DoD Research and Engineering Enterprise

April 2014

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

Department of Defense Research & Engineering Enterprise

"Our reviews [over the past year] made two new realities very clear: First, the development and proliferation of more advanced military technologies by other nations means that we are entering an era where American dominance on the seas, in the skies, and in space can no longer be taken for granted. Second, defense spending is not expected to reach the levels projected in the five-year budget plan submitted by the President last year. Given these realities, we must now adapt, innovate, and make difficult decisions to ensure that our military remains ready and capable – maintaining its technological edge over all potential adversaries. However, as a consequence of large budget cuts, our future force will assume additional risks in certain areas."

Secretary of Defense Hagel, Pentagon Press Briefing Room, February 24, 2014

Technological superiority has been central to the strategy of the Department of Defense (DoD) for the past Century. The current Defense Strategy, dated January 2012, is based on five high-level tenets—two of which rely directly on the continued technology superiority of the Department of Defense:

- The military will be smaller and leaner, but it will be agile, flexible, ready and technologically advanced.

- The Department will protect and prioritize key investments in technology and new capabilities, as well as our capacity to grow, adapt and mobilize as needed.

The Department and nation are at a strategic crossroads—the funds available to the Department (and government in general) are decreasing, while the complexity and depth of national security challenges are growing. The preservation and advancement of technology superiority requires heightened levels of cooperation, coordination, and collaboration between all members of the DoD Research and Engineering (R&E) Enterprise.

The external factors that shape the Department's ability to deliver advanced technology-based capabilities continue to evolve, making the delivery of such capabilities more complex. While challenging, there is no doubt that exploiting advanced technologies will continue to be at the center of the Department's strategic path forward.

The foundation of the Department's technological strength is its wide-ranging Research and Engineering (R&E) Enterprise. The enterprise includes the military departments and their laboratories, all other DoD laboratories and product centers, defense agencies such as the Defense Advanced Research Projects Agency (DARPA), the Defense Threat Reduction Agency (DTRA), and the Missile Defense Agency (MDA), other federal government laboratories, federally funded research and development centers, university affiliated research centers, United States and allied universities, our allied and partner government laboratories, and the U.S.

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

industrial base. Regardless of the fiscal environment, preservation and delivery of advanced technology remain a high priority, and require the efforts of all of the partners mentioned above.

As the nation is emerging from over a decade of focusing on countering terrorism and insurgency, new national security challenges are emerging—cyber operations, advanced electronic warfare, proliferation of ballistic missiles for both strategic and tactical intent, contested space, and networked integrated air defenses. At the same time, the Department is shifting to a focus on the Asia-Pacific region, a region with unique geographic and cultural features.

The following provides strategic guidance for DoD components to shape their R&E programs. While different components of the enterprise (e.g., services and agencies) will have different mission foci, the basic principles of the guidance are valid across the enterprise and will allow all components to establish priorities in line with a set of enduring principles.

I. Three Enduring Principles

While the size and technical content of the Department will evolve over time, the Department conducts research and engineering for three primary reasons:

1. ***Mitigate or eliminate new and emerging threats to national security*****:** The Department must be prepared to meet its current and future national security missions. The priorities in this principle include these enduring requirements:

a) Protecting the nation against nuclear, chemical, and biological weapons, from both state and non-state actors;

b) Protecting the nation against new and maturing threats, such as cyber, proliferating cruise and ballistic missiles and unmanned air, undersea and ground vehicles; and

c) Finding solutions to the new capabilities that would prevent the U.S. armed forces from fulfilling our national security missions. There is a host of enabling technologies and capabilities being developed world-wide that could restrict the U.S. ability to project our armed forces. These new threats include (but are not limited to):

- <u>Electronic warfare (both attack and protection</u>). Digital electronics open a whole new class of jammers, radars operating in different frequencies, and new communication links. Rapid advancement of technologies and tactics that erode the U.S. ability to operate freely in the electromagnetic spectrum are affecting operational performance.

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

- Loss of assured access to space. We are increasingly reliant on assured access to capabilities that are currently space-based, such as satellite communications, precision navigation and timing through Global Positioning Systems (GPS), and on-demand intelligence, surveillance, and reconnaissance (ISR). However, we are facing a growing ability by nations and non-state actors to use means both kinetic and non-kinetic to degrade or deny these capabilities. The U.S. must find ways to assure access to our current space-based capabilities while developing alternative means to deliver these capabilities without a space layer. Research in this area includes but is not limited to: enhanced terrestrial communications; jam resistant communications (such as laser communications); novel timing devices decoupled from continuous access to GPS; high-performance inertial measurement units; and alternative ISR resources.

