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Volume I of the Defense Science Board 2006 Summer Study on 21st Century Strategic Technology Vectors represents the consensus view of the study's membership. This volume (III) is the report of the Strategic Technology Planning panel of the summer study. Its findings and recommendations were used to create volume I and it provides additional detail. Findings and recommendations provided in this and the other panel reports (volumes II and IV) do not necessarily represent the consensus view of the full summer study membership.

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Summary

The 2006 Quadrennial Defense Review (QDR) emphasized the need for greater agility in the Department of Defense (DOD)—a need amplified as terrorists exhibit the very adaptability so desired. The QDR also specified that to achieve this goal, DOD must undertake organizational change.

The QDR provided insights into the potential threat environment for decades to come. The current and future threats to national security cannot be addressed and managed by simple, single-dimensional actions. Rather, an enterprise-wide action plan is called for that includes changes to people, processes, and technologies. To achieve such drastic enhancements, actions are needed throughout the department.

As part of the Defense Science Board 2006 Summer Study on 21st Century Strategic Technology Vectors (see Terms of Reference in Appendix A), this report focuses on the DOD science and technology enterprise and how it could be transformed to meet the nation's future security challenges. It reflects the findings and recommendations of the study's panel on strategic technology planning (see Panel Membership in Appendix B), which was charged with reviewing the processes by which national security objectives are used to derive needed operational capabilities, which in turn are used to develop and prioritize science and technology plans and programs.

Chapter 1. Strategic Context

The Quadrennial Defense Review (QDR) and other strategic documents identify key future challenges and the broad capabilities required to meet those challenges—in other words, the "what." This report addresses the "how"—the processes by which technologies are developed against the context of those challenges to better deliver required capabilities.

Any assessment must begin with the acknowledgement that many of the relevant global environmental factors influencing the explosive development of technology are also creating challenges to U.S. security. These factors enable state and non-state actors to develop capabilities that can be used against the United States and its allies. These factors are increasingly outside of U.S. control or influence. Thus, it is not feasible to separate the technology-threat-countermeasure sequence in the way that was once possible. This relationship will become more critical as the ability to leverage relevant commercial technologies shortens the time from idea to deployment and reduces the costs to adversaries.

Uncertainty and Surprise

The uncertainty and surprise that will dominate the strategic environment, as outlined in the QDR, should itself not be a surprise. Rather, the post-Cold War paradigm is predictably dynamic. Therefore, the Department of Defense (DOD) must establish processes and environments for technology and systems development that can function in a rapidly changing world.

Current threats challenge traditional, overpowering U.S. superiority by finding and exploiting asymmetric advantage. In the QDR framework the asymmetries are:

- Global war on terror: The use of unconventional means to traditional standing military power.
- Emergence of peer: The use of conventional means in dimensions that avoid closing on U.S. strengths or that favor their strategic advantages, such as deep sea or dispersed ground (not air or space).
- Rogue adversary: The use of weapons of mass destruction (WMD).
- Unstable nation states: Placing at risk or destroying the foundations of civil society or government with the use of chaos or violating the established rules of engagement.

DOD needs to develop a response capability that is more than equally ingenious as the current evolution of asymmetric threats. Fostering this new ingenuity will require that many forces within the department work together. Of these many factors, improving the strategic technology planning process is a key to providing the disruptive capability needed to enhance security in this dynamic global environment. To be successful, the department should establish a new framework for technologies, systems, and capabilities development that overcomes or offsets the responsiveness of current and future adversaries.

U.S. Strategic Technology Advantages are Eroding

Since WWII, the United States has exploited technology to its advantage more quickly and efficiently and with more powerful results than any other country. This crucial national advantage was empowered by:

- a previously simple threat-peer environment
- technical leadership that was the mainstay of the department
- relatively small levels of innovation by nations other than the United States and its traditional allies
- U.S. science and technology (S&T) investment that dwarfed the levels of S&T investment elsewhere

- a military-industrial complex that was the primary source for U.S. technology
- a DOD that drew the best technical minds available
- a national outlook that valued strategic technology.

Today, many, if not all, of these factors have changed. The dynamic in which the department must function is different, requiring adjustment to expectations and accordingly to processes.

Asymmetric Adversaries and Technology Programs

Improvements in technology could enable DOD to create the systems needed to prevail over the systems deployed by new adversaries. But adversaries are likely to be leveraging much of the same global technology base in developing threats and countermeasures. In this highly mobile, global technological environment, the same technology concepts and sources the DOD should seek will likely be sought for exploitation by adversaries. This challenge will increase as commercial technologies become more commonly integrated into high- and low-cost weapon systems.

Current adversaries have shown an increasing ability to respond to U.S. deployed capabilities in innovative, fast, low-cost, and regional-specific ways. In response, the United States struggles to exercise the entire "legacy S&T development system" to counteract these threats. While the legacy S&T development system is optimized to produce high quality, reliable systems, its products are slow to be fielded, expensive, and too often optimized for global deployment, rather than the fleeting and regional problems at hand. In addition, decision aids for commanding and controlling the force, or to effectively integrate coalition forces, must continuously evolve so as to remain ahead of these newly delivered systems.

The United States must be capable of fighting in a way that emphasizes its superior innovative capabilities. Effective technology development is essential to turn the adaptation cycle to the advantage of the United States. The adaptation cycle of adversaries is often facilitated by their willingness to apply available commercial technology in creative ways and to rapidly integrate technologies into systems.

This new exploitation of asymmetry between U.S. forces and a suite of adversaries accentuates the differences in motivations and norms. America's focus on quality of life, the respect for human life, and individual liberty is countered by the reckless disregard for human life, lack of focus on a stable nation-state foundation, and a greater emphasis on religious and ethnic ties rather than national loyalties. In addition, employing non-kinetic instruments of warfare blurs the definition of winning or losing in war as the motivations, goals, and assumptions of U.S. adversaries are so elucidated. These circumstances amplify the asymmetry by providing small, disenfranchised groups with disproportionate power against traditional armies or established nation states.

To these ends U.S. adversaries have sought the capability to accelerate the development and deployment of systems using:

- globalization and the Internet, which enables the rapid spread of technology and proliferation of information gleaned from the relative openness of the American defense industry and multinational firms
- integrative innovation to quickly achieve new capabilities without using exotic technologies
- global knowledge and quality education to make adherents more capable in areas that directly enhance their ability to engineer new asymmetric capabilities
- experimentation, basic operations, and enhanced operations that are being combined into one continuous, rapid effort to develop solutions to system deployment challenges.

Pace of Adversarial Changes and DOD Technology Implementation

A primary issue is the time sequencing of activities. The department should establish processes that will exploit this rapidly changing global technology domain. A concerted effort is needed to develop a DOD technology strategy that not only continues to addresses long-term concerns but also evolves to support rapidly changing, short-term needs.

DOD should assemble and manage its capabilities development process to exploit the same attributes of highly compressed urgent collaboration, innovation, and expediency that U.S. adversaries are exercising to adapt to the modern operational battlefield.

Currently, the technology development budget process does neither well, since strategic technology planning is more the product of stakeholder consensus. Furthermore, incentives create an environment where participants are more likely to disrupt progress with their bureaucratic self-interests rather than facilitate advances.[1]

As a result, the end state must take into account the elements of costs, resources, and speed. The cost/resource struggle is exacerbated by the fact that the United States will likely have more demands and fewer resources to meet them. Conversely, adversaries will likely, as a deliberate strategy, refine their exploitation of technologies to deploy new capabilities ever more expeditiously, rather than respond to a lack of resources. Finally, western cultures require a high wage for technology workers who are needed to support these new development paradigms while many adversaries have significantly lower manpower costs.

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1. For example, with a relatively fixed top-line budget for DOD technology development, Congressional earmarks for S&T projects not requested by the war fighters can displace other funded S&T projects. Without a clearly articulated vision that would enable the department to more effectively say no to these additional programs, earmarks will continue to divert scarce S&T staff resources in the military service and defense agencies. Additionally, many “earmarks” are not even mandated by statute, but by committee report language.

Chapter 2.
What Is Not Working Well Enough

DOD science and technology programs are not well-positioned to meet the nation's strategic challenges.

The challenges described in the QDR place even greater demands on the department's deployed forces. DOD needs to be more adaptive in order for these forces to continue to meet future challenges. A better linkage is needed between the technology community and the war fighter so that deployed forces are better informed about technological possibilities and the department's ability to develop missions, capabilities, and requirements is enhanced.

A Lack of Strategic Direction

Today's complex and changing environment demands careful strategic direction to better focus technology development and investments. The Department of Defense needs an overarching strategic plan that identifies all capabilities likely to be needed in the near- and far-term to address major challenges. This strategic plan should identify existing capabilities, those in need of improvement, and those in need of development. Capability areas in need of improvement or development should be prioritized relative to the demands of the strategic environment. The plan should also be capable of identifying those technologies that are reaching or past their utility.

Future joint concepts and capability needs would be better developed with an informed understanding of the technological possibilities available to the United States, as well as the technology options available to adversaries. These technology vectors need to be well considered before capabilities and concepts are fixed. A high degree of peer-to-peer interaction between technologists and mission-planners will be required to achieve these results.

Whether it is future technological developments by a near peer or future commercial technological developments in the hands of terrorists, technologists must anticipate these possibilities if the capabilities development enterprise is to be fully prepared to meet the threat posed by adaptive adversaries. Thus, the requirement to help shape the scope and focus of future capabilities must be part of the department's strategic technology plan. Pure war-fighter-driven technology programs are insufficient to assure that the necessary technologies will be in place to meet future needs, given the pace and nature of current and future operating environments.

Enterprise Processes Have Deteriorated

The launch of Sputnik on October 4, 1957 triggered a major reorganization of military research and development (R&D). The Defense Reorganization Act of 1958 created the office of the Director of Defense Research and Engineering (DDR&E) to provide a centralized authority to approve, disapprove, or modify all R&D programs of the Defense Department. In that post–Korean War period, concern about the Soviet Union's possession of the hydrogen bomb and its potential to deliver one over intercontinental distances provided a renewed high-level interest in the ability of science and technology to develop defensive and offensive counters to this threat. Science and technology programs became quickly focused on the space and missile defense arenas. The Advanced Research Projects Agency (later renamed the Defense Advanced Research Projects Agency [DARPA]) was created to conduct special projects in this area, free from interference by the military services. The emphasis in DOD was on establishing the overall technology agenda, eliminating redundancy, and reducing inter-service rivalry, with the DDR&E serving as the final authority. These strategic technology processes remained relatively constant throughout the Cold War.

But, since the mid-1980s, the department's management of S&T has been dispersed and decentralized. The role of the Office of the Secretary of Defense (OSD) is best described as one of policy and oversight. This role contrasts with the more proactive, high-level direction and strategy-shaping role characteristic of the 1960s and 1970s. The events of

September 11, 2001, drastically changed the strategic thinking of the Department of Defense, while S&T approaches have remained stuck in the 1980s. It is of immense importance that DOD's current proactive approach to strategies, plans, and programs be accompanied by a proactive technology enterprise that is refocused to address the current strategic environment and its compelling new challenges.

The Joint Capabilities Integration Development System (JCIDS) was created to replace the previous service-specific requirements-generation system, which was widely seen as having created redundancies in capabilities and failed to meet the combined needs of the combatant commanders who actually employ the capabilities provided by the services, Special Operations Command, and the defense agencies.[2] As the JCIDS process is struggling to evolve into an effective system, the current strategic technology planning process is still criticized as simply compiling a list of service technology programs and not an *enterprise strategic plan*. Additionally, it is not informed by, nor does it effectively inform, the JCIDS requirement process.

Strategic technology planning is the responsibility of the DDR&E in the role of principal staff advisor to the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD [AT&L]). The DDR&E staff of approximately 60 people has the following responsibilities:

- develop strategies and supporting plans
- conduct analyses and studies
- develop policies
- provide technical leadership, oversight, and advice
- make recommendations
- issue guidance
- recommend approval, modification, or disapproval of programs and projects

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2. Appendix E contains more detailed explanation of the JDICS and S&T processes within DOD.

- provide guidance during the Planning, Programming, Budgeting and Execution (PPBE) process
- develop defense and transformation planning guidance consistent with a capabilities-based planning approach
- develop technology planning guidance for the Secretary of Defense
- recommend appropriate funding levels
- represent the research and engineering (R&E) program as a member of the Program Review Group
- recommend programmatic adjustments
- advise the Secretary of Defense on whether the President's budget meets DOD goals and objectives
- oversee the DOD laboratories
- promote coordination and cooperation within DOD and between DOD and other federal agencies and the civilian community
- ensure R&E interchange with allied and friendly nations
- provide support to the Defense Technology Security Administration
- provide advice and assistance for rapid technology transition
- develop and maintain an R&E metrics program to measure and assess progress
- provide technical evaluation of DOD component special access programs
- provide technical support to USD (AT&L) on technology readiness of programs for the Defense Acquisition Board and industrial base issues

- serve on boards, committees, and other groups in R&E functional areas and represent OSD on DDR&E matters outside the DOD.[3]

The current staff is overwhelmed with day-to-day activities inherent within these assigned responsibilities. For example, they are often given only a short time period to perform a technical readiness assessment for a complex acquisition program consisting of multiple technical risks and a variety of performing contractors. In addition to performing these technical readiness assessments, they are often called upon to recommend ways to mitigate high-risk programs. In part, these short-term requests have in essence transformed the DOD Chief Technology Officer into the DOD Chief Engineer. The Chief Engineer's staff is then constrained to an approximately two-week period to review the service Program Objective Memorandum submissions for compliance with departmental guidance. **Because of the press of these day-to-day activities, important long-term functions such as strategic planning do not receive the necessary attention.**

Strategic technology planning by the DDR&E has been further hampered by an inability to arrive at an intimate understanding of war fighter needs. These insights can only be obtained from a frequent and continuing peer-to-peer interaction with operational military personnel. They require in-depth knowledge of national and departmental strategic goals and objectives and an ability to translate these objectives into specific strategic technology vectors to guide the creation of service and agency technology plans. It also requires deep technical knowledge to understand what is possible and what is not. Finally, it requires sufficient staff for contemplative thinking and collaboration with the services, other government agencies, and with industry, universities, and allies. DDR&E currently accomplishes strategic planning during lulls between day-to-day demands, rather than with sufficient people to dedicate to the process.

This failure to develop a credible strategic plan in some part results in an uninspired technology community that tends to revert to an over-emphasis on immediate problems—resulting in a near-term rather than

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3. DOD Directive 5134.3.

strategic focus. The increasingly near-term and risk-averse science and technology investment accounts (budget categories 6.2 and 6.3) reflect this trend, aggravated by the natural tendency of service program managers to focus technology resources toward solving their current programmatic challenges.

In contrast, a credible, continually refreshed strategic technology plan will:

- provide meaningful technical goals and objectives (from the vision) to better prepare for an uncertain future
- inspire and encourage technologists to take risks (longer term vision)
- balance technology investments between requirements and opportunities
- build consensus and advocacy within the user community to support technology investments and pave the way for technology transition
- rationalize and justify the technology program to Congress with arguments that give strong support for the priorities set out in the President's budget.

Over the past several decades, DOD (and, in some cases, the nation) has lost its leadership position in technical areas that are important to maintaining military superiority. For example, in technical areas such as information technology, biology, and microelectronics, the DOD is no longer a significant player as a technology developer or even as a significant buyer. Because of the huge world-wide market in these high-technology areas, the DOD is now a small-volume buyer. The relevant industry is willing to sell the department standard commercial products but is increasingly hesitant to alter technology or production process just to satisfy unique military needs.

In other cases, the best available technology is not always available to the DOD. Federal Acquisition Regulations require specific and rigid cost accounting standards that differ markedly from those used by commercial industry and are often too much of a burden for some organizations. Another impediment is the regulations that require rights to intellectual property that serve to discourage industry from entering into DOD R&D contracts. These regulations especially impact small companies that typically have new and innovative technology. Even the best and brightest industry scientists and engineers who once were traditionally drawn to DOD technologies and programs now often choose to work in the more lucrative and faster evolving commercial arena.

With so much technology innovation in the world markets, the DOD has yet to organize and staff accordingly. The DOD does not know what it does not know and to date has yet to construct solutions or processes to overcome this important barrier. There are no systematic and enterprise-wide mechanisms to determine how global technologies can be used to enhance military capabilities or how these technologies can be used against the United States by potential adversaries.

Defense companies (such as Boeing, Lockheed Martin, Northrop Grumman, and Raytheon) typically allocate significant amounts (approximately $1.5 billion annually) of discretionary independent research and development funding each year. Yet, without a strategic plan, DOD lacks the ability to leverage and optimize industry investment for mutual benefit. Major commercial companies allocate even larger discretionary resources for research and development (such as the pharmaceutical, automotive, and electronics industries). Sony alone, for example, spends in research and development more than DARPA's annual budget.

