days." COTS Journal Aug. 2002: 36-43.

Rogerson, William P. Profit Regulation of Defense Contractors and Prizes for Innovation Journal of Political Economy - Vol. 97, # 6 1989.

Sabo, Michael and Greg Puschnigg. Telephone interview. 25 Oct. 2002.

Sauer, Ann, et al. Telephone interview. 13 Dec. 2002.

Scarborough, Rowan. "Rumsfeld Comfortable With Carriers Proposal." *Washington Times* 5 Nov. 2002: 8.

Schlesinger, James R. Defense Restructuring and the Future of the U.S. Defense Industrial Base: A Report the CSIS Senior Policy Panel on The Defense Industrial Base March 1998.

Schwind, Francis and Patrick Schwind. Telephone interview. 8 Nov. 2002.

Sheehan, Charles. "Armed And Dangerous SUV Won't Be At A Store Near You." *The Virginian Pilot* <<http://www.pilotonline.com>>.

Sherman, Jason. "Low Cost UAV's Draw US Navy Interest." Defense News <<http://defensenews.com>>.

---. "U.S. Moving Toward Top-Down Acquisition." Defense News 27 Jan. 2003.

Sherwood, Kent and Mike Kramer. Telephone interview. 28 Oct. 2002.

Slitz, John and Brian Sullivan. Telephone interview. 30 Sep. 2002.

Smith, Giles. Assessing the Use of "Other Transactions" Authority for Prototype Projects RAND, 2002.

"Speech to the Defence Industry Conference."  
<[http://news.mod.uk/news/press/news\\_press\\_notice.asp?newsItem\\_id=2070](http://news.mod.uk/news/press/news_press_notice.asp?newsItem_id=2070)>.

Squeo, Anne Marie. "Defense Industry Sees More Dials On The Horizon." *Wall Street Journal* 25 Sep. 2002: C1-C3.

---. "General Atomics Takes on Rivals In Unmanned Aircraft." *Wall Street Journal* 29 Jan. 2003.

Squitieri, Tom. "U.S. Soldiers Lack Weapon To Breach Walls." *USA Today* 21 Nov. 2002: 11.

Steckler, Vincent, et al. Telephone interview. 13 Nov. 2002.

Stephens, Hampton. "Aldridge: Strong Corporate Ethics Key to National Security." Inside Defense 1 Aug. 2002. <<http://insidedefense.com>>.

Strass, Marc. "MCWL To Become "Skunk Works" For Marine Corps." Defense Daily 19 July 2002: 6-7.

Sudovar, Stephen, et al. Telephone interview. 6 Nov. 2002.

Svitak, Amy. "Clear Role Eludes U.S. Transformation Office." Defense News 23-29 Sep. 2002: 22.

---. "Pending Pentagon Guidance Slows Transformation." Defense News 6-12 Sep. 2002: 29.

---. "Force Of The Future." *Army Times* 25 Nov. 2002: 22.

---. "Disjointed First Steps." Defense News Vol. 17, No.32: 8.

"Teaching Old Dogs." Defense Daily 25 Nov. 2002.

"Technology Innovation Awards Nominees." Aviation Week And Space Technology 30 Sep. 2002: 71.

"The Finalists Are..." Government Executive. 15 Aug 2002: 11.

Thom, Gary. Personal interview. 17 Oct. 2002.

Thompson, Loren. "Transformation, or Ideology?" Defense News 23-29 Sep. 2002: 15.

Tiboni, Frank. "IT Spending For US TO Swell, Study Says." Defense News 4-10 Nov. 2002.  
<<http://defensenews.com>>.

---. "Top US Army Program Officer Warns Industry: Make Products Network-Centric Or Take A Hike." DefenseNews 3 Dec. 2002. <<http://defensenews.com>>.

---. "Transformation's Catch-22." Defense News 21-27 Oct. 2002: 1.

"Transformed?" Economist 20 July 2002.

"United Kingdom Defense Industrial Policy." Ministry of Defence. October 2002.

Vaznis, James. "Signs Of Economic Optimism." Boston Sunday Globe 1 Dec. 2002.

Volgenau, Ernst. Telephone interview. 25 Oct. 2002.

Wall, Washington and Farnborough. "Manufacturers' Visions Clash over Unmanned Aircraft." Aviation Week & Space and Technology 26 Aug. 2002.

Weintraub, Arlene. "High Tech's Future is in the Toy Chest." Business Week 26 Aug. 2002.

Williams, Mark and Madden, Andrew P. "Military Revolution." Red Herring 1 Aug. 2001: 47.

Winograd, Erin Q. "Cambone Crafts Proposal To Cut Army's Top Four Weapons Programs." Inside The Army 14 Oct. 2002.

Yoran, Amit. Telephone interview. 21 Nov. 2002.