- Proliferated theater and cruise missiles. Other nations have been developing and deploying high numbers of new missiles with advanced capabilities. Our traditional approach is based only on kinetic defense and requires a U.S. missile intercept against proliferated missiles, which is no longer practical or cost-effective. Our new approach must deliver both kinetic and non-kinetic options to reduce the effectiveness of advanced theater and cruise missiles. Other defeat or disrupt technology systems such as jammers and decoys also should be explored.

2. ***Affordably enable new or extended military capabilities:*** The acquisition costs of defense systems continue to challenge the Department. Cost effectiveness and affordability must begin before the acquisition process. Over the past three years, the Department has introduced efforts to continuously improve the acquisition process, and to drive affordability into every aspect of the acquisition system. There are two vectors to increase affordability: technologies to lower cost and extend life cycle; and research and engineering processes to address costs early in system development.

- Technologies to lower life cycle cost**.** The Department has an uneven history of developing technology to reduce life cycle cost, and we should be depending heavily on the private sector to assist us in this area. Examples include:

  a) Condition-based maintenance. Sensors embedded into existing platforms to alert when maintenance is needed are becoming an industry standard; scheduled maintenance may become unnecessary.

  b) Interoperability and open systems. Lack of interoperability and open systems are a substantial driver in the cost of software-intensive systems. The DoD R&E enterprise can make a significant contribution to the use of open systems and to

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

making systems interoperate more easily. Commercial companies dominate the work in this area and the Department should be learning, and using, these techniques wherever possible.

c) Modeling and Simulation (M&S). M&S is a key enabler of capabilities supporting real world applications that underpin innovative technology solutions, act as force multipliers, save resources, and save lives by: (1) promoting cooperation and collaboration to remove barriers to interoperability and reuse; and (2) providing a common technical framework (architectures, data standards, and common M&S services) that improves interoperability, reuse, and cost effectiveness.

- R&E Processes to Reduce Cost**.** The most recent revision to the Defense acquisition regulation includes a key change that is related to cost. Specifically, the phase between Milestone A and Milestone B (Engineering and Manufacturing Development) has been renamed from "Technology Development" to "Technology Maturation and Risk Reduction." This change highlights that there are certain processes that can be refined to reduce risk.

a) Development Planning**:** Development planning is a structured process to allow a design engineer to consider system trades in the pre-Milestone A (Technology Maturation and Risk Reduction) phase. By using a structured developmental planning process as outlined in the Defense Acquisition Guidebook, we can address cost drivers early in the development process.

b) Model-Based Design**:** In traditional design, if a requirement changes, the engineer has to return to the beginning. Model-based design allows a change to be made without starting over, and further, allows cost to be a key parameter. The private sector – and not only the traditional defense industry - is leading the way in designing systems on a computer. We continue to adopt and expand upon these techniques in the DoD. By initializing a design correctly, we have shown it is possible to modify a large number of parameters to obtain an optimized design. We also have shown that it is possible to redesign very quickly after the initialization of the design. We will see extended use of model-based design as the "toolbox" is built.

c) Prototyping**:** To advance our emphasis on future threats we are expanding the use of developmental and operational prototyping. Prototyping is a set of design and development activities intended to reduce technical uncertainty and to generate information that will improve the quality of subsequent decision making. The

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

Department distinguishes between developmental and operational prototyping. Developmental prototyping demonstrates the feasibility of emerging technologies, and helps the promising ones overcome technical risk. Operational prototyping focuses on assessing the military utility and integration potential of more mature technologies.

Throughout the history of the Department, periods of fiscal constraint have been marked by the use of prototyping to mature technology and keep design teams active in advancing the state of practice. We will use prototyping to demonstrate capability early in the acquisition process, before all the reports affiliated with the acquisition process begin. Prototyping will also help us improve development methods and manufacturing techniques, evaluate new concepts, and speed fielding initial quantities of new systems. The ability of prototyping to evaluate and reduce technical risk, and clarify the resource picture that drives costs, makes it a critical piece of the larger research and engineering strategy.

3. ***Create technology surprise through science and engineering:*** The third reason to conduct research and engineering is to create surprise for potential adversaries. The Department has a long history of developing technologies that led to superior capabilities, including stealth, the Internet, synthetic aperture radar, precision weapons, infrared focal planes and night vision devices. Creation of surprise requires both a robust basic research program and strong applied research programs. While it is not possible to know where technology surprise will come from, the following areas are examples that highlight the possibilities:

- Autonomy: A major cost driver to the Department is force structure, but technology to augment the human is maturing. Autonomous systems range from software to aid the intelligence analyst in processing, exploitation and dissemination, through very complex autonomous air systems networked in tandem with unmanned ground or undersea vehicles. The technologies associated with autonomy are multiplying: from sensors that can understand the environment, to software algorithms that can make a decision or seek human assistance. Through autonomy, we should be able to greatly reduce the manpower required to safely conduct missions.