Chapter 3. What is Needed

To address the problems described in the previous chapter and establish an effective strategic technology planning process in the Department of Defense, the panel identified two broad areas where improvements can be made: mission-oriented planning and enhanced execution.

Strategic Technology Planning: Mission Portfolios

The 2006 QDR characterized the future environment—with all its myriad uncertainties—well enough to pose a meaningful list of strategic challenges. But beyond those broad challenges, the DOD requires a set of overarching operational objectives to provide a focus for technology development. An example of such an objective, used in earlier decades by the Air Force, was "having the capability to strike any target, at any place, at any time, with precision." An attribute-related expression of this objective might have been "We seek stealth, precision, and speed."

This compact objective provided a trajectory to the S&T community and shaped technology development activities at all levels. Well-articulated operational objectives of this nature are required to develop mission-relevant technology visions that will provide a context for setting resource priorities. Once the technology vision is defined, a set of technology strategies is required to guide planning and programming and to outline the mechanisms by which the defined technology objectives will be inserted into the capability planning process.

A strong partnership between the USD (AT&L) and the Vice Chairman of the Joint Chiefs of Staff (VCJCS) will be a key enabler for the development and execution of the technology vision and strategy. Their leadership will guide the S&T community to leverage the best solutions from both a capabilities focus (demand-pull) as well as an S&T focus (technology-push).

A dedicated cadre of mission portfolio strategists will be needed to develop the technology visions and associated strategies. This group should be tasked to assess current technological realities and the technological possibilities, from near- to far-term, which hold the potential to create the key capabilities needed to meet the range of challenges facing the department (such as the global war on terror, an emerging peer, rogue states, and failing states).

Through this portfolio approach, plans can be put in place for enterprise-wide investment strategies that are needed to direct the development of technologies over multiple timeframes, as well as to highlight relevant risks and opportunities. Furthermore, if called upon, a mission-oriented portfolio approach could provide the basis for investment and disinvestment decisions, driven by available resources, shifting strategies, or concepts that do not prove out.

Enhanced Execution Capacity

In addition to establishing a cadre of mission portfolio strategists, DOD needs to bolster its ability to execute the technology strategies. In broad terms, this means establishing technology development mechanisms, as described in Table 1. Five execution agents are needed: developer, innovator, speculator, prospector, and expeditor.[4]

As noted, the DOD must operate in an unpredictable world, where new threats and new national security challenges can emerge very quickly. Thus, while preparing a best estimate of what the future will bring is prudent, there must be a recognition that the future cannot be known with certainty and DOD needs to be prepared to adapt quickly to changing strategic environments.

In addition, commercially developed technologies are universally available, improving quickly, and are increasingly being adapted for military purposes through aggressive Darwinian "real world development

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4. Volume I, which integrates across all the panel reports, identifies a sixth execution agent, the "anticipator." The anticipator explores how foes could use technology to field capabilities disruptive to U.S. goals.

and testing" processes seeking to thwart U.S. defenses—the threat from improvised explosive devices (IED) is a current deadly example, but others just as serious and surprising will certainly follow. Just as these new commercial technologies can quickly turn into threats, DOD needs to have an efficient mechanism to exploit the emergence of these technologies to improve its own capabilities.

Table 1. Taxonomy of Technology Development Mechanisms

Taxonomy	Functions
Developer	Develops systems in direct response to requirements using the established acquisition system; delivers to users.
Innovator	Funds risky technologies with the potential for enormous payoff in military capability; develops prototypes; responds to current or anticipated needs; delivers to developer or expeditor.
Speculator	Funds "bottoms-up" discovery to create disruptive breakthroughs in DOD areas without clear commercial application; not directly requirements-driven; very high risk; typically requires sustained investments over substantial time horizons; delivers to innovator, developer, or expeditor.
Prospector	Finds global solutions to address current needs; informs execution agents of what's available now.
Expeditor	Accelerates technology to war fighter in less than two years, especially in response to changing operational needs; uses current or developmental technologies; driven by "requirements pull"; conducts rapid prototyping, testing, and demonstration; delivers to users.

For these reasons, the United States must balance its goal of prioritizing technology development resources based on assumptions about the future, with the need to be adaptive in a rapidly changing world. Furthermore, the DOD must continue to foster (through empowered people) the innovation that has long been a hallmark of U.S. technological dominance—bringing change to the larger world, rather than simply being on the receiving end of change as described above. This "bottoms-up" innovation is an important element in the technology development arsenal.

These fundamental tensions—between "top-down" versus "bottoms-up" and fast-cycle-time versus sustained effort—call for a number of execution agents, each with a different purpose, discrete core competency, and focus. Summed together, this suite of agents can better foster the competition of ideas required for continued U.S. dominance. The job of the USD (AT&L), in the "technology" role, is to create an environment, across the full taxonomy of S&T domains, where the technology aperture can be open as wide as possible. Further, when appropriate, it should adjudicate between the efforts of its various execution agencies. The USD (AT&L) must aim to create a Darwinian competition of ideas, resulting in the development of the full mix of capabilities: near- and long-term, requirements-driven and innovation-enabled, developed by DOD and harvested from commercial technologies.

"Developers" mature technology in direct response to requirements and operate within the traditional (often ponderous) acquisition system. As requirements-driven organizations, they are focused on delivering a specified level of performance to the user on a set schedule, at a set cost that is determined well in advance. They are well suited to implement the top-down S&T prioritization, especially those with long-time horizons.

Other mechanisms are required for more risky technology development. Another element in the suite of execution agents is the "innovator," funding very risky technologies beyond those within the charter of the developers that, if successful, have the potential for enormous payoff in military capability. The innovator should not be constrained by excess oversight or peer-reviewed processes, since these can prevent the emergence of very high-risk technologies. Innovators are a complement to, not a replacement for, the developers.

Where innovators select their technology investments based on directly supporting military capability needs, experience shows that it is also important to provide a "speculator" mechanism to fund "bottoms-up" discovery in those areas important to DOD, often initially without a clear war fighter application. Such efforts are not requirements-driven and, further, are typically very high risk. Therefore, they may not appear to be wise bets when viewed through the lens of capability needs based on mission analysis. However, history shows that creative risk-taking is important in achieving disruptive breakthroughs, which in turn are necessary for providing the unexpected technology opportunities that enable new, unforeseen, war fighting capabilities—new and better ways to do things that have heretofore been seen as "acceptable." This function is becoming increasingly important to fund within the DOD, since the defense sector's speculative independent research and development investments have fallen victim to the extreme pressures of the market. To be successful, such efforts typically require sustained investments over substantial time horizons in order to bear fruit.

One of the more important aspects of the security environment is the proliferation of commercial technologies. These are globally available to U.S. enemies and can be expected to be effectively, often asymmetrically, exploited by them. The United States should do the same. In addition, one of the key assumptions of the QDR is the potential for sudden surprise. In a newly emerging strategic reality, there may be an abundance of "low-hanging technology fruit" that could be fielded more or less directly. A healthy S&T system would create a process to harvest commercial technologies into effective capabilities for the DOD through a "prospector" mechanism.

Fast cycle times are critical to this function, in order to keep pace with the fast-changing commercial environment, to identify mission solutions or new capabilities of which war fighters would otherwise be unaware, and to respond quickly to new threats as they come to the fore. This insight is gained by trawling the world market, especially the commercial market, for promising concepts and technologies that could be acquired and easily adapted in the very near-term ("off the shelf"). These concepts and technologies would then be quickly handed off to others in the DOD to capture and create the connection to immediate war fighter needs.

Finally, it is important to have an "expeditor" mechanism to rapidly fill requirements gaps with those technologies that can be matured relatively quickly—that is, in less than two years. The goal is to accelerate the transition of technology into fielded capabilities in much shorter times than is typical today. This type of work is driven by "requirements pull" rather than "technology push," and may use existing technology directly or adapt it as necessary to fit within a time-certain window. The scope of this effort must include rapid prototyping, testing, and, ultimately, demonstration of new capabilities.[5]

To summarize, a number of different types of execution agents, each with distinct core competences and cultures and governed by different rules sets and incentives, are required to meet conflicting demands: top-down versus bottom-up, long development time versus quick response time, requirements-driven versus innovation-driven, DOD-specific technologies versus commercial technologies, and planned-for threat versus newly emerged threat.

5. Volume IV of the 2006 summer study report, *Accelerating the Transition of Technologies in U.S. Capabilities*, discuses the expeditor function in greater detail, including recommendations for implementation in DOD.

Chapter 4. Historical Precedent

An examination of how DOD has, in the past, executed technology strategies developed to meet then-relevant security challenges provides ample precedent for the panel's broad prescriptions described in the previous chapter.

Features of Most Great Developments

A historical look at many developments reveals some common features that are instructive in the context of implementing the recommendations of this report.[6]

The "great" developments have been conceived and championed by remarkable individuals who provided vision and effective management. The approaches consistently used by such individuals focused on people, not processes. This context is in stark contrast to a current Pentagon culture that emphasizes processes over people. Indeed, this cultural shift has now existed for so long that today the very existence of many people in the system revolves around processes and consensus, with resulting "capabilities processes" that are bloated, intellectually numbing acts.

The great developments of the past have often had a driving vision that provided coherence and direction over time—a vision characterized by substance and depth. These coherent visions identified "thrusts," examples of which will be described later in this chapter. These thrusts were developed and honed by small groups of top-notch, mid-level "up and comers" who were given the freedom to innovate. Within the military, these young officers often became well-known general officers in later years.

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6. Appendix G elaborates more on the features of great developments and offers examples of many past successes.

Such concepts, however, would have gone nowhere except for the senior leadership who championed the activities—service chiefs or senior officials such as the DDR&E, for example. Typically, such innovative concepts were disruptive and were therefore resisted by existing organizations. As a result, senior leaders had to override this tendency to resist. That they often did so is perhaps remarkable to those familiar with the "innovator's dilemma" in industry, but defense planning has objectors playing far different roles than in profit-making institutions.

Mission Portfolios in the 1960s and 1970s

In the 1960s and 1970s, during the height of the Cold War, the United States had four diverse strategic missions: strategic deterrence, assuring the North Atlantic Treaty Organization (NATO), containing Asian communism, and opposing Soviet "wars of national liberation." Each was addressed with a different mixture of political means, technical programs, military deployments, and combat interventions. As a result, the *de facto* centers for decision-making developed in different parts of the federal government.

Table 2 identifies the principal *de facto* "mission portfolio strategists" that operated within each mission area. While other organizations could properly qualify as portfolio strategists, only the principal ones are listed in the interest of space. The role of the portfolio strategist is characterized by an end-to-end perspective of the whole mission response, even though some mission portfolio strategists focused their attention on particular programs and technical domains. The mission portfolio strategists often exercised some degree of authority over technical direction and budget. In other cases, the mission portfolio strategists exercised only advisory functions. Some mission portfolio strategists were focused on technical programs, others focused on diplomatic actions.

The sections that follow describe each of these strategic missions and examine how they were approached in a mission-oriented context. They serve as example of the mission portfolios needed in the department today.

Table 2. *De facto* "Mission Portfolio Strategists" of the 1960s and 1970s

Mission
Strategic Deterrence ▪ DDR&E Strategic Office ▪ RAND Physics Department ▪ Joint Strategic Targeting and Planning Staff Scientific Advisory Group ▪ Air Force Scientific Advisory Board Nuclear Panel
NATO Assurance ▪ DDR&E Tactical Office ▪ RAND, Institute for Defense Analyses, and other federally funded research and development centers ▪ Air Force Scientific Advisory Board, Army Science Board, and Naval Studies Board ▪ Assistant secretaries in Departments of Defense and State
Asia Containment Mission ▪ Assistant secretaries in Departments of Defense and State ▪ Office of the Chief of Naval Operations and Commander in Chief Pacific ▪ Commander, U.S. Forces Korea
Wars of National Liberation Mission ▪ National Security Council and senior officials in Department of State ▪ Intelligence community: collection, analysis, and operations
NOW—AT&L, and others, are organized by function, not by mission

Strategic Deterrence Mission

The strategy to deter nuclear strikes by the Soviet Union relied largely on the development and deployment of early warning surveillance satellites and strategic nuclear retaliatory forces, to include specialized intelligence collection, communication means, and command arrangements. This high dependence upon relatively novel technical means led inevitably to a central role in decision-making by technical leaders in the DOD and those national laboratories engaged in nuclear weapons development. Those leaders routinely discussed problems, progress, and choices with the national security leadership, including the President of the United States. The home office of the head of the U.S. arms control negotiating team, Paul Nitze, was located within the offices of the DDR&E (when that job had roughly the scope of the current USD [AT&L]).

Aircraft designed to deliver nuclear weapons were acquired through existing organizations. However, the nuclear-capable missile programs in all the military services were executed through newly established special purpose acquisition organizations. Similarly, ballistic missile defense programs were conducted by dedicated organizations, largely in the Army. All of these special acquisition teams were, to varying degrees, monitored and controlled directly by the DDR&E Strategic Office. In addition to these hardware acquisition teams, there were many dedicated teams of technical personnel that devoted intense time looking for unsuspected difficulties in executing retaliatory strikes and devising solutions to suspected problems. DARPA was established in 1958 in response the “technical surprise” of the Soviet Sputnik satellite program. In its early days DARPA focused on ballistic missile defense and directed energy—both of which are just now becoming fielded weapons.

Moreover, several specialized S&T execution agents were established or modified to bolster specific technical aspects of the strategic mission capability. Two notable examples were the Defense Nuclear Agency that performed S&T on nuclear weapons effects, and the Ballistic Missile Submarine (SSBN) Security Program that performed S&T on those aspects of anti-submarine warfare related to the SSBN force, to assure its survivability. In both cases, the Strategic Office of DDR&E exercised direct technical direction, as well as funding and policy oversight. Moreover, the DDR&E Strategic Office received the knowledge generated by this specialized S&T and used it to inform decisions on major weapons programs. During this period, the National Reconnaissance Office was established to provide detailed intelligence in support of the strategic mission. Due to security concerns, the National Reconnaissance Office directed and funded its own supporting S&T.

Portfolio Strategist

Since the strategic deterrence mission was heavily based on advanced technical programs in missiles and nuclear weapons, the mission portfolio strategists were predominantly technical in perspective and position.

The personnel within the DDR&E Strategic Office were, with rare exceptions, professionally trained scientists and engineers, often with executive experience in the aerospace industry. The director of the office had a flag officer as his military assistant, who also had professional technical education and program management experience. About 20 percent of the professional staff were military officers with similar backgrounds. The total office consisted of about two dozen professionals.

Project RAND was established in the late 1940s to provide planning and technical advice to the newly created U.S. Air Force. The RAND physics department was primarily concerned with nuclear weapons and strategic nuclear delivery systems, including Army and Navy programs of that type. It also had direct contractual relationships with national laboratories developing nuclear weapons and made several key scientific contributions to those programs. Members of the physics department served on a number of high-level formal advisory committees in Washington, thus providing essential connectivity to the arms control and national strategy communities. Other RAND departments contributed strongly to the development of concepts and strategy for deterrence, extended deterrence, and political strategy.[7]

The Joint Strategic Targeting and Planning Staff was the joint organization based at the Strategic Air Command headquarters in Omaha, Nebrasks that prepared the operational plans for the employment of nuclear weapons in support of the strategic mission. Its scientific advisory group was composed of outside persons, properly cleared, with both technical and operational experience. It was charged with assuring that the strategic operational forces had the technical ability to conduct their operational plans. In that role, the scientific advisory group directed many S&T activities whose output included

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7. Non-physics members included Albert Wohlstetter, Bernard Brodie, Fred Ikle, and B. W. Augenstein, among others.

assessments and new opportunities, as well as proposals for technical solutions for problems. In 1992, the Strategic Air Command and the JSTPS were disestablished, their functions assumed by the newly formed U.S. Strategic Command.

The Air Force Scientific Advisory Board has a broad charter, exercised through standing panels each devoted to particular technical areas. In the Cold War era, nuclear weapons were deemed important enough to garner a panel devoted to them. That panel became involved in nuclear arms control matters, as well as nuclear weapons development and strategic nuclear delivery systems. It routinely established sub-panels to oversee critical technical issues affecting Air Force strategic forces.

NATO Assurance Mission

To assure the U.S. commitment to Europe, the nation drew on a broad solution space within a political framework provided by NATO's newly established military command arrangements. Permanent deployment of large U.S. forces—land, sea, and air—on European soil provided both symbolic and actual capability to oppose a Soviet-led invasion of Western Europe. Equipping those forces with nuclear weapons provided a link to the U.S. strategic nuclear forces. The continual modernization of those forces with advanced non-nuclear weapons, platforms, communications, intelligence collection, and logistics provided assurance that the United States was serious and prepared. Contrary to much conventional wisdom, the bulk of overall defense expenditures, defense acquisition programs, and S&T expenditures were devoted to this "NATO mission." Cooperative R&D programs, as well as shared production of selected items, notably fighter planes, served to maintain vitality in European industrial sources. This mixed dependence on military and political means led to dedicated organizations within the Department of State (State) and the DOD and became known as "the NATO mission."

Because of certain tensions that arose, the National Security Council became deeply involved and, depending upon the issue, often became the *de facto* decision forum. Because the weapon systems relevant to NATO were largely "traditional" in nature, the S&T that supported their design and development was largely controlled within the military services. The rise of the "air-land battle" and "follow-on forces attack" operational concepts in the 1970s did lead to intense Army–Air Force collaboration, but this collaboration was conducted largely outside of the formal Joint Chiefs of Staff or OSD decision forums.

Portfolio Strategists

The DDR&E Tactical Office was organized and staffed in a similar fashion to the DDR&E Strategic Office. It concerned itself with weapon systems and munitions for land, sea, and air. Most of its acquisition programs were conceived and directly managed by the services. At the time, the combatant commanders did not have the obligation, military staff, or technical support to participate in weapon system decisions, much less in S&T decisions. A notable exception was the Strategic Air Command, which as a specified combatant command could rely upon its strong Air Force connections. But Strategic Air Command did not really play in the NATO mission arena, though at the time many thought it should.

RAND, the Institute for Defense Analyses, and several other federally funded research and development centers conducted extensive studies and provided much cogent and influential advice regarding weapon systems and promising avenues of S&T exploration in support of the NATO mission. The Institute for Defense Analyses was tasked by OSD for the most part, but also housed the Weapon System Evaluation Group, which served the Joint Staff and the Chairman of the Joint Chiefs of Staff. Each of the services had an advisory body composed of senior technical outsiders. They operated predominantly in a single-service mode. However, that presented a true portfolio strategist view in only a small minority of cases, but some were very important.

Tactical communications was probably the most notable case and the lack of interoperable communications in legacy systems has survived to this day. In reaction to this, OSD established a succession of DOD-wide policies and OSD oversight organizations, of which the Assistant Secretary of Defense for Networks Information and Integration is the current successor. Technical change has been rapid in this area, of course, and policy change has had a hard time keeping up with technical opportunity.

The Assistant Secretary of Defense for International Security Affairs and the Assistant Secretary of State for Europe played very important roles in portfolio strategy because everything associated with NATO had a political dimension. In the S&T arena this was manifested most directly in two nominally contradictory matters: (1) formal and very active collaboration with NATO allies on many aspects of military related technology, and (2) increasingly strong U.S. laws restricting the export of “sensitive” U.S. products and technology.

Asia Containment Mission

Containing communism in Asia was supported by a mixed response of political arrangements, forward military deployment—including nuclear delivery systems—and large-scale conventional combat in Vietnam until the early 1970s. During that combat, which included traditional and counter-insurgency operations, there were major efforts, mostly within the services, to bring S&T products quickly to the battlefield. The response then shifted, with diminishing deployment of military forces, to an increase in political engagement among the major world powers, including Nixon’s opening to China. In this later period, very few technical programs were justified based on the Asia mission—most were in support of naval forces. As a result, the OSD-level technical community was not a major force in the decision-making, and direct and useful collaboration between the U.S. Navy and Department of State became the forum for major decisions. The Navy technical structure largely took care of such S&T as it was in direct support of this mission.

Portfolio Strategist

During the combat phase of Vietnam, efforts to rapidly insert technical solutions to solve real problems that were identified by the operational forces led to the establishment of *ad hoc* organizations to execute these programs. These organizations focused on the narrow but consuming task of getting things built and delivered. Development planning organizations in the services did provide some end-to-end portfolio strategist activity, particularly with respect to air-to-air combat (resulting in training programs such as Top Gun) and suppression of surface-to-air missiles and antiaircraft artillery threats (resulting in a revival of electronic countermeasure pods for fighter aircraft and tactics revisions for B-52s).

After combat came to a close, there was very little drive to orient S&T toward the Asia containment mission. To be sure, some portfolio strategic efforts on naval matters uncharacteristic to the Pacific were undertaken by Office of the Chief of Naval Operations and the Pacific Command, and DARPA funded some interesting and strong work in this regard. There was a growing effort on the diplomatic front that entailed issues of forward basing and cooperative training programs. The portfolio strategy aspects were driven primarily by the regional policy staffs in the Office of the Joint Chiefs of Staff, the Office of the Secretary of Defense, and Department of State.

Wars of National Liberation Mission

Opposition to Soviet “wars of national liberation” was undertaken with a mix of economic support and political engagement with Soviet target states, together with a wide variety of overt to covert actions. Most of these actions did not involve DOD resources, personnel, or S&T programs to a significant degree. The bulk of the defense S&T community was not particularly involved in the decision forum—although the S&T arm of the intelligence community did play important roles. As such, the *de facto* mission portfolio strategists were in the National Security Council staff, high-level officials in the Department of State, and particular planning cells in the intelligence community.

Summary

All of the portfolio strategists of the 1960s and 1970s were “mission-oriented.” Often they had a limited scope of activity within their planning purview and an even more limited scope of action. More importantly, however, they uniformly had a wide, end-to-end perspective of the whole mission. Indeed, those individuals who were unable to have this “big picture” perspective were ridiculed and shoved aside in the decision process.

Roughly coincident with the end of the Cold War, the office of the USD (AT&L) and many other relevant organizations changed from a mission-oriented to a function-oriented basis. As a result, there is a fairly limited capability in place to develop mission-oriented portfolio strategies.

Beyond broad mission challenges, the DOD needs a set of more distinct candidates on which to focus its S&T planning and investments—that is, *overarching operational objectives.* As mentioned earlier, an example used previously by the Air Force was "having the capability to strike any target, at any place, at any time, with precision." This compact objective pointed S&T in the right direction and affected all levels of activity. An attribute-related expression of objectives, noted earlier, might have been "We seek stealth, precision, and speed." The candidates for such overarching objectives, ideally articulated by the USD (AT&L) and the VCJCS, must be plausible and *would truly make a difference strategically.* (Volume I and II of this report describe such strategic objectives and commensurate technology vectors for the 21st century.) With such alternatives declared, the question becomes how to organize investments, structures, and processes for success, all of which are reflected in this report's recommendations.

Chapter 5. Recommendations

At the heart of the panel's recommendations is a central philosophy: the Department of Defense can only meet the strategic challenges of the 21st century with a tighter integration of the user and technology communities.

In a complex, rapidly changing environment filled with problems of a large scale, **the department needs to integrate the deep domain expertise resident throughout its organization with enterprise-wide, mission-oriented visions.** DOD's mission solutions need to be better informed by the technological possibilities being generated throughout the world, present and future, in order to avoid both the risk of degenerating into wishful thinking and falling prey to a disruptive surprise.

Furthermore, the technology development community should be better informed by the mission needs of the department—thus bounding innovation and experimentation within the department's priorities and resources of the. The development of a rich peer-to-peer dialogue between the capability definition communities of the combatant commanders and force providers, and the DOD-wide technology development enterprise should become the basis for future requirements definition and technology planning, just as this partnership has been a key component of success in the department's past.

In order to complement a more informed capabilities generation and planning process, **the department needs a robust set of technology development capacities.** While the department once had numerous technology development institutions that covered most of the relevant technology domains, today gaps have emerged as the commercial market place has grown. In particular, the department needs an organized function that can "prospect" commercial, non-DOD, and foreign technologies for good ideas and products.

In addition, the department needs to institutionalize its "expediting" functions to ensure the war fighter can receive needed capabilities rapidly. The department needs to strengthen and protect its "speculators" operating on the technology frontiers, looking for the truly disruptive solutions. This set of technology development functions not only enhances the department's ability to execute plans and visions, but also it acts as the ultimate hedge against poor plans and misguided visions.

The remainder of this chapter provides specific recommendations in support of these two broad areas.

Strategic Technology Planning

In the area of strategic technology planning, the panel offers three principal recommendations.

Recommendation #1: Establish Mission Portfolios

During the Cold War, the DOD enterprise could self-organize and prioritize based on a single, well-known overarching challenge—the strategic threat from the Soviet Union. Current and future environments are far more complex with a multitude of strategic challenges. In the absence of overarching visions or guidance, the department tends to approach the threat along vertical and functional lines—that is, the military services and agencies.

Yet, in most cases, and certainly in the business world, the better response to global, complex environments has been to create matrix organizations combining functional expertise with deep mission (or customer) expertise. Institutions in the DOD that can provide a cross-cutting, enterprise-wide, mission-oriented perspective are few and far between—particularly with peer-level participation from the technology world.

In order to offset this deficiency and provide a holistic, mission-oriented view to help guide technology investments, the USD (AT&L) and VCJCS should establish mission portfolios. These portfolios would serve as the basis for developing an investment strategy that cuts across strategic challenges and reflects both the needs of the war fighter and the possibilities identified by technologists.

The number of portfolios should be reasonably small. The panel recommends no more than five, each of which is mission-specific. The set of missions should encompass the full range of strategic challenges that the nation faces. These mission portfolios should be based on or relate to the set of missions identified in the broader strategy documents used in the department—the National Security Strategy, the National Defense Strategy, the QDR, the Defense Planning Scenarios, and others.

For the purposes of this report, the panel has used challenges identified within the QDR—emerging peer, rogue states, the global war on terror, and failed states—to illustrate one possible organizing construct for the portfolios. Ultimately, a key task of the USD (AT&L) and VCJCS will be to identify the boundaries of the portfolios. It should be noted that because the portfolios are organized by mission, there will be intentional overlap in terms of capabilities that can be used to solve the mission. Finally, the number and organization of the portfolios should be reviewed periodically, perhaps during each or every other QDR cycle.

The mission portfolio should represent an understanding of:

- the assumptions related to the current and future mission
- the risks related to the mission
- the capabilities across the doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF) spectrum and technologies anticipated and necessary over the near-, mid-, and long-term to successfully execute the mission challenges
- capability and technology gap assessments associated with the mission and potential new areas of investment
- alternative solutions and hedges to fill the gaps
- the metrics of success.

A key function of the mission portfolios will be to identify the range of capabilities necessary to successfully execute the mission, enabled by available and developmental technologies. As illustrated by "capability 1" in figure 1, in the near-term, existing technologies would enable the evolution of capabilities that are currently undefined—providing a "technology push."

Capability 2 illustrates the situation where technologies in development will be phased-in as older technologies and older capabilities face obsolescence and are no longer able to meet the challenges of the evolving threat. Generally, there is strong visibility in terms of the technology potential.

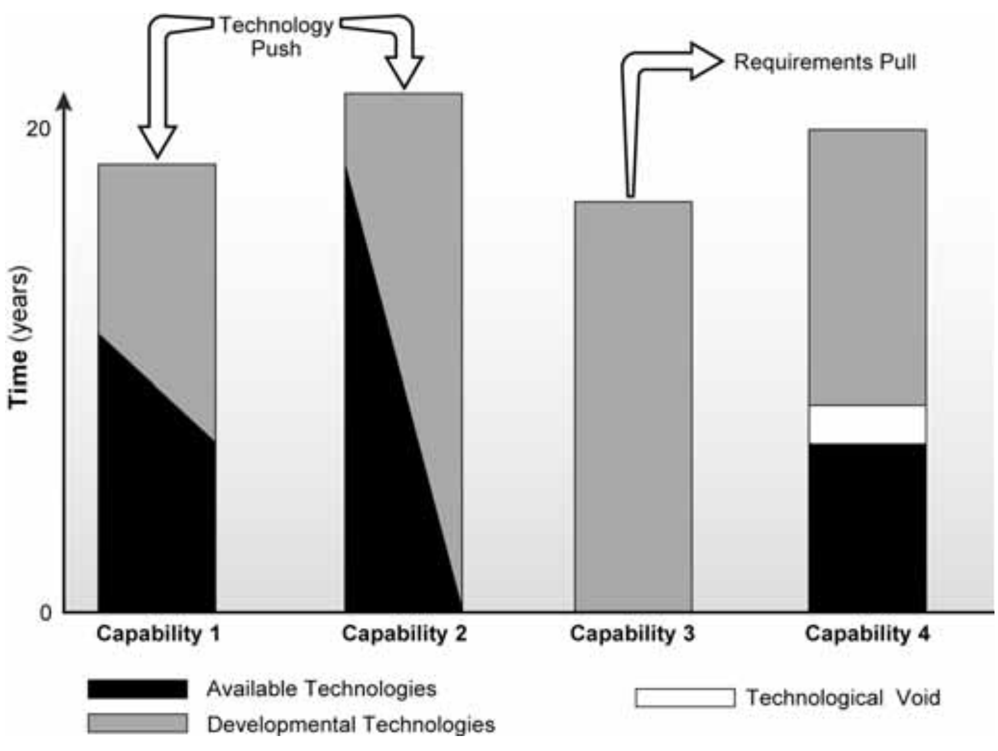

Figure 1. Mission Portfolios Include a Variety of Capabilities Enabled by Available and Developmental Technologies

The global war on terror demonstrates the need to continually meet technological challenges as adversary methods and means become more sophisticated and difficult to counter with currently deployed capabilities. Notionally, there is a pressing need to rapidly perform capability and technology gap assessments associated with the mission and to field system solutions supported by available technology. In this case, technology push comes from the DOD development environment with technology available from the commercial and industrial sectors.

“Capability 3” encompasses “requirements pull,” where extensive technology development is required to enable defined new capabilities. This case would occur when considerable technology would be developed to enable new strategic vectors.

In “capability 4,” technology development lags the timing proposed for a particular defined capability, thus creating a “technology void.” The availability of technology *after* the operational need is recognized arises in situations that are driven by technological surprise and rapid development and deployment of the threat. In these situations, there is a potential to close the technology gap through either greater S&T investment in the area or a decision to shift the effort to a high-risk technology development.

The task of identifying the range of needed capabilities to accomplish mission objectives, and marrying those needs with the development of technology over time, is a complex task beyond the competency of any individual. For that reason, the panel recommends establishing a cadre of strategists (recommendation #2) charged with this responsibility.

Interaction With and Benefits for the Partnership between the USD (AT&L) and VCJCS

The development of mission portfolios will enhance the growing “capabilities” partnership between the USD (AT&L) and the VCJCS. As in the past, the VCJCS provides “demand” planning through the Joint Staff (J7 and J8) and linkage with the joint world, including managing joint capability areas, the JCIDS and Joint Requirements Oversight Council (JROC) processes, and the integration of the combatant commanders' priorities. The USD (AT&L) is providing the traditional "supply" planning from technology to delivered material solutions.

Together, the USD (AT&L) and VCJCS are currently partnering for a variety of cross-cutting guidance and reviews where their responsibilities intersect. Joint capability area reviews are being conducted to ensure acquisition activities are consistent with broad guidance in planning documents and with planning, programming, and evaluation products. Their collective influence over mission requirements is further enhanced through joint participation in the JROC, the Senior Level Review Group, and the Deputy's Advisory Working Group (DAWG).

This partnership has recently engaged the Director, Program Analysis and Evaluation (PA&E) to provide programmatic analysis to their deliberations and decision-making. The mission portfolios will significantly strengthen their deliberations and decision-making insights for the front end of mission-wide requirements. This horizontal perspective will buttress the existing structures that manage programmatic, acquisition, and requirements activities. Individually the USD (AT&L) and the VCJCS have sufficient bureaucratic "carrots and sticks" to encourage compliance by the services, agencies, and the combatant commanders.

The USD (AT&L) and VCJCS will have many opportunities to influence the mission portfolio development process. The first and most strategic is the selection of the portfolios themselves. The second major point for the USD (AT&L) and VCJCS will be the validation and evaluation of the completed mission portfolios—the futures assumed, risk assumptions, trade-off parameters, success metrics, and other defining components. Finally, the cross-mission analysis, strengths and weaknesses of options, and trade-off decisions will be a third strategic point of engagement.

Recommendation #2: Establish Mission Portfolio Strategists

In order to create the mission portfolios, the USD (AT&L) and VCJCS will need a cadre of mission portfolio strategists. This group is intended to be small, with both military and civilian representation. While each strategist group is a part of the USD (AT&L) organization, the strategists are selected and staffed by both the USD (AT&L) and VCJCS. It is important to note that the panel intends for this cadre to be a staff group with no direct authority or control over budgets, except as provided through AT&L under current rules and regulations. Finally, these mission portfolio strategists should be hired for three- to five-year terms. This work requires a substantial investment in time and multiple cycles of analysis to achieve competence. The past successes described earlier resulted in large part from the combination of hand-picked personnel and long tours of duty. Any less and the required depth of understanding cannot be achieved; any more and bureaucratic ossification will set in.

The mission portfolio strategists' positions will not be easy to fill given the necessary technology expertise required to relate to the technology development enterprise, as well as a working knowledge of the mission's operational strategy. The mission portfolio strategists are meant to serve as the mission-oriented, technology intellectual capital of the USD (AT&L) and VCJCS.

Because of the breadth of the task and the group's small size, the cadre cannot exist in a vacuum and will need to interact with many organizations and individuals throughout the department, as illustrated in Figure 2. To inform their deliberations in the mission area, the strategist will need to interact with the combatant commanders to understand how these organizations envision carrying out the mission and the shortcomings they see in their current and future ability to meet missions. They will interact with the services and agencies to gain an understanding of their operational and war fighting visions, their current S&T development capabilities, and their planned enhancements. This perspective will include insights into all acquisition programs of record. They will similarly engage with the defense and joint processes communities such as the JROC, JCIDS, Functional Capability Boards, and others.

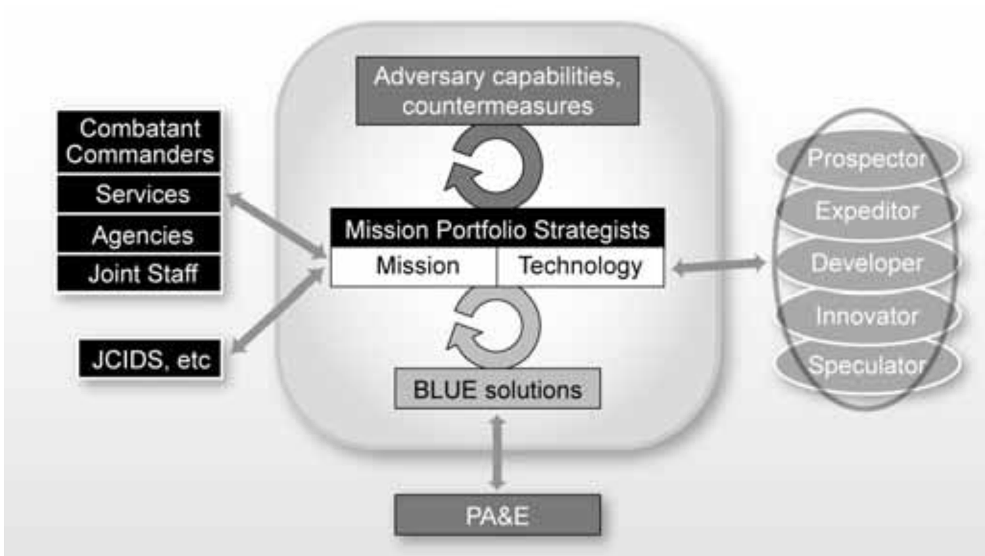

Figure 2. Interactions Enabling Portfolio Strategies

Similarly, the strategists will reach out to the broad technology community. The existing DOD technology development institutions, such as the service labs, will be critical partners in developing an understanding of the department's technological possibilities. Interaction with the department's "innovation" factories such as DARPA, the Defense Threat Reduction Agency (DTRA), and those particular entities "speculating" in the fringes of technology, will provide insights into what is possible on the horizon. The strategists must develop an understanding of what is technologically possible from commercial industry, DOD contractors, and other sources. In addition to developing a set of broad social networks the strategists will have to rely heavily on the "prospector" organization for insights into global trends and innovations otherwise beyond the lens of the traditional DOD S&T enterprises.

Because all proposed mission solutions should ultimately be cost-constrained, the strategist team must also iteratively engage with cost estimators, from the Director of Program Analysis and Evaluation and within the Services. The ultimate success of the portfolios will be based on the strategists' ability to deliver mission cost analyses and information to the USD (AT&L) and the VCJCS.

Finally, each mission portfolio strategist team will need to stay attuned to the directions and intentions of the other strategist teams, because the final recommendations about how to best balance within and among the missions will be based on cost-benefit trade-offs across all the missions.

Mission Portfolio Strategist Tasks

Although each individual would have his or her own style, the panel expects that each mission portfolio strategist would conduct the following tasks:

1. Identify the critical-component capabilities necessary to accomplish the mission. This task can be seen as a "systems engineering" approach, but it will also seem natural to commanders experienced in developing operation plans. The key idea is that all critical components must be developed, not just those that are technically, organizationally, or doctrinally convenient. The critical-component capabilities must be specified at a meaningful level of detail if they are to be useful.

2. Alternative Projections. A key task of the mission portfolio strategists will be to develop alternative projections of the future, including the potential interaction of measure-countermeasure competition for the critical capability components. It is an enduring characteristic of planning that as one side develops successful capabilities, the other will look for ways to undercut them—whether by low-technology tactics or high-technology solutions.

One consequence for defense planners is the need to constantly assess whether the time is ripe to continue or accelerate investment in systems that currently provide high capability or whether it is instead time to slow investment and begin the transition to the next generation of technology. In such situations, planners are seldom sure how quickly current capabilities will be obviated, which new technologies and operational concepts will prove out, or how quickly and at what cost they can be fielded. This is not a subject to be addressed with simple-minded focus on the alleged best estimate: there are too many uncertainties. Instead, planners should encourage experimentation, variation, and competition.

3. Recommendations for well-hedged investments. The implication of the task above is the need for well-hedged investment programs. This need translates into funding “redundant” efforts, especially with S&T. It is not, however, a blank check to pursue all ideas at any cost. Some ideas can be culled out by good analysis; other ideas can lose out (or be deferred) after their development encounters serious problems; still others can lose out when prototypes are competed. To make this philosophy effective, however, planners need to have relatively concrete notions of what metrics to use in tracking progress or non-progress and conducting competitions. At some point, painful program cancellations will be necessary, even though program proponents will fight them.

The mission portfolio strategists should be sensitive to these issues and should have concrete recommendations for hedging, decision points, and metrics. Finally, they should identify natural “increments” of capability that should be separately priced and evaluated. Foregoing “nice to have” features, particularly on early blocks, can both save money and avoid serious problems that result from immature technology. Similarly, the traditional question of “How much is enough?” is always relevant. Program proponents are often hesitant to provide alternative increments for acquisition, but the information is essential for sound planning and tradeoffs.

Fortunately, when making investment decisions, it is sometimes possible to learn a great deal about alternative approaches with relatively small S&T expenditures; in other cases, relatively definitive assessments can be achieved with only moderately expensive prototypes. In still other cases, parallel engineering development and even limited production is necessary before uncertainties about both need and capability will resolve themselves.

4. The need for special measures. The mission portfolio strategists will find themselves distinguishing sharply among what can be accomplished “now,” in the near-term, in the mid-term, and eventually. For the “now” and “near-term” possibilities, they may conclude that nothing will in fact happen unless special measures are taken to expedite development along with all the other aspects of DOTMLPF necessary for successful fielding. They may then identify possible expediting mechanisms. In other cases, they may believe that commercial or other-country technology “should” be very relevant, but is not well understood. In that case, they may look for potential “prospectors” to do more careful evaluation. When thinking about the long-term, they may have the sense that technology might allow for revolutionary change, even though key enablers are just not available and the requisite interest not yet stimulated.

Figure 3 shows an illustrative flow pulling together the various concepts described here. At the left are the four portfolios recommended by the panel, one of which relates to the global war on terror (GWOT) mission. One of the first things for the portfolio manager to develop would be a set of the “critical component” capabilities—that is, those capabilities on which success of the mission depends. These are not just contributors to the mission, but necessary for success.

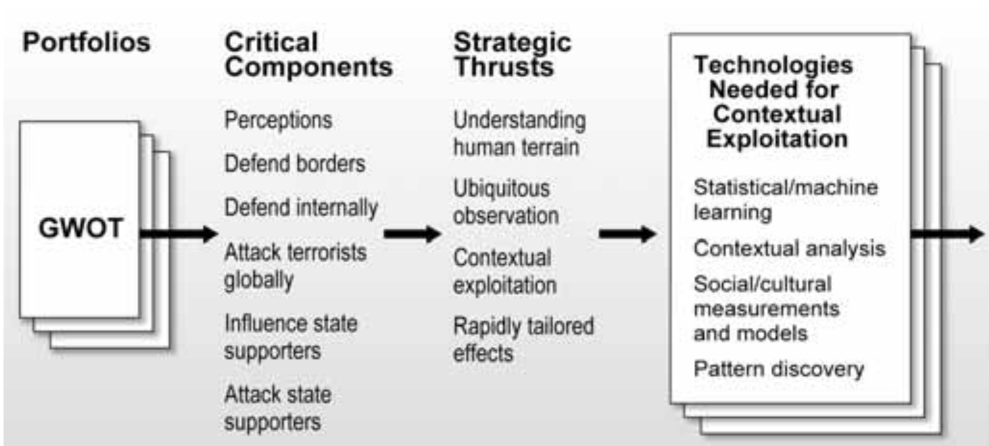

Figure 3. Illustrative Logical Flow from Portfolios to Technologies

Since the mission portfolio strategist is not intended to do everything, much less reproduce the vast work of the services, there should be an effort to find a smaller subset of cross-cutting strategic technology thrusts with particular salience for the office of the USD (AT&L). In Figure 3, for illustrative purposes, it is assumed that the four cross-cutting thrusts are: understanding human terrain, ubiquitous observation and recording, contextual exploitation, and rapidly tailored effects—as described in Volumes I and II of this report. It then becomes necessary to identify the key technologies enabling each of the cross-cutting thrusts. Other DOD components (such as the Functional Capabilities Boards established by the JROC) organize problems differently and it is assumed that the mission portfolio strategists will draw upon these for insight and data.

Recommendation # 3: Develop a Mission-Oriented Strategic Technology Plan

One of the uses of the mission portfolio output should be to serve as the foundation of a strategic technology plan. As noted previously in this chapter, the mission portfolio strategists will be developing a cross-cutting, mission-oriented view of the capabilities and technologies required. At this point the mission portfolio strategists will have the insights from the range of actors within the DOD enterprise: the services, combatant commanders, Joint Staff, agencies, the broader technical community, industry, and others—all of whom are necessary to develop a horizontal, mission perspective.

In its “technology” role, USD (AT&L) should be able to leverage the technology component of the mission portfolio work and develop an enterprise-wide strategic technology plan. In order to translate the mission portfolio work into a strategic technology plan, functional analyses will have to be undertaken, whereby cross-mission gaps and overlaps in technology over a 20-year time span are identified. In addition, input from the “prospecting” and “speculating” functions of the technology development enterprise should be used to identify new technology thrusts capable of enabling entirely new capabilities, not identified via the mission perspective. As a product of the USD (AT&L) and VCJCS mission portfolio analysis, this plan will be derived from a mission context and informed by both the operational requirements and the technological possibilities. As such, the plan will be more than just an amalgamation of the services’ strategic technology plans.

The strategic technology plan is the portfolio of technology development necessary to enable emerging war fighting concepts. It should have several key components:

- Establish the state of DOD's current technology base as it relates to the five or fewer mission areas.
- Based upon a clear understanding of the operational requirements of each mission, derive the projected technology needs identified across the missions. As an output of the mission portfolio process it should reflect a period of iteration between the strategic technology plan and the operators that will identify the realism of operational objectives given the limits of technology. Following this iterative process, the USD (AT&L) should be able to project desired technology end state requirements for both the mid- and long-term.
- Clearly enumerate the resulting technology gaps and the resources (time, money, and people) necessary to close these gaps. A significant amount of effort will be necessary on the part of USD (AT&L), in conjunction with the technology development execution agents in the services, agencies, OSD and industry, to determine: how these gaps get closed, by whom, and in what priority. This process will, by definition, highlight the ongoing technology programs that are not a mission priority and that should, therefore, be terminated.

Implied in this process is the need to create a truly robust ability to anticipate technology advances and to anticipate how potential adversaries will adapt to these advances. This is a dynamic task, as is tracking metrics and continually updating the plan. Given the conviction that in this era operational capabilities are so dependent upon S&T insights, the panel believes that the department's operational destiny should be influenced in large part by the S&T enterprise, supported by the intelligence enterprise.

The completed strategic technology plan should stand on its own as the rationale for S&T budget requests and as the conceptual framework within which new technology investments are proposed. Given its origins in the mission portfolio analysis, the proposed technology investments will have a linkage to either missions or their ability to enable new capabilities; will reflect an enterprise-wide perspective and will be resourced (providing an element of financial realism often missing). The plan will thus provide a rationale for investment beyond some arbitrary target, such as "S&T should be 3 percent of the top line." Furthermore, once analyzed within the cross-cutting, horizontal, mission-context, the ability to make hard trade-offs in declining budget environments—including what should be cut in order to free resources to begin new initiatives—should be made easier. It should also provide the S&T enterprise a basis to articulate why proffered Congressional earmarks are helpful or not.

Enhanced Execution Capability

Recommendation # 4:
Expand Technology Development Execution Capacity

To complement a more informed capabilities generation and planning process, the department needs a robust set of technology development capacities. A broad set of technology development functions not only enhances the ability to execute the department's plans and visions, but also strengthens the technology development enterprise's ability to "push" technology. Most importantly, a robust set of technology development capabilities become the ultimate hedge against poor plans and misguided visions (someone, somewhere will be thinking of a solution).

The current technology development environment is mapped in Figure 4, showing the execution agents and their activities as described earlier in this report.

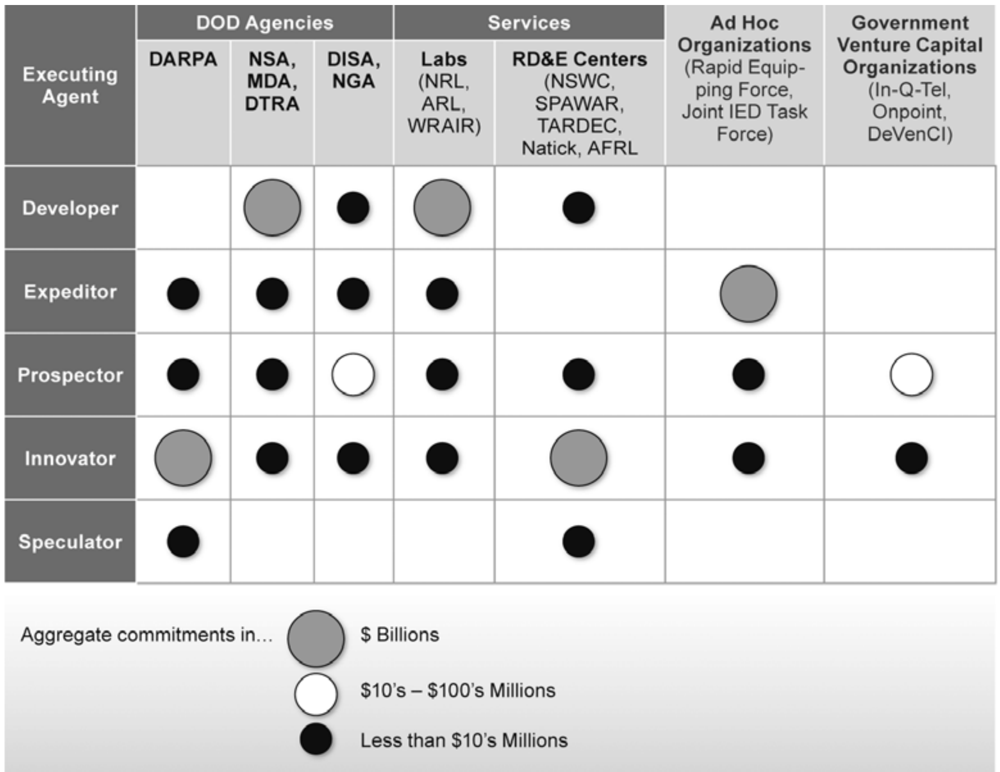

Figure 4. Current Technology Development Environment

Any individual organization that funds technology development uses one or more of the elements of this taxonomy. The developer and innovator mechanisms are currently well covered. The expeditor mechanism has been created using *ad hoc* structures, such as those established to face the problem associated with IEDs (initially the Joint IED Task Force, which transitioned first into the Joint IED Task Force and then to the Joint IED Defeat Organization). However, there is no standing "expeditor" capacity to expeditiously meet emerging war fighter requirements and inadequate DOD-wide investment in truly speculative technology research.

- **Expeditor.** The panel recommends the department create standing institutional capacity to rapidly (less than two years) move technology to fielded systems. (The expeditor is discussed in further detail in Volumes I and IV of this report.)

- **Speculator.** This capability is a key shortfall in an environment where avoiding technological surprise is a strategic challenge. This capacity is needed to invest in speculative (inventor-like), high-risk, high pay-off technologies that might satisfy future needs—not meeting existing requirements. In a sense the speculator is anticipating future needs. There will be many failures, but without speculating, we are likely to be surprised or caught short in the future.

The third area, the prospector, is less a technology developer than a technology finder. For this reason the panel addresses the prospector in a separate recommendation below.

Recommendation # 5: Establish a Prospector Function

In the new technology environment, identifying the global ideas that can be acquired or adapted for DOD needs is a critically needed capability. The DOD enterprise needs a "prospector" capacity designed to find solutions to current and future needs—including solutions to problems not yet recognized—that are emerging in the non–DOD world. Further, this entity also searches for ideas that might enable capabilities not envisioned by the department or its adversaries. This capability currently exists on an *ad hoc* and small basis throughout DOD and the intelligence community. For example, the Navy has a group of individuals based around the globe tasked to monitor relevant foreign sea power technologies. However, it is a capability that is severely lacking on a systematic and enterprise-wide basis.

The USD (AT&L) should establish a group of people knowledgeable about the needs of the DOD to trawl commercial industry, foreign governments, and academia for promising products and technology solutions. This group's role will be to inform the mission portfolio strategists and all participants in the DOD chain of the technology investment process, including the war fighters (combatant commanders and joint community), the services and laboratories, PA&E, and USD (AT&L) and DDR&E, about emerging problems, solutions, and promising research that could provide needed or new capabilities. The goal is to keep the DOD community intimately part of and not apart from the wider, global technological community. The prospectors should also inform the DOD enterprise about the range of technological options available to adversaries.

The prospector fulfills an additional critical function. In a world of rapid technological development occurring outside of government (including adversary adaptation of such technologies), the United States cannot simply react to fielded weapons or countermeasures. It is too late to wait to respond until confronted with a system on the battlefield. But it is not possible to anticipate what our adversaries might do, and how they might do it, unless we are intimately familiar with the range of technologies that might be available to them. The prospector can anticipate what might occur in the battlefield by seeing what is happening in the marketplace of products, ideas, and technologies.

A Refocused AT&L Enterprise

Implementing these challenging recommendations will result in a refocused USD (AT&L) enterprise—one oriented around missions rather than functions.

The payoff to such change will be a capabilities-generation process that is more in sync with the global marketplace. It will return the DOD technology enterprise to a strategic investment focus that was once successful, vice the current emphasis on process reviews, oversight, and day-to-day emergencies. It will enhance effectiveness across multiple time frames and economic futures, and, using the QDR as a point of departure, it will address multiple capabilities in multiple domains.

The ways and means to implement this study lie within the AT&L enterprise. The required organizational and process efficiencies to free these resources can be found in the details of recommendations in prior Defense Science Board (DSB) reports.

Chapter 6. Conclusion

The recommendations in this report are designed to equip the DOD to lead technology development in the 21st century, leveraging the pace and change occurring in the non–DOD environment.

The most important benefit of the portfolio-strategist approach is that the priorities of the Secretary of Defense will be directly and explicitly addressed in a way that cuts through the fog of Pentagon bureaucracy to recommend meaningful, well-defined, effective actions; to monitor the effects of implementation; and to adapt as necessary.

This role is not subordinate to other planning processes, but rather is a “special” role that draws on and connects to the myriad other processes as proves useful. Over time, perhaps this special role will no longer be necessary because routine processes will become more effective and streamlined. And, over even more time, new and different techniques for accomplishing these “special” functions will need to be introduced.

The mission portfolio strategists, recommended in this report, would inform and motivate strategic thrusts not only for the department, but over time for national strategy as well, thereby affecting other agencies such as the Departments of Energy, Homeland Security, State, and others.

The mission portfolio strategists would not only recommend how to allocate resources within their separate portfolios, but would also provide the insights necessary to inform cross-portfolio tradeoffs. The panel understands that these trade-offs are not likely to be a result of highly quantitative decision analysis. Rather, top-level decisions will be informed by clearly developed characterizations where investments would most likely have big benefits and where somewhat reduced investments would introduce only tolerable risk.

The cadre of mission portfolio strategists and a strategic technology plan will serve as leverage points for a DOD-wide discourse between and among the components of the technology development enterprise, which is necessary for a technology strategy that transparently optimizes its investment strategy. Complemented with more capacity in execution, through the expeditor's rapid fielding and the speculator's investment in the future, as well as the prospector's identification of emerging risks and opportunities, the department will be better equipped to meet the challenges that the nation faces today and in the future.

Appendix A. Terms of Reference

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

ACQUISITION, TECHNOLOGY AND LOGISTICS

JAN 13 2006

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference – 2006 Summer Study on 21st Century Strategic Technology Vectors

Many technology thrusts were initiated during the Cold War to support operational needs, but a few strategic capabilities proved enormously successful to enhancing U.S. combat capabilities. Stealth, speed, precision, and tactical ISR were developed to penetrate enemy battlespace with minimal losses and increase combat effectiveness. These capabilities provided the highest operational leverage, especially against State actors who chose massed force on force modes of conflict. Although hindsight easily verifies the importance of these capabilities, their implementation was uneven and problematic.

Today, adversaries (both State and non State) have moved away from massed forces to negate or mitigate U.S. combat capabilities. Denial and deception proved very effective in reducing air power effectiveness in the Kosovo air campaign. Dual use technology bestows strategic capability to small groups for relatively low investments and also allows both State and non State adversaries to economically develop effective countermeasures which lessen U.S. capabilities. The very nature of dual use technology creates significant uncertainty about any group's capabilities. Non state actors exploit seams in the international system by operating within the boundaries of sovereign states and take advantage of legal systems to plan, equip and train their forces. In effect, adversaries created operational safe havens against U.S. military capabilities.

In addition, the Department of Defense (DoD) is increasingly involved in two major mission areas of non combat operations. These include stability operations and domestic civil support missions during catastrophic natural incidents or WMD events. These mission areas stress DoD differently than combat operations and require the identification and development of new DoD capabilities.

The next generation of DoD capabilities must counter or negate safe havens and provide more effective capability in the new mission areas. Potential operational mission characteristics include:

1) US and allied freedom to operate in both State and non State's safe havens in order to deny the adversary sanctuary;
2) Ability to identify and track at suitable standoff distances, material, transactions, and items of interest across all environments;
3) Creation of sufficient situational awareness at all user levels to know when action is required and then act upon it with a high degree of effectiveness.
4) Ability to avoid substantial collateral damage and non-combatant casualties in all environments.

The Summer Study should:

1) Review previous attempts (both successful and not) by DoD to identify critical technologies in order to derive lessons that would help illuminate the current challenge;
2) Identify the National Security objectives for the 21^{st} century and the operational missions that U.S. military will be called upon to support these objectives;
3) Identify new operational capabilities needed for the proposed missions;
4) Identify the critical science technology, and other related enablers of the desired capabilities. In addition, the Study should identify the initiatives and developments needed to achieve these enablers including human capital and industrial base issues;
5) Assess current S&T investment plans' relevance to the needed operational capabilities and enablers and recommend needed changes to the plans;
6) Identify mechanisms to accelerate and assure the transition of technology into U.S. military capabilities.
7) Review, and recommend changes as needed, the current processes by which national security objectives and needed operational capabilities are used to develop and prioritize science, technology, and other related enablers, and how those enablers are then developed.

The Study will report its results on an interim basis to me. Its final product should provide an evaluation process by which decisions can be made and a technology roadmap to achieve the desired operational capabilities.

The study will be sponsored by me as the Under Secretary of Defense (Acquisition, Technology and Logistics), and Director, Defense Research and Engineering. Dr. Ted Gold and Dr Bill Graham will serve as the Summer Study Chairmen. Ms. Beth Foster will serve as the Executive Secretary. CDR Cliff Phillips will serve as the Defense Science Board Secretariat representative.

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

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

Kenneth J. Krieg

Appendix B. Panel Membership

MEMBERS

Name	Affiliation
Mike Bayer (Chair)	Private Consultant
Amy Alving	SAIC
Russ Barber	Raytheon
Pierre Chao	Center for Strategic and International Studies
Paul Davis	RAND
Jim Kurtz	Institute for Defense Analyses
Darren McKnight	SAIC
Art Money	Private Consultant
Wick Murray	Institute for Defense Analyses
Alan Schwartz	Private Consultant
Dick Urban	Charles Stark Draper Laboratory
Charlie Wasaff	National Capital Companies, LLC
Maj Gen Jasper Welch, USAF (Ret)	Private Consultant

GOVERNMENT ADVISORS

Col Donnie Davis, USAF	U.S. Joint Forces Command, J-8
Robert Foster	BioSystems, OSD
Terry Pudas	Force Transformation Office, Office of the Secretary of Defense

STAFF

Stacy Zelenski O’Mara	Strategic Analysis, Inc.

Appendix C.
Presentations to the Panel

Name	Topic
MARCH 10, 2006	
Mr. Andy Marshall OSD Net Assessment	Discussion
Mr. John Higbee and Mr. Dave Ahern Defense Acquisition University	Big "A"
Dr. Linton Wells Office of the Assistant Secretary of Defense for Networks Information and Integration	Technology Trends and Net-Centric Operations
APRIL 21, 2006	
Lt Gen Ron Kadish, USAF (Ret)	Defense Acquisition Performance Assessment
Mr. Keith Englander	Missile Defense Agency Architecture
MAY 16, 2006	
Dr. Thomas Killion Deputy Assistant Secretary (Research and Technology)/Chief Scientist, Headquarters, Department of the Army	Army Science and Technology
Mr. Larry Lynn Private Consultant	Comments on the S&T Management Processes
Dr. James A. Tegnelia Director, DTRA	Overview of the Defense Threat Reduction Agency
Mr. Greg Henry Executive Office of the President, Office of Management and Budget	Resource Planning Factors for Defense S&T: An OMB Perspective
Mr. Clay Jones Chairman, President and CEO Rockwell Collins	Technology Investments—Linkage to Corporate Strategies

JUNE 8, 2006

Dr. Delores Etter Assistant Secretary of the Navy for Research Development and Acquisition	Navy S&T Priorities
Dr. Timothy Coffey National Defense University	DOD S&T Assessment
Dr. Craig Fields Private Consultant	S&T Leadership and Management
Dr. Jacques Gansler University of Maryland	Realizing Military Needs

JULY 12, 2006

Dr. Tony Tether Director, Defense Advanced Research Projects Agency	DARPA Overview

Appendix D.
Statute and Policy Background

Not later than 150 days after a new President takes office, and annually thereafter, Congress requires the President to submit a national security strategy report that sets forth the national security strategy of the United States and includes a comprehensive description and discussion of (1) the worldwide interests, goals, and objectives of the United States; (2) the foreign policy, worldwide commitments, and national defense capabilities necessary to deter aggression and to implement the national security strategy; (3) the proposed short- and long-term uses of the political, economic, military, and other elements of national power to protect or promote the interests and achieve national security goals and objectives; and (4) the adequacy of the capabilities of the United States to carry out the national security strategy.[8]

In addition, Congress requires that every four years, the Secretary of Defense conduct, in consultation with the Chairman of the Joint Chiefs of Staff, a comprehensive examination known as a *Quadrennial Defense Review* to (1) delineate a national defense strategy consistent with the most recent national security strategy prescribed by the President; (2) define sufficient force structure, force modernization plans, infrastructure, budget plan, and other elements that would be required to execute successfully the full range of missions called for in that national defense strategy; and (3) identify the budget plan required to provide sufficient resources to execute the missions called for in the national defense strategy at a low-to-moderate level of risk, and any additional resources (beyond those programmed in the current future-years defense program) required to achieve such a level of risk.[9]

The Joint Capabilities Integration and Development System (JCIDS) further defines the military capabilities needed to execute the

8. 50 U.S.C. 404a
9. 10 U.S.C. 118

national security and national military strategies, and identifies and prioritizes gaps in those capabilities. The S&T planning process seeks to translate those capability gaps into prioritized S&T plans and programs.

Appendix E.
Current JCIDS and S&T Processes

This appendix offers a description of DOD's processes and outputs as presented to the DSB during the panel's deliberations (March-August 2006). This information served as a baseline to inform the discussions of what new processes would be needed in the future to implement "strategic technology vectors." The recommendations of this report do not depend on the specific details below; they are included in the report as background and for the purpose of full disclosure on the data that was consulted.

Joint Capabilities Integration Development System

JCIDS, a capability needs identification process, is officially described as "an enhanced methodology using joint concepts that will identify and describe existing or future shortcomings and redundancies in war fighting capabilities; describe effective solutions; identify potential approaches to resolve those shortcomings; and provide a foundation for further development and enhancements of integrated architectures."[10]

The Planning Panel did not seek to assess how well JCIDS succeeds in accomplishing these aims. Other Defense Science Board studies, particularly the 2005 summer study on *Transformation: A Strategic Appraisal,* have done that. Instead, this study focused on the relationship between JCIDS capability needs identification and technology planning. The panel assessed the balance between "technology push" and "operator pull."

Figure E-1 illustrates how the family of joint future concepts (also known as the joint operations concepts or "JOpsC" family) feeds a capability-based assessment process that produces recommendations regarding capability needs and DOTMLPF changes.

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10. Chairman Joint Chiefs of Staff Instruction (CJCSI) 3170.01E

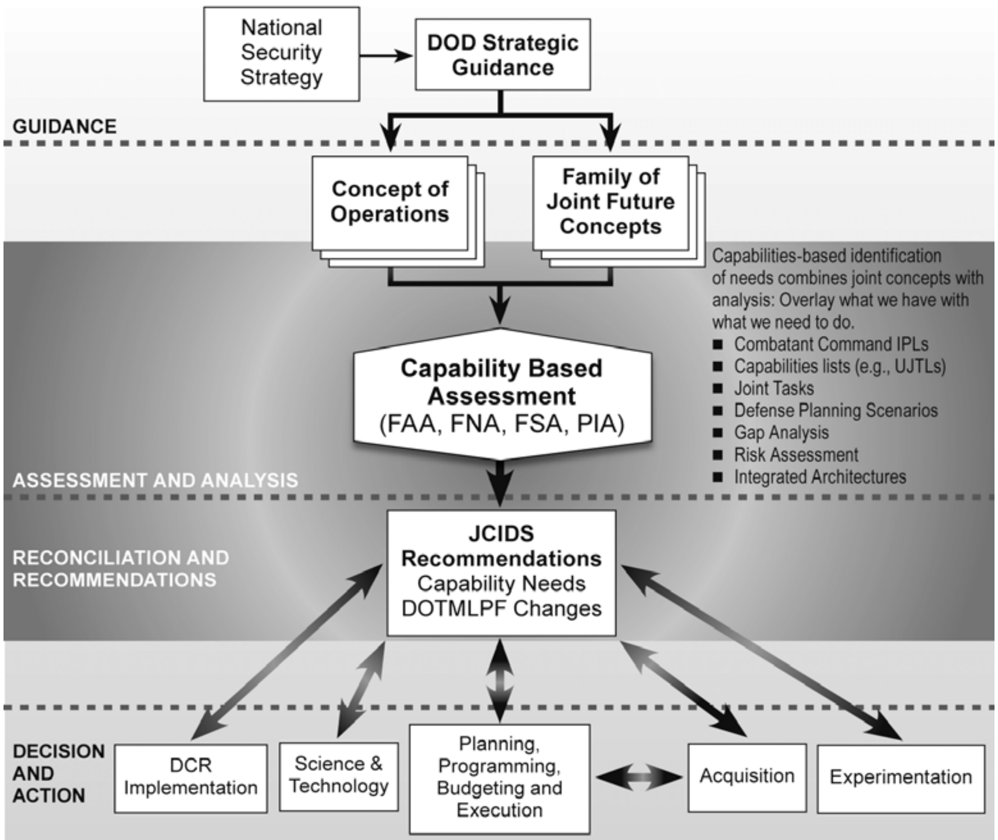

Figure E-1. JCIDS Capability Needs Identification Process[11]

Importantly for this study, there is a conspicuous inconsistency in the chart that provides justification for delving into the relationship between the JCIDS and S&T planning processes. Specifically, while the chart shows a two-way arrow linking JCIDS recommendations to science and technology, the accompanying text suggests a one-way flow only. Indeed, the prioritized joint war fighting capabilities identified through the JCIDS process should serve to inform the S&T community and focus the developmental efforts of the community as specified in the Defense Technology Area Plan (DTAP) and the Joint Warfighting Science and Technology Plan (JWSTP). Joint future concepts in the JOpsC family

11. CJCSI 3170.01E

therefore should exert operator pull on the DTAP and JWSTP, but the question remains whether a corresponding mechanism exists to push technological possibilities into the family of future joint concepts. Thus, the inherent dependency of the two processes on an active bilateral, continuing dialogue was explored during the study in depth.

S&T Planning Process

Research and engineering goals are central to the DOD S&T planning process. They provide the strategic framework for the supporting Basic Research Plan (BRP), DTAP, and JWSTP. These documents are collaborative products of OSD, the Joint Staff, the military services, and various defense agencies.

As shown in Figure E-2, the R&E goals and plans respond to the JOpsC family of future joint concepts and the QDR, which, as previously noted, delineates the defense strategy needed to achieve the national security objectives of the President’s National Security Strategy. The JOpsC family, QDR, and supporting service and defense agency S&T plans guide the annual preparation of the DOD S&T budget. DDR&E makes the R&E goals and plans available to S&T budget stakeholders with the intended goal of focusing collective efforts on superior joint warfare capabilities and improving interoperability.

The R&E goals were developed to provide near-term capability options for today’s war fighters while maintaining a steady flow of technology that will provide advanced capabilities for the future force. The R&E goals are characterized as technical capability goals, process goals, and enabling technology goals.[12]

12. Joint Warfighting Science and Technology Plan, Washington, D.C.: Office of the Director, Defense Research and Engineering, February 2006.

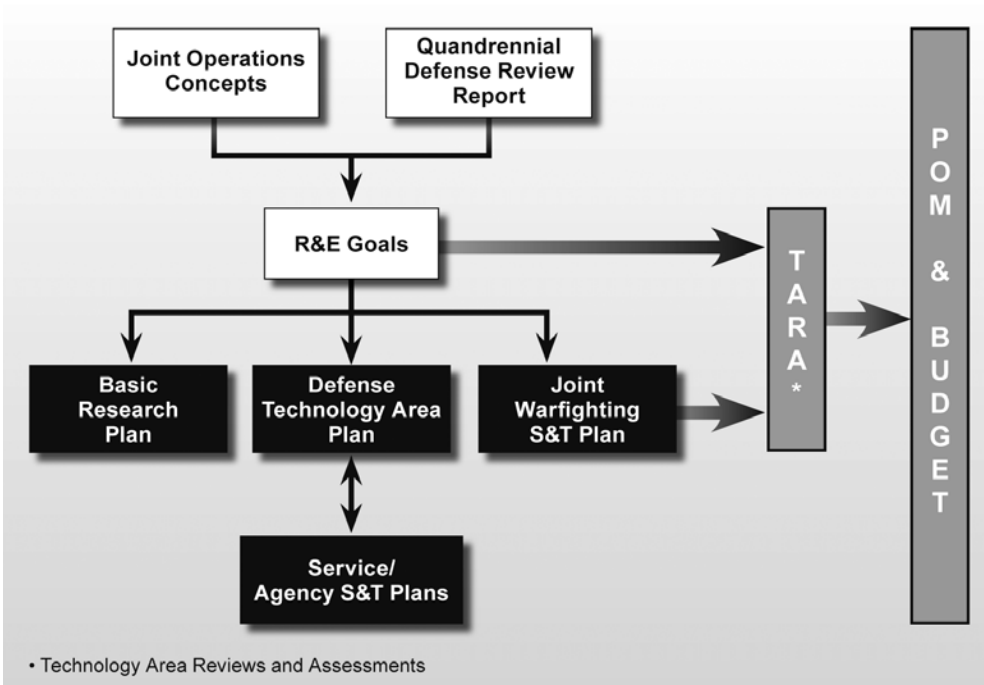

Figure E-2. S&T Planning Process[13]

Three S&T plans address three distinct time frames:

- **Basic research (long-term):** The BRP presents a 20–25 year outlook on DOD objectives and investment strategy for DOD-sponsored basic research (6.1) performed by universities, industry, and service laboratories. In addition, it presents the planned investment in each of 12 technical disciplines composing the basic research program.
- **Defense technology area research (mid-to-long-term):** The DTAP presents the DOD objectives and the applied research (6.2) and advanced technology development (6.3) investment strategies for technologies critical to DOD acquisition plans, service war fighter capabilities, and the JWSTP. The

13. The S&T planning process depicted is extracted from the February 2006 Joint Warfighting Science and Technology Plan. JWSTP was signed by both the Joint Staff Director for Force Structure, Resources, and Assessment (J-8) and the Director of Defense Research and Engineering.

DTAP's outlook ranges from 5 to 20 years. It charts the total DOD investment for a given technology, providing a horizontal perspective across service and defense agency efforts. The DTAP documents the focus, content, and principal objectives of DOD S&T efforts overall. This plan provides a sound basis for acquisition decisions, structured to respond to the DDR&E emphasis on maturing technology for rapid transition to the operating forces.

- **Joint war fighting application research (near-term):** The JWSTP, focusing on an outlook of five years or less, looks across the applied research (6.2) and advanced technology development (6.3) plans of the services and defense agencies. Its objective is to help ensure that the S&T program supports priority future joint war fighting capabilities as determined by the eight Functional Capabilities Boards (FCBs) chartered by the Joint Requirements Oversight Council. Each FCB is responsible for developing and maintaining a Joint Functional Concept (JFC). The JWSTP focuses on developing technology options to support the achievement of the eight JFCs, and devotes a separate chapter to each.

Of the three plans, the JWSTP is the only S&T planning document directly linked to JCIDS. The short-term JWSTP is thus driven by the JFCs—a clear instance of operator pull.

In order to determine whether the S&T plans exert technology push on the joint functional concept (or others in the JOpsC family), the panel reviewed the February 2005 DTAP against the eight JFCs. Of the eight, only one—battle space awareness—makes any reference to the DTAP (it should be noted that this JFC reference was merely made in a footnote and not even in the bibliography). Both the BRP and DTAP repeatedly point out the joint and service concepts to which technology programs might have applicability, but the concepts themselves do not take the technological possibilities into account.

Opportunities for Integrating Joint Capabilities and S&T Planning

The CJCSI on the Joint Operations Concepts development process provides guidance for developing joint concepts to link strategic guidance to the development and employment of future joint force capabilities. As shown in Figure E-3, the JOpsC family comprises four types of joint concepts.

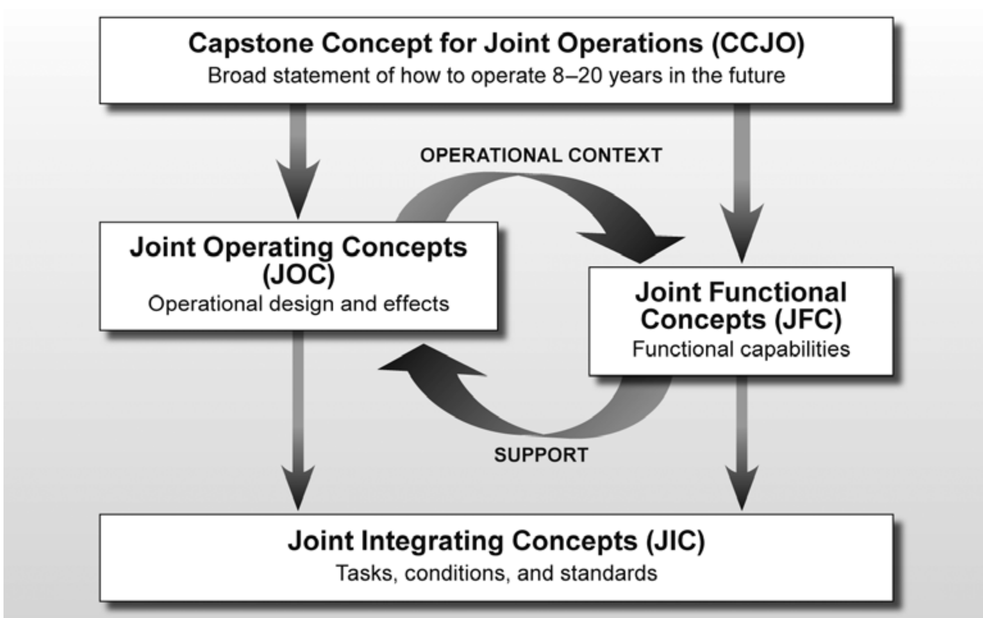

Figure E-3. JOpsC Family of Future Joint Concepts[14]

- **Capstone concept for joint operations (CCJO):** This overarching concept guides the development of future joint capabilities. Its purpose is to lead force development and employment by providing a broad description of how future joint forces are expected to operate across the range of military operations 8–20 years into the future. Service concepts and subordinate joint concepts expand on the CCJO solution.

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14. CJCSI 3010.02B, Joint Operations Concepts Development Process (JOpsC DP), January 27, 2006, p. A-2.

- **Joint operating concepts (JOCs):** These concepts apply the CCJO solution in greater detail to a specified mission area, describing how a joint force commander, 8–20 years into the future, might conduct operations within a military campaign. A joint operating concept identifies the operational level effects that are considered essential for achieving the end states envisioned by the concept, and focuses on the broad military capabilities necessary to create those effects. Five JOCs have been completed to date, including (1) homeland defense and civil support operations; (2) strategic deterrence operations; (3) major combat operations; and (4) stability operations: military support to security, transition, and reconstruction; and (5) irregular warfare. A sixth JOC, addressing shaping operations, was recently initiated.[15]
- **Joint functional concepts (JFCs):** JFCs apply elements of the CCJO solution to describe how the joint force, 8–20 years into the future, might perform an enduring military function across the full range of military operations. A JFC identifies the operational-level capabilities required and the key attributes necessary to compare capability or solution alternatives. JFCs also determine any additional military capabilities required to create the effects identified in JOCs. FCBs chartered by the JROC are responsible for writing, developing, and assessing joint functional concepts. The JROC establishes FCBs according to functional areas, and the vice director of J-8 approves FCB portfolios within each functional area. Each of the eight FCBs maintains a corresponding joint functional concept by the same name. FCBs continually assess the joint functional concept and relationships with other concepts.

15. Joint Transformation and Concepts, joint concept status briefing at the Future Joint Warfare website, http://www.dtic.mil/futurejointwarfare/joc.htm.

- **Joint integrating concepts (JICs):** JICs are operational-level descriptions of how a joint force commander, 8–20 years into the future, might perform a specific operation or function derived from a JOC or a JFC. JICs are narrowly scoped to identify, describe, and apply specific military capabilities, which are then translated into fundamental tasks, conditions, and standards. Further analyses and expansion of tasks, conditions, and standards is accomplished after JIC completion in order to effectively execute a capabilities-based assessment.

Current policy describes the “proper military-technological context” as a consideration when writing a concept, explaining that “concepts are designed to exploit new technologies or to respond to the proliferation of new technologies.”[16] However, neither the instruction nor any of the templates it contains (for the CCJO, JOCs, JFCs, and JICs) requires explicit consideration of the technologies that might be applicable to the timeframe or the missions or functions addressed by joint concepts. Therefore the enormous effort being expended to develop future concepts may fail to take into account the possibilities raised by billions of dollars in S&T investment.

Planning in OSD and DOD Components

The panel’s evaluation of the JCIDS and S&T planning processes found that current S&T technology planning processes do not appear to be well connected with other capabilities-based planning processes. An extension of that conclusion might be that processes for translating future capability needs into strategic technology vectors and plans are not well defined at the department level. The short-term JWSTP is informed by and well-connected to JFCs, but the technological possibilities addressed in the longer-term DTAP and BRP do not appear to be considered when new concepts or plans are developed.

In contrast to department-level S&T planning processes, there is evidence that the services have very mature capabilities-based planning processes centered around the force provider—processes that are directly

16. CJCSI 3010.02B, January 27, 2006, p. B-E-1.

linked to their unique S&T planning processes. That said, even in the more mature service processes, technology planning reacts to future joint concepts but does not initially shape them. Thus, throughout the DOD there is a need for closer collaboration between concept developers and technology planners to allow early consideration of longer term technological opportunities and the co-evolution of the doctrine, organization, and training needed to turn technology into materiel and materiel into usable capabilities.

While DOD is shifting to joint capability areas as the taxonomy and framework for capabilities-based planning, this is not the case for S&T planning. At present the longer term S&T plans (such as DTAP, BRP, and military department S&T plans) are still focused on a taxonomy of S&T areas that cannot be directly translated to capabilities—science-centered areas as in the BRP strategic research areas, or technology-centered areas as in the DTAP 12 "technology areas."

Roles and Authorities of Key Officials

In addition to looking at the processes by which national security objectives and the military capabilities necessary to attain them are used to develop and prioritize S&T enablers, the panel looked at the senior officials who "own" those processes and considered their roles and authorities, and the mechanisms available to help them fulfill those roles.

The three officials considered were the Under Secretary of Defense for Acquisition, Technology, and Logistics; the DDR&E, who reports directly to the USD (AT&L); and the Vice Chairman of the Joint Chiefs of Staff.

Under Secretary of Defense for Acquisition, Technology, and Logistics

By statute, the USD (AT&L) has the authority to direct the secretaries of the military departments and the heads of all other elements of DOD with regard to matters for which the Under Secretary has responsibility.[17] These responsibilities include, but are by no means limited to, the following:

- serve as the Defense Acquisition Executive with overall responsibility for supervising the performance of the DOD acquisition system (which the establishing DOD directive says exists “to manage the nation’s investments in technologies, programs, and product support necessary to achieve the National Security Strategy and support the United States Armed Forces—not only today’s force, but also the next force, and future forces beyond that”)
- coordinate research, development, and production programs DOD-wide to eliminate duplication of effort and ensure that available resources are used to maximum advantage
- establish policies and programs that improve, streamline, and strengthen DOD component technology access and development programs; encourage open market competition and technology-driven prototype efforts that offer increased military capabilities at lower total ownership costs and faster fielding times; and exploit the cost-reduction potential of accessing innovative or commercially developed technologies
- develop acquisition-related plans, strategies, guidance, and assessments to ensure that acquisition milestone review and the planning, programming, budgeting, and execution processes are timely and effectively implemented
- in coordination with the Under Secretary of Defense for Policy, ensure homeland defense and special operations and low-intensity conflict programs, systems, and activities related to acquisition will effectively support the combatant commanders and war fighters
- in coordination with the Under Secretary of Defense for Intelligence, ensuring intelligence and intelligence-related programs, systems, and activities related to acquisition effectively support the combatant commanders and war fighters

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17. 10 U.S.C. 133(b)(5)

- synchronize strategic planning related to assigned responsibilities and functions and those organizations reporting to the USD (AT&L).[18]

These authorities and responsibilities of the USD (AT&L) are currently the basis for two enablers that could be elaborated to improve S&T planning, portfolio management, and program funding guidance.

A key issue identified by the panel is whether the "portfolio management" processes from the experiment will be robust enough to inform and guide any new S&T planning processes required to implement S&T strategic vectors.

"Supervising the performance" of acquisition programs does not necessarily include direct authority over the funding resources. Conveniently, USD (AT&L) also has delegated authority to withhold funds from an acquisition program that does not meet established criteria. Internally, the process by which this authority is exercised is called the "Format I" process. In this context, a key issue identified by the panel is whether the USD (AT&L)'s statutory authority to direct the acquisition activities of the military departments extends to their S&T programs as well.

The USD (AT&L) has delegated authority to withhold funds from an *acquisition program*, which is defined as "a directed, funded effort that provides a new, improved, or continuing materiel, weapon, or information system or service capability in response to an approved need." [19]

Director, Defense Research and Engineering

The position of the DDR&E was established by Congress at the request of President Eisenhower in 1958, following the Soviet Union's launch of the *Sputnik* satellite. Originally, the DDR&E was given direct authority to approve, disapprove, or modify all research and development programs in DOD, with rank equal to the secretaries of the military

18. DODD 5134.01
19. DODD 5000.1

departments, greater than any of the assistant secretaries of defense, and subordinate only to the secretary and deputy secretary of defense. In 1977, an Under Secretary of Defense for Research and Engineering was created, and the DDR&E title disappeared. The Goldwater-Nichols Act of 1986 created the position of Under Secretary of Defense for Acquisition (changed to Acquisition and Technology in 1993 and later to Acquisition, Technology and Logistics), and the DDR&E position was reestablished, reporting to the Under Secretary.[20]

Today the DDR&E is established by law in title 10, section 139a, "to perform such duties relating to research and engineering as the USD (AT&L) may prescribe." DOD Directive 5134.3, dated November 2003, constitutes the DDR&E's charter. This DOD policy names the DDR&E the Chief Technology Officer of the department, and assigns the DDR&E authority and responsibility to:

- develop the strategies and supporting plans that exploit technology and prototypes to respond to the needs of DOD and ensure U.S. technological superiority
- develop policies; provide technical leadership, oversight and advice; make recommendations; and issue guidance for the DOD research and engineering plans and programs (research and engineering includes S&T programs, consisting of basic research, applied research, and advanced technology development; and advanced component development and prototypes programs)
- recommend approval, modification, or disapproval of programs and projects of the military departments and other DOD components in assigned fields to eliminate unpromising or unnecessarily duplicative programs, and initiation or support of promising ones
- provide input into the Defense Planning Guidance (since replaced by two documents, the Strategic Planning Guidance and Joint Programming Guidance) and Transformation

20. *Defense Science Board Task Force on the Toles and Authorities of the Director of Defense Research and Engineering*, Washington D.C.: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics..

Planning Guidance concerning critical technology areas and overall content of the research and engineering program, consistent with a capabilities-based planning approach.