- Quantum Sciences: Understanding how to use the atom for numerous tasks is not a new concept. However, the progress in recent years suggests that we are on the verge of turning quantum science into a capability. The first pseudo-quantum computers are a commercial product[1], and quantum key distribution for data encryption is nearly a commercial product. These two applications are just the beginning. Evidence that

[1] The "D-wave" computers from Canada are not "true" quantum computers, but mimic the quantum computer using the atom as Joesephson junction.

quantum effects can be used as a very accurate gravity sensor at long distances exists, opening the possibility of remote detection of tunnels or submarines. Quantum effects have been demonstrated to provide precision timekeeping 100-1,000 times as accurate as GPS. Other military applications are just being realized, but quantum science is a technology that will provide surprise.

- Human Systems: Previous wars were won by physical power. It is not clear such will be the case in future conflict. With the proliferation of sensors and data, future conflict may well be won by those whose reactions are quickest. Studies of human performance suggest that cognitive response time can be reduced, and such reductions could give a decided advantage to the force that can best make use of them. In addition, we are learning how to tailor training. Reducing the time to train forces for a specific situation will be a decided advantage.

- Nanoengineering/Nanotechnology: We are learning how to engineer systems at the molecular level; this will lead to new system-level capabilities. For example, thermal management is one limitation to systems like directed energy. It is possible to increase thermal management by several orders of magnitude by designing systems at the molecular level. Meta-materials (materials engineered for specific properties) promise development of radars and electromagnetic systems that operate much more effectively at much broader frequency ranges.

There is a theme evolving in the technology surprise elements highlighted above. In the near past, technology surprise came largely through new platforms. This may not be the case in the near future. The operational advantage may well come from new technologies and capabilities, or from new ways to use existing technologies that enhance and enable the platforms the United States already employs. The research and engineering community must contribute to all aspects of technology surprise.

II. DoD S&T Portfolio Management – Reliance 21

"[Research and Development] is not a variable cost; R&D drives our rate of modernization. It has nothing to do with the size of the force structure. So when you cut R&D, you are cutting your ability to modernize on a certain time scale, no matter how big your force structure is."

Under Secretary of Defense for Acquisition, Technology, and Logistics, Frank Kendall, Defense Programs Conference, February, 25, 2014

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

As the Department faces a near future with fewer research and development dollars and increasing threats, it is imperative that we optimize our R&E investment across all components. We have started this process through the reintroduction of *Reliance 21*, a portfolio management approach to improve coordination and alignment of the R&E program with Departmental goals. The DoD is estimated to have approximately 10,000 unique science and technology projects.[2] The Department has neither the manpower nor the resources to align these projects from 1-10,000, as required by a zero based budget[3].

In lieu of that, *Reliance 21* decomposes the Science and Technology (S&T) program into 17 distinct portfolios, or Communities of Interest (COI), comprised of all the people working in the technical area. At the head of each COI is a Steering Committee with senior SES or GS-15 level personnel who represent their respective component and are responsible for optimizing their portfolio.

We believe this construct will allow the individuals responsible for delivery of capability in their technical area to optimize their program. Each COI will report the overall state of their technical area to the S&T EXCOM annually, and approximately one-third of the COIs will deliver a detailed strategic roadmap each year, aligning their objectives to Department priorities.

The 17 portfolios are comprised of the "S&T priorities" issued by then-Secretary Robert Gates in 2011, supplemented by additional technical areas where multiple components have a substantial investment. We do not have COIs in those technical areas that are the province of a single military department. For instance, oceanography is a Navy responsibility, while terrain and topography is the province of the Army.

III. DoD S&T Priorities and Communities of Interest

"*Because, now more than ever, maintaining a technological edge over our competitors is the surest way to deter conflict, we must continue to invest in technologies that will be essential to 21st century defense*."

Deputy Secretary of Defense Ashton Carter, U.S. Naval Academy, 22 November 2013

The 17 Community of Interest portfolios begin with the seven Science and Technology priorities:

[2] Most S&T projects are on the order of $1M; 10,000 projects equate to $10B.

[3] A zero based budget is one where every individual project is prioritized from 1 to last. Then, if a new project is generated, it displaces those items on the bottom of the list.