The charter says the DDR&E may *recommend* certain actions with respect to programs and projects of the military departments, but does not say who has authority to *approve* those recommendations. This raises the issue of whether DOD has a principal staff assistant with an unambiguous mandate to set, monitor, and adjust strategic S&T plans, programs, and budgets. Additional ambiguity emerges when one considers that the USD (AT&L)'s charter also does not explicitly provide for that authority. Thus, the question arises as to whether the USD (AT&L) has authority to act on the DDR&E's recommendations regarding military department S&T programs (as opposed to acquisition programs) or whether that authority is reserved unto the Secretary or Deputy Secretary Of Defense.[21]

Vice Chairman, Joint Chiefs of Staff

The Goldwater-Nichols Act created the position of Vice Chairman, Joint Chiefs of Staff, and stipulated that the Vice Chairman could perform the duties as prescribed by the Chairman and approved by the Secretary of Defense.[22] Section 181 of title 10 establishes the Joint Requirements Oversight Council, names the Chairman of the Joint Chiefs of Staff as the chairman of the Council, and says that this function may only be delegated to the Vice Chairman. Most recently, the Strategic Planning Guidance for fiscal years 2008–2013 established the Deputy's Advisory Working Group, co-chaired by the Deputy Secretary of Defense and the VCJCS. Established to oversee implementation of the 2006 QDR strategic priorities and other cross-cutting, high-leverage issues, DAWG responsibilities include implementation and oversight of the following:

21. DODD 5134.01
22. Prior to the Goldwater-Nichols Act of 1986, there was no Vice Chairman of the Joint Chiefs of Staff. When the Chairman was absent, the acting chairmanship rotated among other members of the Joint Chiefs, disrupting continuity.

- execution of action items, roadmaps, follow-up, management, and closure of the 2006 QDR
- coordination of Strategic Planning Guidance, Joint Programming Guidance, and key elements of the fiscal years 2008–2013 defense program
- governance of the department's special access programs
- other cross-cutting governance issues as selected by the co-chairs
- additional issues nominated for consideration by members of the DAWG.[23]

In regards to capabilities-based planning, the Vice Chairman's duties are as prescribed by the Chairman and of those the most important and relevant to this DSB study are the responsibilities for operating the JROC and the JCIDS processes.[24] The JROC and JCIDS are the mechanisms that enable the Chairman to submit to the congressional defense committees a report on the requirements of the combatant commands that contains a consolidation of the integrated priority lists of requirements of the combatant commands. The report includes the Chairman's views on the consolidated lists; a description of the extent to which the most recent future-years defense program (FYDP) addresses the requirements on the consolidated lists; and a description of the funding proposed in the President's budget for the next fiscal year, and for the subsequent fiscal years covered by the most recent FYDP. It also addresses each deficiency in readiness identified during the joint readiness review conducted for the first quarter of the current fiscal year.

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23. Throughout this report, references to the authority and responsibilities of the VCJCS are related to the Vice Chairman's delegated role as the chairman of the JROC and co-chairman of the DAWG.

24. By law, the Secretary of Defense, through the use of DOD directives, may assign to the Chairman responsibility for overseeing the activities of the combatant commanders. The Chairman serves as the spokesperson for the commanders of the combatant commands, especially on the operational requirements of their commands. In performing such function, title 10 specifies that the Chairman shall confer with and obtain information from the combatant commanders with respect to the requirements of their commands; evaluate and integrate such information; advise and make recommendations to the Secretary with respect to the requirements of the combatant commands, individually and collectively; and communicate the requirements of the combatant commands to other elements of the Department of Defense.

Other responsibilities relevant to analyses of this study include the Chairman's statutory obligation to provide strategic direction, strategic planning, contingency planning and preparedness; and advice on requirements, programs, and budget. In this last category, the Chairman is specifically responsible for advising the Secretary on the priorities of requirements identified by the combatant commanders; advising the secretary on the extent to which the program recommendations and budget proposals of the military departments and other DOD components for a fiscal year conform with established priorities; submitting to the Secretary alternative program recommendations and budget proposals, within projected resource levels and guidance, in order to achieve greater conformance with established priorities; and assessing military requirements for defense acquisition programs. In fulfilling his statutory responsibility to provide advice on requirements, programs, and budget, the Chairman is assisted by the JROC.[25] FCBs, created by the JROC, play a key role in identifying capability needs that should drive S&T strategies and programs.

With the Vice Chairman's endorsement, FCBs can provide the USD (AT&L) with priority joint war fighting capabilities for each of the JFCs. These priority joint war fighting capabilities are intended to inform the S&T community and focus the technology development efforts specified in the Joint Warfighting Science and Technology Plan. These priority joint war fighting capabilities are also intended to inform USD (AT&L)-led capability roadmaps, capability area reviews, and industrial base capability studies.

The promise of effective capabilities-based planning depends on a two-way dialogue between FCBs and S&T planners. In-depth interviews with senior S&T planners and Joint Staff members during

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25. The JROC was formed in the late 1980s and for years operated under a charter issued by the Chairman of the Joint Chiefs of Staff. The Defense Authorization Act for Fiscal Year 1996 enshrined the JROC in title 10, but made its establishment the responsibility of the Secretary of Defense and defined its mission to assist the Chairman of the Joint Chiefs of Staff as being *in addition to* other matters assigned to it by the President or the Secretary of Defense. There is no record of the Secretary's ever having "established" the JROC or issuing any guidance as to what he wants it to do. The JROC still operates under a charter signed by the Chairman (CJCSI 5123.01B, Charter of the Joint Requirements Oversight Council, 15 April 2004).

the course of this study failed to uncover evidence that this essential dialogue has emerged. This lack of effective dialogue is of great significance to planning for strategic S&T vectors and its resulting "technology push" opportunities.

USD (AT&L) Role in S&T Planning and Execution—Formal Mechanisms

In addition to the authority to withhold funds from programs that do not meet specified criteria, the USD (AT&L) has a number of other mechanisms available to affect the planning and execution of S&T programs of the DOD components. These mechanisms include

- inputs to the QDR—identification of issues, participation in integrated product teams and working groups
- inputs to PPBE processes and documents— Strategic Planning Guidance, Joint Programming Guidance, program review
- membership in senior decision bodies—Defense Senior Leadership Council, Senior Level Review Group, and Deputy's Advisory Working Group
- assignment of missions and goals to direct-reporting organizations—DDR&E, DARPA, Missile Defense Agency
- establishment of DOD-wide policies and programs
- development of DOD directives and instructions
- approval and support of new programs

Details of JCIDS Processes Relevant to S&T Planning

Capabilities-Based Identification of Needs

The JCIDS instruction accurately and succinctly relates what is needed for a capabilities-based assessment of needs. By overlaying existing threats with the capabilities available to meet those threats, capability gaps (threats that need to be addressed for which no capability exists) are easily identifiable. Additionally, capability redundancies (tasks for which abundant capabilities exist) are made apparent in this process. At times, some of the redundancies become candidates to provide the resources necessary to develop and acquire new capabilities needed to fill the identified gaps.

The process works as follows:

First, the combatant commanders analyze the missions assigned to them by the Unified Command Plan, Contingency Planning Guidance, Security Cooperation Guidance, and Joint Strategic Capabilities Plan. Service and joint force developers analyze various “future missions” represented by service vision documents and concepts, the JOpsC family of future joint concepts, defense planning scenarios, and the QDR focus areas, among others.

Second, the combatant commanders analyze capabilities to determine which required tasks can and cannot be accomplished by available forces and enablers. The combatant commanders analyze forces apportioned in the Global Force Management Guidance (forces available in the next two or three years) and other enablers, such as basing and over flight rights and bandwidth availability. Force developers analyze the programmed force (at the end of the FYDP) and beyond (represented by Multi-Service Force Deployment documents).

Third, the combatant commanders identify capability gaps. These gaps are tasks identified in earlier analyses that have been classified as unattainable by any combination of current or programmed capabilities, or that can only be accomplished at great cost in terms of lives at risk and time. The combatant commanders identify shortfalls in their plans and consequently list them in their respective Integrated Priority Lists. Force developers maintain a running inventory of capabilities, to include those that currently exist, those expected to become available as the result of executing approved programs, and those that are needed but not available.

And finally, technology gaps are identified. Not all capability gaps are amenable to technological solutions. Technologists who understand the demands of each mission in some depth and who have visibility across the breadth of technological possibilities on the horizon are best suited to identify technology gaps that, when filled, will enable the fielding of new capabilities.

Mission Analysis

Near-term mission analysis is conducted by combatant commanders and their staffs. The combatant commanders analyze the missions assigned to them to identify all stated and implied tasks. Planners develop and game alternative courses of action to determine the best way to apply available capabilities to accomplish campaign objectives. The combatant commander selects a concept of operations that may be submitted to the Chairman, Joint Chiefs of Staff or the Secretary of Defense for approval, as specified in the Joint Strategic Capabilities Plan. Planners at the combatant commander headquarters and at component levels develop the approved concept of operations into a complete plan, with a supporting plan. Shortfalls that cannot be resolved through adjustment of the concept of operations or provision of additional resources are submitted with the plan when it is forwarded for approval, and may be highlighted in the combatant commander's Integrated Priority Lists.

JCIDS Functional Needs Analysis

In the mid- to long-term, from just beyond the FYDP out to 20 years in the future, JOCs represent how future missions will be carried out. When applied to specified defense planning scenarios, they provide the tasks against which future capabilities, as represented by JFCs, are compared to determine which tasks can and cannot be accomplished. The resulting capability gaps are prioritized within each FCB, and then across all functional areas, to produce a prioritized list of capability gaps that can be analyzed by technologists to identify technology gaps that can be addressed in S&T plans and programs.

Functional Capabilities Boards

FCBs are established according to functional areas by the JROC, which determines which boards will be established, disbanded, or combined. The JROC also determines which specific area(s) are assigned to each board and the lead organization(s) responsible for sponsoring the board. The gatekeeper (vice director, J-8) approves FCB portfolios inside each functional area.

The stated mission of these boards is to support the JROC by integrating stakeholder (OSD, combatant commands, services, defense agencies, Joint Staff, and other federal agencies) views in concept development, capabilities planning, and force development to ensure the U.S. military can execute assigned missions. FCBs provide assessments and recommendations that enhance capabilities integration; examine joint priorities among existing and future programs; assess program alternatives (including unclassified, collateral, compartmented, and special access programs); minimize duplication of effort throughout the services; and provide oversight in the management of materiel and non-materiel changes that support the national defense and military strategies to achieve optimum effectiveness and efficiency of the armed forces.

Each FCB evaluates issues that impact its functional area and provides subject matter expertise and input to the JROC. Specific functions that are assigned to the boards include the following:

- report findings and make recommendations on issues requiring JROC review
- provide assessments of capabilities issues to support PPBE process activities
- coordinate and integrate department-wide participation to ensure that supporting analyses adequately leverage the expertise of the DOD components to identify promising materiel and non-materiel approaches
- conduct capability evaluations through assessments and studies, using common assessment frameworks (as appropriate), to structure issues and assess impact to joint war fighting

- assist the JROC in overseeing materiel and non-materiel capabilities development
- develop and maintain portfolios to assist in managing capability issues and documents[26]

FCBs participate in the development and use of joint concepts that support the joint capabilities identification process. Specifically, each board is responsible for developing and maintaining a Joint Functional Concept that describes how the future joint force will perform a particular military function across the full range of military operations (that is, across all relevant mission sets) 10–20 years in the future. FCBs continually assess their joint functional concept and relationships with other concepts.

The leading role of the FCBs in assessing and prioritizing capability needs and in developing and integrating new capabilities to fill capability gaps is underlined in the Chairman's Instruction for JCIDS, which declares that "Each FCB is responsible for all aspects, materiel and non-materiel, of its assigned functional area."

Chartered Functional Capability Boards

The JROC charters FCBs, assigns their functional areas, and identifies their chairs, based on recommendations from the Joint Staff's Director for Force Structure, Resources, and Assessment (J-8). Eight FCBs are currently chartered, as shown in Figure E-4 along with the general or flag officer who chairs each. Each FCB maintains a joint functional concept, the title of which matches the name of the responsible FCB.

26. CJCSI 3137.01.

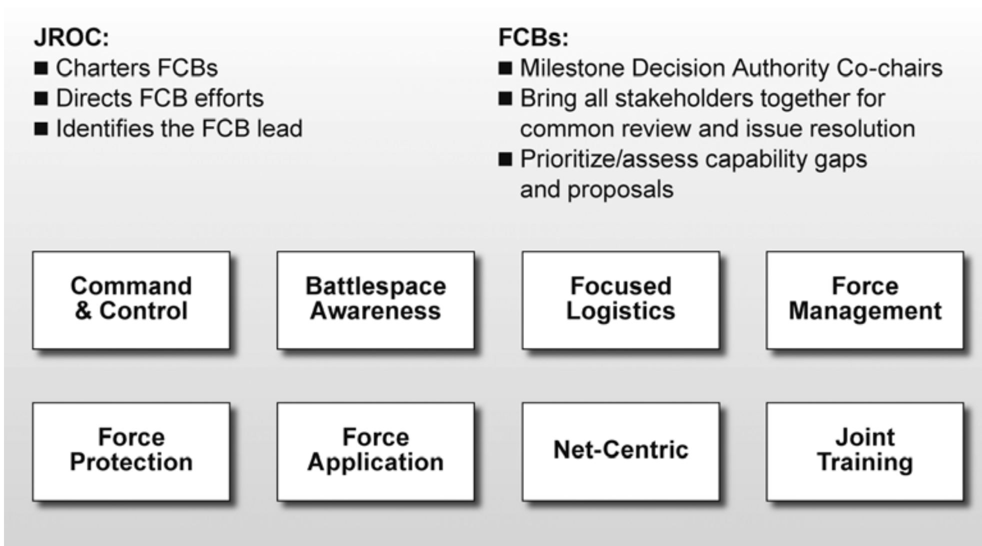

Figure E-4. Chartered Functional Capability Boards

Appendix F. Illustrative Execution Agent Roles

Figure F-1 illustrates the type of analysis that might be done with a priority list of enabling technologies. The figure draws on the strategic technology vectors identified in Volumes I and II of this study as example (first column), in this case showing some of the technologies needed for ubiquitous observation. The portfolio manager might characterize each of these technologies into categories such as the following:

- not yet in development, but of the high-potential-payoff (probably with high risk as well), in which case development might depend on finding a "speculator"
- in development and proceeding
- not yet in development but ripe for being so because of commercial activities (a prime candidate for a prospector to identify and recommend)
- "ready to go," that is, ready to be put into the field with minimal special work; in this case, what would be needed would be an expeditor.

Where the speculator, prospector, and expeditor would be found would depend on the technology. A particular department of a particular laboratory might, at a particular time, be ideal for any of them. In another case, DARPA might take on the job. Or perhaps something new and special would be needed.

The portfolio strategist would be thinking about these functions and eager to identify how they could be accomplished.

Technology Areas	High Risk/High Reward: Speculator/Innovator	Under Development Showing Progress: Developer	Leverage Commercial Development: Prospector	Mature Within DOD: Expeditor
Ubiquitous Observation				
Day/night all-weather wide area surveillance	High altitude, long endurance platforms	Space-based ground moving target indication/synthetic aperture radar		Active/passive hyperspectral sensing
	Giga pixel optical imaging			Foliage penetration sensors
Close-in sensor and tagging systems	Miniature sensor technology	High performance/high efficiency signal processing	Efficient energy storage technology	
	Stealthy/precision delivery platforms	High density packaging		
Soldier as a collector	Miniature sensor technology	All domain precision geolocation	Efficient energy storage technology	
	Interactive automated debriefing	Soldier centric communications/ networking technology		
		Body borne flexible displays		
Human/system collaboration	Human guided algorithms	Natural man-machine interface		

Figure F-1. Technology Areas Associated with Ubiquitous Observation

Appendix G. Historical Perspective

This appendix draws upon historical developments for insights about past capability developments and implications for planning and processes by the office of the USD (AT&L). It first looks at what has characterized successful past developments. Second, it comments on the role of overarching visions. Last, it examines how defense secretaries in effect took "portfolio views" to conceive strategy and identify and enforce priorities.

Illustrative Past Successes

Figure G-1 summarizes the panel's brief review of about fifty capability developments that came about in separate programs. It shows capability categories in which major advances were made—not just theoretical advances, but advances that reached the field and made a very big difference, often a difference warranting the term *transformation*.

Capability (example)	**Dates**	**Sponsor**
Precision Fires (Cruise missiles. Armed Predator, laser guided bomb, GPS)	1970s–90s	USAF
Littoral Control (Littoral Combat Ship)	2004–2006	USN
Surveillance (Global Hawk, Predator, Joint Surveillance and Target Attack Radar System)	1980s–1990s	USAF
Tactical Mobility for Ground Forces (M1A1, Bradley, Stryker)	1980s–2002	USA
Penetration of Air Defenses (F117, B1, B2)	1970s–1990s	USAF
Maritime Superiority (carrier battle groups, boomers, fast attacks)	1920s–30s; 1950s–60s	USN
Personal and Vehicle Protection (active armor; body armor)	1980s–2004	USA

Figure G-1. Example Capability Developments

Precision Fires

Precision fires developed over a period of several decades, far more slowly than proponents hoped. In some respects, this reflected the time required for technology to advance. In other cases, it reflected consistent resistance by the services to protect related developments when budget cuts occurred. There were always reasons. For example, early technologies for achieving accuracy required multiple ground points and a heavy operational burden to fly the aircraft needed. Developing the exquisite technology for precise assessment of time and for space-based navigation aids took many years and, in the interim, systems were imperfect and difficult to work with.

Laser-guided bombs, which were feasible in the 1960s and were eventually used in Vietnam, depended on good weather conditions. Despite these various problems, however, visionaries saw with great clarity the enormous potential of precision weapons. They were a small and distinct minority always having to fight for development dollars and opportunities to demonstrate and later field their results. In the 1970s, Secretary of Defense Brown intervened to support developments, even though he had no convenient "requirement" upon which to draw. Perhaps tragically, the names of only some of the key scientists, engineers, and officers behind precision fires are well known today (for example, Ivan Getting, who contributed much to the Global Positioning System (GPS); less so, Roger Easton, whose contributions were from the Naval Research Laboratory).

Organizational and bureaucratic problems were often an impediment. The idea behind the wildly successful Joint Direct Air Munition, which couples a GPS kit to an existing iron bomb, was well developed years before it was procured. Indeed, at one point a RAND study for the Air Force convinced General Lee Butler (Strategic Air Command and its successor U.S. Strategic Command) to approve its development. Proponents were ecstatic. Development did not in fact proceed, however, because—according to lore—someone in the acquisition community concluded that it would be illegal to proceed without a formally blessed "requirement." In this instance, as with many, the definitive history needs to be developed before those with first-hand knowledge are no longer available for interviews or to provide documents.

The Littoral Combat Ship

The Littoral Combat Ship, which is now in procurement, was the result of low-cost exploration championed by VADM Art Cebrowski while at the Naval War College, and by the Chief of Naval Operations (CNO) Admiral Vern Clark. The CNO's personal intervention was essential in overcoming the resistance and, indeed, the hostility of most Navy "barons." Ultimately, it was the hands-on use of an existing commercial ship, borrowed from Australia for the experimentation, which convinced fleet commanders that great benefits could be obtained from having a number of such ships. In this case, the issue was not so much enabling technology, but the willingness to adapt existing commercial technology.

Surveillance, Reconnaissance, and Targeting

This report shall not recount the well-known story of how satellite reconnaissance was developed, primarily in the 1950s and 1960s, except to note that deep-seated resistance was common. The reasons included parochialism by aviators, the worry that satellites would be vulnerable, and the high technical risks and costs associated with early satellite programs.

More recently, Global Hawk and Predator, which are typically referred to today as glorious successes, were seen for years as flawed programs being foisted upon the Air Force by "techies" in DARPA. Aside from the usual parochial issues, the best was definitely the enemy of the good. Many people were deeply skeptical and even hostile because, in essence, unmanned aerial vehicles could not do some of the things that pilots can do, and had their usual share of technical and cost problems. It was Israel not the United States that plunged ahead early because military necessity sometimes trumps other matters.

Even when Global Hawk and Predator were pushed into operational service (by what we call "expeditors"), skeptics focused on the shortcomings. There were great pressures to build better versions, but with substantial related delays and prospects for cost growth. There were champions within the DOD for holding down requirements, but historians will probably identify Congress as having been crucial. It mandated procurement of essentially as-was versions, thereby precluding delays. There were and are arguments on both sides of the debate, but it is clear that normal processes have the ability to delay "forever," obtaining highly valuable operational capabilities.[27]

The Joint Surveillance and Target Attack Radar System (JSTARS) provides a similar example. JSTARS has a moving-target-indicator radar allowing it to track moving vehicles, providing commanders with an unprecedented view of large invasion forces and providing essential information for devastating interdiction of armored forces ("halting invading armies"). The JSTARS was a mere R&D system at the time of the first Gulf War, but was pushed into the field by proponents and "expeditors" against the wishes of the establishment. It quickly demonstrated its potential to those who noticed. In one unusual but dramatic part of the Gulf War, six Iraqi Republican Guard divisions tried to fight, which required maneuver. A combination of unmanned aerial vehicles and JSTARS tracked their movements even during sandstorms and all but a few dozen of the armored vehicles were destroyed or abandoned. This demonstrated vividly how certain aspects of warfare had in fact been transformed. Fifteen years later, we take it for granted that adversary armored forces cannot maneuver much less invade along classic corridors, if U.S. forces can operate with systems such as JSTARS and precision weapons.

JSTARS was also quite imperfect as an operational system, not having been developed with the requisite support structure among other things. Still, a squadron was acquired and deployed. Superior alternatives were subsequently pursued.

Tactical Mobility

The U.S. Army (and Marines) of the 1990s still had many units dependent on the foot-march. They were light, but so light as to lack tactical mobility. They also lacked adequate lethality. The 82nd Airborne was regarded to have been potentially a mere "speed bump" in the first

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27. See, for example, Jeff Drezner and Robert Leonard, *Innovative Development: Global Hawk and Dark Star*, Santa Monica, Calif.: RAND, 2002.

Gulf War. Further, as the ability of the Air Force to halt invading armies became evident, the Army felt competitive pressures to improve its ability to rapidly deploy lethal, mobile forces. Many studies, such as those of the Army Science Board, emphasized not only the need, but the technological feasibility of doing something.

Stryker emerged from an acrimonious debate about wheels versus tracked, and homegrown versus borrowed. Army Chief of Staff Shinseki made the decision against considerable opposition. Operators have applauded the Stryker vehicle, despite its limitations and need for upgrading after learning on the battlefield of Iraq. Despite initial shortcomings, however, it is today evident that experience with Stryker brigades is transforming Army doctrine.[28]

From a technological perspective, Stryker brigades incorporate many of the ideas and capabilities pursued initially by Chief of Staff Gordon Sullivan with his experiments on the "digitized division." Some of the ideas trace back to experiments during the 1980s, again at the personal instigation of the Chief of Staff General Shy Meyer. As always, there was much learning and iteration as technologies finally reached the hands of operators.

Penetration of Air Defenses

Perhaps the best documented and best known of the great developments in modern times has been that of stealth aircraft.[29] Initiated at Lockheed's legendary Skunk Works as the result of suggestions from mathematical theory (some of it first discussed in the Soviet literature), the beginnings consisted of fundamental S&T, leading to a point at which representatives could visit a select few figures in the Air Force and the DDR&E and announce, in effect, that an airplane could be built with a radar cross section approximately the size of a

28. See, for example, Dan Gonzales, et al., *Network-Centric Operations Case History: the Stryker Brigade Combat Teem*, Santa Monica, Calif.: RAND, 2005. Major General James Dubik (USA) briefed the summer study on the learning processes being followed by the Stryker community and the extent to which fundamental changes in doctrine and tactics, techniques, and procedures have been and continue to be necessary.
29 Ben Rich and Leo Janos, *Skunk Works: a Personal Memoir*, 1994.

marble. A few individuals, including the Chief of Staff, the DDR&E, and some others destined for high positions later, became champions and monitors. The DDR&E (William Perry, later Secretary of Defense) found ways to pursue the program in deep secrecy and with minimal interference by the "normal" system or Congress. The F-117 and B-2 arrived in due course.

Aircraft Carriers

Many other examples can be discussed over the years, but looking back to the 1920s and 1930s, it is evident how, in some respects, nothing changes. In the aftermath of World War I, battleships reigned supreme. Nonetheless, there were some visionaries who could imagine a "transformation" based on airpower from ships. That their ideas were resisted by the battleship navy should hardly be a surprise, especially given the primitive state of aviation at the time.

Remarkably, a cadre of scientists, engineers, aviators, and naval officers pursued the vision—and found the necessary champions at the top of the Navy, notably a review board created to think strategically. Their pursuits were largely R&D and were not treated as competitive with battleships; instead, the story went, carriers would be scouts. Despite the shortage of funds in the intra-war era, the Navy actually built early carriers, slowly perfecting the myriad of skills and technologies necessary. So did the Japanese, but more overtly with a carrier focus. After Pearl Harbor, of course, it was evident that the day of the battleship was over and that aircraft carriers were now the core of all that would follow. The Navy and its industrial base were able to act with alacrity.[30]

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30. A good account of the history of these developments is Richard Hundley, *Past Revolutions, Future Transformations*, Santa Monica, Calif.: RAND, 1999.

Features of Most Great Developments

Looking across the many developments, some general features can be identified.

People

The "great" developments have had remarkable individual *people* as conceivers, visionaries, managers, or champions. The consistent emphasis in interviews of "old timers" is people, not processes. This is in contrast to a current Pentagon culture emphasizing consensus and process. Indeed, this culture has now existed for so long that the very intuition of many people in the system revolves around consensus and process, with resulting "requirements" for bloated, exhausting activities with no one having the freedom to act.

The Role of Visions

The great developments have often had an accompanying vision that provided coherence and direction over time, a vision with both substance and legs. These coherent visions identified "thrusts," examples of which we shall show later. These were developed and honed by small groups of top-notch "up and comers" at mid-level. Within the military, these young officers often became well known general officers in later years.

Champions

Such concepts, however, would have gone nowhere except for championing by senior leadership e.g., the service chief and senior officials such as the DDR&E. Typically, the concepts were disruptive, and were therefore resisted by the existing organizations. Leaders, then, had to override this tendency to resist. That they often did so is perhaps remarkable to those familiar with the "innovator's dilemma" in industry, but defense planning has objectors very different from profit-making.

Broad Thinking

Significantly, for this study with a terms of reference that focused on S&T, top leaders associated with the great developments thought about the near-, mid-, and long-term, and across development categories. They were *not* particularly focused on S&T; they did, however, value it greatly and pushed innovation in diverse ways (e.g., advanced concept technology system and continuing DARPA activities). They thought in terms of phased, evolutionary developments.

Service Opposition

The great developments usually had to overcome non-interest or even strong opposition within the eventually sponsoring service (e.g., Global Hawk, Predator, NLCS, and F-16s). Often, service chiefs played a *critical* role by "reaching down" and championing innovators who would otherwise have lost out in the competition for funding and priority. Similarly, service chiefs were often the ones who "faced reality" about the need for tradeoffs. Sometimes, they did so in behind-closed-doors cooperation with the DDR&E and Secretary of Defense, without consensus within the service (an example is the procurement of the F-16 as the low-end portion of a high-low mix).

Intervention by the Secretary of Defense

Upon occasion, the Secretary of Defense had to intervene, overriding the preferences of the services and even the service chiefs. Sometimes it was as part of introducing new missions; sometimes it was to protect "national" programs; sometimes it was to reflect conclusions of economic analysis (such as increasing the rate of procurement of precision weapons or unmanned air vehicles).

Finessing or Evading Processes

Especially relevant is the observation that the great developments succeeded despite, rather than because, of normal processes. Nothing so complex as the JCIDS process existed until recent years, but at any given time the then-"normal" process was almost always regarded as too burdensome and too perilous. The champions usually found ways to avoid the normal process (e.g., black programs). In more recent times, senior officials have again noted that "important" developments are dealt with outside the normal process (e.g., the IED task force). This observation should be a sobering cautionary for those who seek to solve current problems by perfecting big processes.

Failures

Failures are also important to notice. The panel identified several examples of outright failures in its historical review. There were some with deep technical roots (e.g., when the F-102 was first built, there was an insufficient understanding of some aspects of aerodynamics). There could have been more disasters, except that "responsible adults," typically a chief of staff, would relax requirements rather than pursue something not yet feasible. For example, during the development of the F-15, there was great technical pressure to push the limits, but the chief of staff relaxed requirements a bit to reduce risk in the first block. This decision permitted earlier success at lower cost. In today's Missile Defense Agency, directors have in recent years followed a policy of building what can be built now (if it is deemed useful), rather than attempting to build what is only desired. These are both variants of what might today be called evolutionary acquisition. The alternative provides failures.

The most notable recent failure was the *first* phase work on the Future Combat System. The Army pursued vague goals that depended upon technologies that were clearly identified by DDR&E as immature. Some senior observers argue that years were lost with "can-do" efforts to meet ill-conceived initial "requirements" such as limiting a new vehicle to 20 tons. The program was substantially restructured by the current Chief of Staff to include well-defined off ramps and a relaxation of unreasonable technical requirements. As of August 2006, many aspects of the program appeared to be in much better condition than previously.

Another example of temporary failure was the unsuccessful THAAD development of the 1990s, in which speed was pursued even as tests failed and reflected a failure to have mastered necessary intermediate steps. After extensive independent reviews, the program was restructured.[31] Recent developments have been more successful, including testing. Thus, a program that was once a failure has apparently recovered.

Visions

Another major point of this historical review is that past successes often benefited from leaders' communicating a simple, coherent, and compelling vision of an overarching capability to be pursued. In addition, however, they conveyed a sense of pragmatism that clearly distinguished among what could be done soon, in the mid-term, or in the long-term, with and without different degrees of risk. That is, the visions were tempered by good sense: instead of recklessly pursuing high-end requirements on an unreasonable time scale, they proceeded with what would now be called evolutionary development.

Figure G-1 shows some of the many visions that have been important over the years. These can be seen as having defined strategic technology thrusts.

Rethinking Contents and Weights of the "Portfolio"

The last point is that the Secretaries of Defense (with at least one very strong deputy) have frequently had to conceive the terms of how to think strategically and how categories of investment should be "rebalanced." They had in mind what is referred to in this report as portfolios, and of making adjustments both within and across portfolios.

The first example, a half century ago, involved creating the mission category of strategic nuclear deterrence (and requirements for assured

31. See "The Welch Report," issued in 1999, which said "the general planning and execution of the THAAD (Theater High Altitude Area Defense) and LEAP (Lightweight Exoatmospheric Projectile) programs are inconsistent with the difficulty of the task. These programs are pursuing very aggressive schedules, but these schedules are not supported by the state of planning and testing." (p.7)

destruction capability and assured-retaliation capability) that was described in Chapter 4. During the 1960s, the *de facto* portfolios were strategic nuclear deterrence, reassuring allies in Europe, containing communism in Asia, and resisting wars of national liberation. In the 1970s, the set was conceived regionally, except that strategic nuclear deterrence was always a mismatch. By the end of the 1970s, Southwest Asia was added as a regional category. In the 1980s, the Secretary emphasized the need to view matters in terms of possible global war: war might begin in Southwest Asia and spread to Europe and then worldwide, or any variation thereof. In the 1990s, the mission category of environment shaping was added, which explicitly legitimized and highlighted the importance of overseas presence, keeping the peace in East Asia, and establishing and maintaining a network of allies and potential allies.

Today, the new categories relate to the global war on terrorism, failed and failing states, rogues, and near peers.

Appendix H. Glossary

AFRL	Air Force Research Laboratory
ARL	U.S. Army Research Laboratory
AT&L	acquisition, technology, and logistics
BRP	Basic Research Plan
CCJO	Capstone Concept for Joint Operations
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CNO	Chief of Naval Operations
DARPA	Defense Advanced Research Projects Agency
DAWG	Deputy's Advisory Working Group
DCR	DOTMLPF change recommendation
DDR&E	Director, Defense Research and Engineering
DISA	Defense Information Systems Agency
DOD	Department of Defense
DOTMLPF	doctrine, organization, training, materiel, leadership, personnel and facilities
DSB	Defense Science Board
DTAP	Defense Technology Area Plan
DTRA	Defense Threat Reduction Agency
FAA	functional area analysis
FCB	Functional Capabilities Board
FNA	functional needs analysis
FSA	functional solution analysis
FYDP	future years defense program
GPS	Global Positioning System
GWOT	global war on terrorism
IED	improvised explosive devices
IPL	integrated priority list
JCIDS	Joint Capabilities Integration and Development System
JFC	Joint Functional Concept
JIC	Joint Integrating Concept
JOC	Joint Operating Concepts

JOpsC	Joint Operations Concepts
JROC	Joint Requirements Oversight Council
JSTARS	Joint Surveillance and Target Attack Radar System
JWSTP	Joint Warfighting Science and Technology Plan
LEAP	Lightweight Exoatmospheric Projectile
MDA	Missile Defense Agency
NATO	North Atlantic Treaty Organization
NGA	National Geospatial-Intelligence Agency
NRL	U.S. Naval Research Laboratory
NSA	National Security Agency
NSWC	Naval Surface Warfare Center
OSD	Office of the Secretary of Defense
PA&E	Program Analysis and Evaluation
PIA	privacy impact assessment
PPBE	planning, programming, budgeting, and execution
QDR	Quadrennial Defense Review
R&D	research and development
RD&E	research, development, and engineering
R&E	research and engineering
REF	Rapid Equipping Force
SPAWAR	Space and Naval Warfare Systems Center
SSBN	ballistic missile submarine (nuclear)
S&T	science and technology
TARA	Technical Area Reviews and Assessments
TARDEC	U.S. Army Tank Automotive Research, Development and Engineering Center
THAAD	Theater High-Altitude Area Defense
UJTL	Universal Joint Task List
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
VCJCS	Vice Chairman, Joint Chiefs of Staff
WMD	weapons of mass destruction
WRAIR	Walter Reed Army Institute of Research