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

(1) **Data to Decisions** – an integral part of the **Command, Control, Communications, Computers, and Intelligence (C4I)** Community of Interest**.** The primary focus areas of this COI are human-computer interfaces, analytics and decision tools, information management, advanced computing and software development, and networks and communications. This COI incorporates the science and applications to reduce cycle time and manpower requirements for analysis and use of large data sets.
(2) **Engineered Resilient Systems** – engineering concept, science, and design tools to protect against malicious compromise of weapons systems and to develop agile manufacturing for trusted and assured defense systems.
(3) **Cyber Science and Technology** – science and technology for efficient, effective cyber capabilities across the spectrum of joint operations.
(4) **Electronic Warfare / Electronic Protection** – new concepts and technology to protect systems and extend capabilities across the electro-magnetic spectrum.
(5) **Counter Weapons of Mass Destruction (WMD)** – advances in DoDs ability to locate, secure, monitor, tag, track, interdict, eliminate and attribute WMD weapons and materials.
(6) **Autonomy** – science and technology to achieve autonomous systems that reliably and safely accomplish complex tasks, in all environments.
(7) **Human Systems** – science and technology to enhance human-machine interfaces to increase productivity and effectiveness across a broad range of missions.

And are augmented by ten other significant technology areas:

(8) **Advanced Electronics**: focused on advancing scientific understanding of new materials and devices, and S&T to enhance exploitation and insertion of advanced microelectronics and reduce microelectronics supply chain risk.
(9) **Air Platforms**: enables more efficient and effective platforms and future concepts, including fixed and rotary wing vehicles, unmanned aircraft systems, gas turbines, hypersonics, and aircraft power and thermal management.
(10) **Biomedical**: operates under the auspices of the Armed Services Biomedical Research Evaluation and Management Committee to develop a coordinated Defense biomedical Research, Development, Testing and Evaluation investment strategy.
(11) **Counter-Improvised Explosive Devices**: supports the objective of defeating IEDs and their threat to national security objectives and provide force-multiplying capabilities to address improvised explosive device threats of the future.
(12) **Energy & Power Technologies**: enhances operational effectiveness through power generation, energy storage, power control and distribution, electromechanical conversion, and thermal management technologies.
(13) **Ground & Sea Platforms**: enhances design and integration, survivability, mobility, modularity, and maintainability of manned and unmanned ground and sea platforms.

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

(14) **Materials and Manufacturing Processes**: develops technology-based options for advanced materials for defense, and seeking excellence in materials technologies, processes and related research.
(15) **Sensors & Processing**: physics-based maritime, ground, air-borne, and space-borne sensing capabilities to include electro-optic and infrared sensors; radio frequency sensors; acoustic, magnetic, seismic sensors; and associated signal processing, fusion and modeling.
(16) **Space**: enhances effectiveness and affordability of space-based capabilities.
(17) **Weapons**: develops technology-based options for weapons, and seeking excellence in weapons technologies and related research, including guidance, navigation and control; ordnance; propulsion; undersea weapons; high energy lasers; radio frequency weapons; non-lethal weapons; modeling, simulation and test infrastructure.

In addition to these 17 portfolios, the Department also manages Basic Research as a single program through the Defense Basic Research Advisory Group.

IV. DoD Research & Engineering Enterprise Approach

"Coming out of more than a decade of war and budget growth, there is a clear opportunity and need to reform and reshape our entire defense enterprise."
Secretary Hagel, Center for Strategic and International Studies, November 5, 2013

The Research and Enterprise activity in the Department is comprised of all major activities through Technology Maturation and Risk Reduction. It includes the offices of basic research for the basic research investment, the Department science laboratories for applied research, the Department science and engineering laboratories for advanced technology development, the systems engineering and developmental test activities within the Services and acquisition program offices. Operated correctly, the DoD R&E enterprise develops new opportunities through science and demonstrations, reduces technology risk before Milestone A, and develops the right test protocol to gain knowledge from Milestone A to Milestone B (and beyond).

The Defense Technical Information Center (DTIC) serves the DoD community as the largest central resource for DoD and government-funded scientific, technical, engineering, and business related information available today. As the storehouse of information for the research and engineering enterprise, DTIC and its Information Analysis Centers (IACs) are research and analysis organizations established by DoD to support researchers, scientists, engineers, and program managers. With a broad footprint across DoD, DTIC and its IACs allow the Department to reduce duplication, building on previous research, development, and operational experience.

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

V. Summary

The pace of scientific and technological innovation is occurring more rapidly, in more places, by more people, and with an increasing ability to spread on a global scale, like never before. It is within this context that the DoD R&E enterprise must remain flexible, responsive, and adaptive; even as budgets decline and new threats, challenges, and opportunities emerge. The DoD R&E enterprise will employ focused and balanced investment in and exploitation of a combination of basic, applied, and advanced development research; testing and evaluation, capability prototyping; and promotion of the skills and infrastructure necessary to support them.

Guided by the three enduring principles, the Department of Defense R&E enterprise will continue to play a critical role in ensuring U.S. military preeminence, addressing both current and future technology needs with balanced and sustainable R&E investment.

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited