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HEARING

ON

NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2010

AND

OVERSIGHT OF PREVIOUSLY AUTHORIZED PROGRAMS

BEFORE THE

COMMITTEE ON ARMED SERVICES HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

TERRORISM, UNCONVENTIONAL THREATS AND CAPABILITIES SUBCOMMITTEE HEARING

ON

BUDGET REQUEST FOR DEPARTMENT OF DEFENSE SCIENCE AND TECHNOLOGY PROGRAMS

HEARING HELD
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WEDNESDAY, MAY 20, 2009

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[There were no Questions submitted post hearing.]

FISCAL YEAR 2010 NATIONAL DEFENSE AUTHORIZATION ACT—BUDGET REQUEST FOR DEPARTMENT OF DEFENSE SCIENCE AND TECHNOLOGY PROGRAMS

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
TERRORISM, UNCONVENTIONAL THREATS AND CAPABILITIES
SUBCOMMITTEE,
Washington, DC, Wednesday, May 20, 2009.

The subcommittee met, pursuant to call, 10:33 a.m., in room 2212, Rayburn House Office Building, Hon. Adam Smith (chairman of the subcommittee) presiding.

OPENING STATEMENT OF HON. ADAM SMITH, A REPRESENTATIVE FROM WASHINGTON, CHAIRMAN, TERRORISM, UNCONVENTIONAL THREATS AND CAPABILITIES SUBCOMMITTEE

Mr. SMITH. Call the meeting to order. Thank you all very much for being here this morning. This morning we are going to talk about the Department of Defense Science and Technology (DOD)(S&T) programs and the administration's priorities for the S&T budget as reflected in their request this year. I will have a brief opening statement and we will also have a statement that, without objection, I will submit for the record.

I just want to welcome all of our witnesses here today to talk about this very important subject. This is going to be a very interesting budget year for the DOD on a wide variety of programs. Certainly we have heard about some of the big ticket items. But this has implications throughout the budget in terms of how we set our priorities and science and technology will be no exception. As we figure out where to do our research, what our priorities should be on how to spend the money, our overall priorities within the DOD budget are going to be critical to assessing that. And all of the gentlemen here today are going to be critical players in making those decisions and moving forward.

In general, I want to say that I feel our research and development in science and technology areas has done quite well. The best thing they have done in the last couple of years has been responsive to the battlefield needs. We would all like to have long-term planning and we are still doing that. There has been I believe a perfectly logical and reasonable shift in focus since 9/11 to what we need in Iraq and Afghanistan. And that help, I think, has been critical to the warfighters in term of meeting their challenges by providing them with the technological advances they need.

In many, many areas of particular note is the significant improvement in the quality of medical care. You know both in terms of battlefield survivability, the various treatments that are now available and those seriously wounded, some of the advances in prosthetics and other care that has really improved the quality of

life for our men and women who have been injured out there. And a lot of that has to do with the investments made within Research and Development (R&D) and science and technology. Certainly there are many other areas where we have made those improvements.

In the balance that we try to strike going forward, just to make sure that we meet those battlefield needs and also look down the road, which was one of the main purposes of research and development off the bat and to see what our challenges are going to be in the future and to improve technology in those areas and to put us in the best position to meet them, to make those investments early on.

So I look forward to hearing from our witnesses. And with that, I turn it over to the ranking member. Mr. Miller for any opening comments he might have.

[The prepared statement of Mr. Smith can be found in the Appendix on page 33.]

STATEMENT OF HON. JEFF MILLER, A REPRESENTATIVE FROM FLORIDA, RANKING MEMBER, TERRORISM, UNCONVENTIONAL THREATS AND CAPABILITIES SUBCOMMITTEE

Mr. MILLER. Thank you, Mr. Chairman. I do have an opening statement that I would like to submit for the record but I have a couple of comments I would like to make as well.

Mr. SMITH. Yes.

Mr. MILLER. Thank you, gentlemen, for being here today. It was April 6th that Secretary Gates had a press conference where he gave us our first and really only glimpse at this time into the significant investments that he was proposing to the President that would later be reflected in the fiscal year 2010 budget request. We have got a lot of questions for the Secretary and the Department that will be coming out over the next couple of weeks. I feel our job is complicated by the fact that we only have fiscal year 2010 figures to work with, and we have been told that future programmatic decisions will be based on the outcome of the 2010 Quadrennial Defense Review (QDR) with some significant budgetary moves found in the fiscal 2010 budget.

I think everybody agrees that we have to get this right, you know. This year's budget shows an overall decrease in the research and development testing, engineering accounts from a previous year. I think it was back in 2009 there was a four percent increase. As I was going to say, if we don't get it right or we don't provide sufficient funding for research and development our forces could find themselves without much needed capabilities.

I look forward to you gentlemen addressing these issues and answering the questions we have for you today.

[The prepared statement of Mr. Miller can be found in the Appendix on page 34.]

Mr. SMITH. Thank you very much, Mr. Miller. I will introduce all of the witnesses and we will take you from left to right. We always strive for between 5- and 10-minute opening statements. There are five of you, but I want to make sure that you get plenty of time to say what you have come to say. So please feel free to use that time.

We are joined first of all by Mr. Alan Shaffer who is the Principal Deputy Director for Defense Research and Engineering (DRE) at the Department of Defense; Dr. Thomas Killion, Deputy Assistant Secretary of Army for Research and Technology, good to see you again; Rear Admiral Nevin Carr, Chief of Naval Research. I thank you in particular for being here this morning, I know you had very significant family health care problem this past week and I appreciate you being with us here.

We also have Mr. Terry Jaggers, who is the Deputy Assistant—you get the prize for the longest title, Deputy Assistant Secretary of the Air Force for Science, Technology & Engineering at the Office of the Assistant Secretary for Acquisition for the Air Force, good to see you. And Dr. Robert Leheny, acting director for the Defense Advanced Research Projects Agency, better known as DARPA. Welcome, and I should make a note that we miss Mr. Tether, appreciate his long service.

Dr. LEHENY. Not as much as I do.

Mr. SMITH. I know, it doesn't seem right doing this without him, but I am sure you will fill in ably.

Mr. Shaffer.

STATEMENT OF ALAN SHAFFER, PRINCIPAL DEPUTY DIRECTOR, DEFENSE RESEARCH AND ENGINEERING, OFFICE OF THE SECRETARY OF DEFENSE

Mr. SHAFFER. Good morning, Chairman Smith, Ranking Member Miller, I ask that my written testimony be entered into the record. I am pleased to be here today on behalf of the nearly 100,000 Department of Defense science and technology men and women who strive to discover, develop, mature and field the best possible technologies at an affordable price for the soldiers, sailors, airmen, Marines and civilians deployed in defense of our Nation.

To meet this challenge requires us to develop the best we can from our DOD laboratories and to partner with all elements of the national science and technology infrastructure: Academia, industry, small business and other federal agencies. Delivering the best possible technology is a complex and multifaceted effort. It is my honor today to show that we are making progress toward this challenge. This is an exciting time to be in the Department of Defense S&T. For the third straight year we submitted a President's budget request that conveys substantial change driven by the shift in national security priorities in response to our current irregular warfare engagement.

Counterinsurgency warfare requires us to expand our capabilities in diverse areas such as persistent surveillance, protection technologies, cultural and social modeling and other non-kinetic capabilities, while maintaining adequate conventional operational capabilities at the same time. We have realigned well over 10 percent of the science and technology investment over the last three budget requests.

This year's budget submission was guided by four strategic principles. The first basic research was articulated by Secretary Gates in his fiscal year 2009 budget posture hearing. The other three were highlighted by the Secretary in his April 6th speech which laid out the budget priorities for the Department of Defense. They

are: Taking care of our people, developing the capabilities to fight the current and future wars, and improving our acquisition capabilities and accountability.

The S&T budget submission we are discussing today addresses all of these priorities and more. Building upon our budget request for the past several years and aligns our investment to irregular warfare challenges.

The S&T Fiscal Year 2010 President's budget request of $11.6 billion represents a strong continued commitment to S&T. Specifically this year's request came within one half of a percent of maintaining real growth compared to 2009, and the combined real growth of the S&T budget request from fiscal year 2008 to 2010 is about 4 percent growth.

Fiscal year 2010 continues the trend of moving investment from kinetic to non-kinetic capabilities. It includes a number of areas of increased emphasis. Medical research and development which increases nearly $500 million for combat casualty care and mitigation rehabilitation of traumatic brain injury, post-traumatic stress disorder and other combat related injuries.

Expanded cyber protection, which increases the DOD in investment by about $50 million a year to fund information assurance science and technology for intrusion prevention and detection. Expanded antitamper technology, which increases efforts and vulnerability assessments of our platforms and development of new technologies to improve antitamper capabilities.

Stand-off detection of fissile materials which increases our investment to improve remote detection capabilities of weapons of mass destruction. Large data handling capabilities starts a new science and technology program to improve our capacity to handle large and increasing amounts of information supporting current and emerging warfighter requirements.

In his April 6th speech, Secretary Gates cited his first priority as taking care of people. The most significant way the S&T community is addressing his charge to take care of our people is medical research and development. About 18 months ago, in recognition of the exceptional importance and urgency and improvements in combat casualty care, the department conducted an extensive review of medical R&D. The assessment resulted in the justification for substantial budget increase which was directed to the services and defense health program.

Secretary Gates's second priority is institutionalizing and enhance our capabilities to fight current and future wars, which means we need to continue the shift of investment from kinetic to non-kinetic capabilities to meet the unique challenges of irregular warfare. We have emphasized development of new capabilities in several high-priority areas to include intelligence, surveillance, reconnaissance (ISR), large data processing, command and control of network sciences, cyber protection, social modeling, irregular warfare modeling and simulation, and energy efficiency for forward deployed forces. I would be happy to discuss any of these areas in detail during the question and answer period.

The final priority highlighted by Secretary Gates is improving acquisition process and accountability. There have been numerous blue ribbon panels or blue ribbon studies pointing to the challenges

facing our acquisition program. The S&T team can play a key role in several areas, including technology maturity assessments, rapid acquisition, agile information tools and high performance computing. Again, I would be happy to discuss any of these in further detail during question and answer.

In conclusion, the DOD S&T community has adapted and will continue to adapt to the needs of the warfighter, as guided by Secretary Gates's core strategic principles. The basic research program is stronger. We are expanding our S&T program to take better care of our people. We are developing capabilities both for the current and future conflicts and we are improving our department's acquisition posture.

In short, the S&T community stands ready to provide combatant commanders the tools necessary to carry out their missions around the world. Our measure of success will always be the ability for our soldiers, sailors, airmen and Marines to maintain a technological advantage on the battlefield. We appreciate the opportunity to provide the update on the status of the DOD enterprise. Thank you.

[The prepared statement of Mr. Shaffer can be found in the Appendix on page 35.]

Mr. SMITH. Thank you very much. Dr. Killion.

STATEMENT OF DR. THOMAS KILLION, DEPUTY ASSISTANT SECRETARY OF THE ARMY FOR RESEARCH AND TECHNOLOGY, U.S. ARMY

Dr. KILLION. Thank you, Chairman Smith and the distinguished members of the subcommittee. I appreciate the opportunity to discuss the fiscal year 2010 Army science and technology program and the significant role that S&T is playing in supporting our warfighters both tomorrow and today. And I have submitted a written statement and request that it be accepted for the record.

Mr. SMITH. Without objection.

Dr. KILLION. I want to thank the members of this committee for your critical role in supporting our soldiers who are at war and for your advocacy of Army S&T investments. They will help to sustain technological preeminence for our soldiers. Your continued support is absolutely vital to our success. The Army's S&T investment strategy is shaped to foster innovation and mature technology to enable future force capabilities, while exploiting opportunities to rapidly transition technology to the current force.

The S&T program retains flexibility to be responsive to unforeseen needs identified through current operations. We have rapidly responded to a broad range of these needs. Our Army scientists and engineers have made significant contributions to the war fighting systems being used to buy today's soldiers.

Recent Army S&T transitions to Operation Iraqi Freedom and Operation Enduring Freedom have significantly reduced soldier and vehicle weight burdens while increasing protection capability. Additionally, because of the Army's S&T's position early in the acquisition process, our work in armor, networks, power and energy and other areas are well positioned to support Army brigade combat team modernization.

Army S&T is seeking to optimize our future investments to mature both vehicle and soldier protection and efficiently reduce

weight burdens as collective systems. S&T investments contributing to soldier weight reduction are approached in a holistic fashion to address personnel load issues. Exploitation of advanced materials and manufacturing processes allow for weight reduction of individual components while increasing the capability of soldier equipment.

Our investment in medical S&T provides the basis for maintaining both the physical and psychological health of our soldiers as well as enhancing their performance. Battle Mind, which is the Army's psychological resiliency building program, prepares soldiers for both the mental and emotional rigors faced during deployment and improves their ability to transition home.

We have also recently initiated a program to develop detection and prevention methods that combat the incidents of suicide in our soldiers.

While much of the focus of our S&T investments is necessarily on near and midterm futures, we have also sustained our commitment to basic research that seeks to enable the next generation of soldiers with paradigm-shifting capabilities to dominate in the full spectrum of battle space environments.

In closing, I would like to thank you, Mr. Chairman, for the opportunity to testify before the subcommittee and for your support to Army, science and technology investments. I am proud to represent the efforts of thousands of Army scientists and engineers dedicating to providing our soldiers with the best possible technology in the shortest possible time. I will be pleased to answer your questions and those of the subcommittee.

Mr. SMITH. Thank you very much.

[The prepared statement of Dr. Killion can be found in the Appendix on page 69.]

Mr. SMITH. Admiral Carr.

STATEMENT OF REAR ADM. NEVIN CARR, JR., USN, CHIEF OF NAVAL RESEARCH, DIRECTOR, TEST AND EVALUATION AND TECHNOLOGY REQUIREMENTS, U.S. NAVY

Admiral CARR. Thank you, Mr. Chairman, and members of the committee. It is an honor to appear before you to report on science and technology efforts within the Department of the Navy and how the President's fiscal year 2010 budget request supports the Navy and Marine Corps.

Accompanying me is the Vice Chief of Naval Research Brigadier General Thomas Murray who also serves as Commanding General of the Marine Corps Warfighting Laboratory. The naval S&T challenge is to support a Navy and Marine Corps capable of prevailing in any threat environment. In order to address critical Navy and Marine Corps challenges today and tomorrow, the Office of Naval Research (ONR) must focus on S&T areas that provide the biggest payoff for our future, be innovative in our thinking and business processes and continuously improve our ability to transition that S&T into acquisition programs.

The President's fiscal year 2010 budget requests 1.8 billion for Naval S&T to accomplish these goals. As you know, it is not just about high tech weapons. Please let me share an example of S&T efforts to protect sailors and Marines in the operational environ-

ment by reducing hearing damage to personnel exposed to high noise. We are working on multiple approaches to reduce, monitor and assess exposure, develop advanced personal protective equipment, and develop enhanced warnings and procedures to insure exposure does not become damaging.

ONR developed technologies are now transitioning to the warfighter as part of the acquisition's sponsors flight deck cranial program. We are also working on treatment, including groundbreaking pharmaceutical inventions for situations where potentially damaging exposure does occur.

In another area of interest to Congress, ONR is working with DOD and Navy task force energy to reduce the amount of fossil fuels used by our forces. We continue to invest in Navy future fuel's efforts to investigate the impact of new fuel formulations on naval machinery. In fiscal year 2009, Congress added 20 million for alternative energy research. We are using the funds to evaluate energy positive structures, advanced solar, wind and ocean thermal technologies. And to address system integration impacts and intermittent time renewable energy sources on power grids.

Finally, ONR continues to support research in fuel cells, methane hydrates and other sources of energy. Significant S&T efforts are dedicated to responsible stewardship of the marine environment. This includes impact of national security requirements on marine mammals. The Navy is the world leader on marine mammal research, with ONR spending approximately 14 million annually to understand how marine mammals may be affected by sound.

Navy investments represent a majority of funding spent on this research in the U.S. and nearly half of that spent worldwide. Congress has been generous in support of these programs, and I look forward to continued partnership in achieving the goal of better protecting the marine environment. Prevailing in today's threat environment and building a strong flexible force in the future requires careful S&T investment to protect the Nation and our warfighters. To achieve that goal we continue moving forward toward a greater integration of capabilities, more effective partnership between research and acquisition and a clearer vision of how to achieve shared goals among DARPA, Army, Air Force and other DOD research organizations. We must monitor and leverage S&T in a global environment, worldwide movement of technology and innovation demands that we be able to take advantage of emerging ideas wherever they originate.

We have an aggressive worldwide presence, with S&T partnerships in 70 countries, 50 states, 900 companies, 3,300 principal investigators, 3,000 graduate students, and 1,000 academic and nonprofit entities. Own our global offices London, Tokyo, Singapore and Santiago, Chile, help us stay abreast of emerging S&T trends around the world and avoid technological surprise.

In order to tap the full spectrum of innovative thinking and discovery, we continue to focus the majority of our investments on performers outside the naval R&D system. Nevertheless, in a ceaseless effort to attract world-class scientists to become part of our organization, we continue to mature world-class skills and innovation within our lab systems and especially a naval research laboratory. For these reasons, I believe our S&T investments are

sound and represent careful stewardship of tax dollars that will significantly enhance the safety and performance of our warfighters.

Thank you for your support, I will do my best to answer your questions.

Mr. SMITH. Thank you, Admiral.

[The prepared statement of Admiral Carr can be found in the Appendix on page 78.]

Mr. SMITH. Mr. Jaggers.

STATEMENT OF TERRY JAGGERS, DEPUTY ASSISTANT SECRETARY OF THE AIR FORCE FOR SCIENCE, TECHNOLOGY AND ENGINEERING, OFFICE OF THE ASSISTANT SECRETARY FOR ACQUISITION, U.S. AIR FORCE

Mr. JAGGERS. Mr. Chairman, members of the subcommittee and staff. Thank you, I am pleased to have this opportunity to provide testimony on the fiscal year 2010 Air Force Science and Technology Program. The Air Force S&T program is a vital element of the Air Force's larger research and development strategy. At approximately $2.2 billion, the fiscal year 2010 President's budget request for S&T includes an increase of $98 million or almost 4 percent real growth over the fiscal year 2009 core S&T request.

For the past 2 years, I have spoken extensively about adapting Air Force S&T to the security environment identified in the 2006 Quadrennial Defense Review and shifting investment emphasis from traditional conventional threats to new unconventional threats such as terrorism. The Air Force S&T program continues to address this challenge by focusing investments on near-term contingency support and far-term capability needs to maintain technological superiority for our Nation.

The five guiding principles I established back in 2005 for S&T now provide a comprehensive framework for our larger Air Force R&D strategy. My number one priority still remains the valuation and protection of our greatest R&D asset, people. To complement our recently approved human capital strategic plan for the acquisition workforce we have created a major initiative to recruit, develop, mentor and retain the Nation's best and brightest scientists, technologists, engineers and mathematicians, otherwise known as STEM.

The National Research Council study we commissioned over a year ago to define Air Force STEM and lay out a road map to manage it effectively is scheduled for completion this summer. We look forward to the NRC recommendations and plan on incorporating them into our new Air Force STEM strategic plan. This STEM strategic plan will address the hundreds of thousands of critical STEM across the Air Force and better integrate the approximately 3,000 STEM at our Air Force research laboratory.

Our hopes are to better synergize the many STEM workforce improvement initiatives across non-S&T, with those targeted for S&T, such as section 1108 and section 219 from the fiscal year 2009 National Defense Authorization Act. We are maximizing the use of these authorities in the laboratory and hope to engage Congress on the larger STEM workforce issues in the future.

My second priority is to maintain stability and balance in the S&T portfolio. An appropriate balance is not only required between the three budget activities of S&T, but also between S&T and the follow on prototyping budget activity four. This is critical to successful technology transition while ensuring our future acquisition programs are structured for success with disciplined, up-front system engineering.

Closely coupled with this is our third S&T guiding principle, to focus technology development on Air Force strategic priorities. Again, our S&T program focuses technology investments on the five priorities of the Air Force: Revitalizing the nuclear enterprise, winning today's fight, developing and caring for airmen, modernizing our air space and cyber inventories, and recapturing acquisition excellence.

Our fourth guiding principle, transition technology to warfighters and system developers, is one that has gained even greater importance during this time of acquisition improvement.

Finding new and improved ways of transitioning technologies directly to the warfighter and into our weapon systems acquisitions is an area that has received special attention since we stood up our technology transition office within the headquarters Air Force last year. Already it has been directly responsible for crafting minimum criteria needed for successful transitions, as well as leading the theory and thought across the Department for early-phase systems engineering and pre-acquisition technology insertion planning.

Last, but certainly not least, is our fundamental principle of honoring commitments we have made with our partners. Whether they are with others across the Air Force, our sister services, Defense agencies, the Office of Secretary of Defense, industry academia, our allies or with you the Congress, Air Force S&T stands by our commitments. Guided by these principles, this budget request focuses investments on Air Force and joint warfighting needs. We continue to shift S&T investments from traditional areas to support unconventional warfare. A specific goal of the 2008 Air Force strategic plan is to bolster the Air Force core function of Intelligence, Surveillance and Reconnaissance, or ISR, support to the joint warfighter, emphasizing irregular warfare scenarios. The S&T program is developing unprecedented, proactive ISR technologies to create a universal situational awareness through a layered and flexible sensing architecture for use not only in traditional air warfare but in unconventional cyberspace warfare as well.

Other focused investments include energy-efficient technologies to reduce our dependence on foreign oil. Sustainment technologies to assist in prolonging the life expectancy of our legacy aircraft, and, of course, game-changing technologies such as directed energy, hypersonics, cyberspace and highly accurate low collateral damage conventional munitions.

Related to S&T and technology development, I know there is a subcommittee interest in leveraging S&T competencies for acquisition improvement. As both the Air Force S&T executive and the Air Force chief engineer, I personally conduct all independent technology readiness assessments on the Air Force major defense acquisition programs. To date, I have led approximately 30 technology readiness assessments, 2 manufacturing readiness assessments, 1

overall program assessment and multiple independent reviews. Obviously, these reviews inspect in quality after the fact and require integration to maximize their utility. In fact, we have a major initiative ongoing with the Office of the Secretary of Defense (OSD) right now to combine these specialty reviews into a single standardized process.

However, to structure programs for success before these inspections begin, the Air Force is proud to have initiated two new programs. First, to address the NRC recommendation for early-phase systems engineering during pre-acquisition concept development. And the second, to reduce integration risks through pre-program of record competitive prototyping.

The Air Force has already developed the policy framework to implement these two programs and are emboldened by the fact that both the Department of Defense instruction 5000.2 and recent House and Senate acquisition legislation reflect these very same NRC recommendations or any adopted by the Air Force.

Guided by Air Force strategic priorities, the Air Force S&T program is rebuilding and reshaping the workforce balancing and focusing investments to modernize our inventories for a wide range of contingencies. Shrinking the technology transition gap, and honoring commitments with joint and coalition teams to win the fight today and tomorrow.

Mr. Chairman, thank you again for the opportunity to present testimony, and I thank you for your continued support of the Air Force S&T program. I look forward to your questions.

Mr. SMITH. Thank you very much.

[The prepared statement of Mr. Jaggers can be found in the Appendix on page 94.]

Mr. SMITH. Dr. Leheny.

STATEMENT OF DR. ROBERT LEHENY, ACTING DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, OFFICE OF THE SECRETARY OF DEFENSE

Dr. LEHENY. Good morning. I would like to thank Chairman Smith and distinguished members of the subcommittee for this opportunity to briefly describe DARPA's programs and accomplishments which are discussed in much greater detail in my written testimony, which I would like to submit for the record.

My remarks this morning I would like to focus on a few examples of how DARPA's work aligns with Secretary Gate's priorities for the department's 2010 budget. As we have already heard this morning, his first priority is to maintain our commitment to the care of all-volunteer forces. For several years, DARPA's bio-revolution programs have supported this commitment with innovative medical research programs. And our flagship program in this area is our revolutionizing prosthetics effort which was recently showcased here on the Hill as part of the Veteran Administration's research week and which was featured a few weeks ago on CBS television's 60 Minutes program.

The big news is that over the next 18 months in final test with the VA, approximately 30 combat veterans will participate in clinical trials of the prosthetic arm that is being developed in this program. And of this group, eight will test the arm at home in their

normal day-to-day activities. In fact, one of these veterans is scheduled to take his arm home this week.

In another of our medical programs, we are investigating the cause and treatment of traumatic brain injury, TBI. While the program is still in its early phases, it is already providing insights into the potential budget of TBI, insights that we believe will lead to new treatments, therapies to minimize the long-term effects of this devastating injury.

The Secretary is also emphasizing the need to rebalance the Department's investments to enhance our ability to fight the kind of wars we are fighting today. At DARPA, we began this process more than a decade ago. And in direct response to challenges our troops are encountering in Iraq and Afghanistan, we identified urban area operations as a specific agency strategic thrust.

One success within this program is our hard wire vehicle armor program which has demonstrated advanced composite armor system that is being used to protect troops on thousands of Mine Resistant Ambush Protected (MRAP) vehicles today. At the same time, we began investigating new modes of ISR capabilities with a goal of creating a decisive edge for our forces: Capabilities for sharing information among small ground units; for better management of manned and unmanned ISR assets; for increasing predator effectiveness by providing video feeds to more than 50 users from a single predator platform; for providing new UAV-based radar capabilities; for finding and tracking ground vehicles and dismounts in cities and under forest canopies.

And in a very ambitious program, we are jointly working with, and recently undertaken, with the Air Force, we will demonstrate a radar-equipped airship that can provide unprecedented wide-area surveillance capabilities, and which, when fully developed, will be capable of operating continuously for up to 10 years.

The current conflict has also highlighted the importance of prompt language translation. DARPA is meeting this need with technology for near-real-time translations of Arabic TV broadcasts, translations that are providing our forces better situational awareness. Our long-term goal is to dramatically reduce the need for human language translators.

And in further keeping with the Secretary's objectives, we continue to invest in conventional force-on-force capabilities by supporting research on space technologies, unmanned systems, novel weapons and technologies for netcentric warfare and information assurance.

Of particular interest are our investments in cybersecurity. These include investigating ways to find malicious elements inserted during manufacture into the microchips that are the brains in so many of our advanced systems. In an effort that we expect will be the foundation for future cybersecurity research, we are creating a national cyber range. This range, by providing tools for establishing and making precision measurements on a large scale, using realistic cyber networks, the test bed will impact—major principal impact—will be to spur further development in cybersecurity.

Finally, in the belief that the best way to prepare for the future is by creating it, we continue to maintain a robust portfolio pro-

gram focused on our core technologies. These programs extend from quantum physics and theoretical mathematics, to material and information science to advanced micro systems. The fruits of these investments will create future capabilities and provide us our longest term guard against conventional or asymmetric surprises. And in an initiative that grew out of our robotic vehicle grand challenge experience, we have begun a program targeted at high school students interested in computer science.

These are just a few examples of what we are doing at DARPA. There are many more in the written testimony. Thank you, and I would be pleased to take your questions at this time.

[The prepared statement of Dr. Leheny can be found in the Appendix on page 105.]

Mr. SMITH. Thank you all. We will do questions under the five-minute rule for everybody, including me. First, I want to ask about the Joint Improvised Explosive Device Defeat Organization (JIEDDO) program and how much progress we are making in terms of dealing with improvised explosive devices, and what your research is focusing on to try to solve that problem. I understand some progress has been made, a vexing, vexing issue, but what S&T approaches are we employing at this point to try to address that?

I guess, Mr. Shaffer, I will start with you, and if anyone else wants to chime in, they may.

Mr. SHAFFER. Yes, sir, thank you sir, that is a tough question and especially to answer in this particular forum.

Mr. SMITH. Yes, I was looking through my series of questions here and a whole bunch of them seem to be generated in areas that we can't answer in this forum. But some broad outlines.

Mr. SHAFFER. I will turn to my compatriots who are in the services, actually doing the work. But what I will tell you this year and really at the insistence and hard dedication of Dr. Andre van Tilborg, who is sitting behind me, the Under Secretary for science and technology, we conducted an end-to-end review, really a focus-deep dive of what JIEDDO is doing in their science and technology program and aligning those efforts with our service programs. And really the JIEDDO program stretches across an entire spectrum of technologies, everything from neutralizing detonation devices, but now starting to work our way back up the chain to understand the network that leads to some of these terrorist bombers. Can we go ahead and get to the network and prevent the IED before the IED is built?

So when you take a look at the JIEDDO program, it is more from just protecting against the specific device to protecting against the event. And I think I would like to turn to my compatriots and my colleagues for specific activities in their areas.

Mr. SMITH. Certainly. Dr. Killion.

Dr. KILLION. Sure, of course is there a broad range of technologies that apply in this case——

Mr. SMITH. I guess when I am trying to get at, sir, what is the most promising? I guess the answer to that is nothing is most promising it is a series of approaches and you have to try all of them.

Dr. KILLION. You have to try a range of them, certainly, and we have applied a number of them what JIEDDO helped to do is aid to provide resources and focus, to actually take the technologies we are working in the labs and quickly bring them to the fore to get them to the field. We actually continue to work the underlying technologies, JIEDDO helps to mature them and get them out.

Mr. SMITH. Right.

Dr. KILLION. That is a good partnership. We are doing that in a number of areas. Armor is clearly an important area in terms of the protection of vehicles, not only for combat vehicles, tactical vehicles. We have done work in the MRAP program in terms of enhancing protection on some of those vehicles where we've added lightweight armor to them that wasn't there to begin with. The electronic warfare domain, which we can't say a whole lot about in this forum, that is an area where in terms of exploiting devices and also coming up with methodologies to feed, control and initiation of those devices, there are tools that have been developed across the service laboratories.

And in the ISR domain, as Al mentioned, in terms of looking at the network, it is a matter of being able to monitor who is doing what, detect the presence of explosives, detect the presence of activities by certain individuals. There is a full range of technologies that do apply to try and disrupt a network of activities and also defeat the device when the time comes to do so.

I think we have been pretty effective in bringing to the fore as many of those as feasible. And that is always the challenge is the balance of what can you actually do and apply it to a vehicle and have it still be able to do its job, for example.

Mr. SMITH. Anybody else have comments?

Admiral CARR. I guess I just would echo the kill chain approach and the good work across the kill chain from understanding the social networks, and who is doing what, and trying to interrupt things before they get to that point of explosion which is not where you want to defeat an IED. I would say there is no single ah-hah technology that will be our panacea, but across that whole chain, lots of work to interrupting that moment of detonation, protecting against it when it does occur and obviously protecting the warfighters that have suffered those detonations, no single-point solution.

Mr. SMITH. Okay.

Dr. LEHENY. I would like to mention DARPA is working closely with JIEDDO. We have created a village in the National Training Center where we are undergoing a number of tests. We are looking at, because the materials themselves are so difficult to detect, the chemical detection systems are not very effective. We are looking at, by having persons in that village, actually assembling the bombs, we are able to determine using the techniques that we know the terrorists use to readily detect the chemicals associated with the fabrication of the bombs.

Mr. SMITH. Learn what you should be looking for in advance. Understood.

Dr. LEHENY. Absolutely.

Mr. SMITH. I am out of time. Mr. Jaggers, really quick. Okay, I yield to Mr. Miller.

Mr. MILLER. Thank you, Mr. Chairman. Dr. Leheny, how is DARPA coordinating its cyber research activities with other relevant federal agencies, including agencies that fund unclassified research in studies the National Science Foundation? And will these agencies and other civilian research agencies have access to the National Cyber Range or other support infrastructure?

Dr. LEHENY. Yes, DARPA is participating with a number of other agencies of the government in an Office of Science and Technology Policy (OSTP)-led effort to coordinate our reaction, the national reaction, if you like, to the cyber threat. It is certainly our intent that the National Cyber Range, once it is established, will be available for both government and nongovernment researchers, and other interested parties to take advantage of the capabilities cyber range will provide.

As one aspect of the range is we believe it would be possible to conduct both classified and unclassified research activities on the range at the same time that the range itself will be capable of separating, if you like, the various activities that are taking place so as to protect the classified nature of that network which has to be classified.

Mr. MILLER. Thank you, sir. A little more broader question, anybody can jump on this one if they want. We all know that rapid fielding has emerged as the way to get things out to the warfighter, but there are challenges that are still out there confronting the process. And what I would like to know is what the is impact that rapid fielding has on traditional or standard testing processes or procedures? Anybody can take that one.

Mr. SHAFFER. Sir, I will try this one, I am not sure I will be able to answer the question. I will speak from the experience of two particular vantage points. One, I am the executive director of the MRAP task force and two, the joint rapid acquisition cell falls under my responsibility. While we strive to push things out just as fast as possible, we always do test things. So, for instance, the MRAP vehicles, the largest amount of time that it takes from the time that we put a contract out, to getting those into the hands of the soldiers and Marines in Iraq and Afghanistan is in testing, so we understand what is going on.

The same thing will happen with the joint rapid acquisitions bill and anything we are pushing out we accelerate testing. I had hoped that Dr. John Foulkes from the Test Research Management Center (TRMC) was going to be here today. He apparently was detained. But we work very closely with TRMC and all of these rapid fielding and Operational Test and Evaluation (OT&E) and Developmental Test and Evaluation (DT&E) in fielding, and with the services to make sure that what we send out we at least understand and test.

Mr. JAGGERS. Sir, I will just add the two things that probably suffer in the test world from rapid fielding, are obviously you are doing developmental test work, piece of developmental test, certainly operational test in theater when that piece is deployed. Things that suffer are things like reliability, maintainability and sustainability, things that you want to define into the system and test those before they go over there before it is a surprise to maintainers and avoid suspicions you have to operate in theater.

The other thing that tends to suffer is interoperability. There are a lot of legacy systems out there that have to interface. And to flesh those things out ahead of time in an operationally relevant environment before you deploy to the operational environment to understand where those interfaces are and interoperability issues obviously would be something of value. I guess my thoughts are as long as the commander in theater knows those risks and limitations and is willing to take the benefits that outweigh those risks and limitations, then it's something that needs to go to the field rapidly.

Mr. MILLER. If I could follow Mr. Jaggers. The Government Accountability Office (GAO) has criticized repeatedly the F–35 program for reducing its Test and Evaluation (T&E) activities and assuming, saying it was assuming too much risk. And the President's budget is accelerating procurement of the Joint Strike Fighter (JSF) and stopping production of the F–22 or procurement of the F–22. Can you expand on what you may see as the current risk to the JSF program due to reduced T&E activity or do you see any?

Mr. JAGGERS. Sir, that is a better question for the service acquisition executive, my boss, the Secretary of the Air Force—Acquisition (SAF AQ). I will take that for the record. In general any time there are two items that tend to get reduced in acquisition programs as a matter of record when they extend out their acquisition life cycle and that is test, and the other one is system engineering. Those tend to be tradeable things, an acquisition program at the expense of cost and schedule.

In general that is a bad practice as a matter of process.

Mr. MILLER. Thank you, my time has expired.

Mr. SMITH. Mr. Ellsworth.

Mr. ELLSWORTH. Thank you, Mr. Chairman. My first question probably is best for Mr. Shaffer and Dr. Leheny. Can you discuss, I represent the 8th district of Indiana. Crane Naval Warfare Center is in my district, and I know they do great work there. Can you talk about the workforce development issues that you might face in research and development in DARPA, difficulty in finding the folks, it is a very rural area of my state, but maybe some of the challenges you are facing finding a workforce and finding the folks to do the Research and Development (R&D) that you find necessary.

Mr. SMITH. That is not just because they do not want to live in Indiana. I have been to Crane, it is a lovely place to work. I am just giving you a bad time, go ahead.

Mr. SHAFFER. Anybody who likes basketball likes to go to Indiana, so I don't understand the problem with Crane.

Science and engineering workforce is a concern of everybody at this table because it is a competitive world. And there are numerous recent reports. We need to do everything we can to grow the entire science and engineering base of America and then be agile and effective in getting workers and researchers into our DOD laboratories. There are a number of recent initiatives and then I will turn it over to Dr. Leheny and others that are allowing us better authorities for hiring people rapidly.

The Department is beginning to use those. And actually the first one out of the shoot is Navy Research Laboratory and the Navy

Surface Warfare Centers. I got a report, and I should probably let Admiral Carr talk about this, but I got a report from Dr. John Montgomery of Navy Research Laboratory who loves the rapid hiring authorities. Since they were approved and delegated to him in March, he has been able to fill nearly his entire quota of 30 people with high-quality people. What you find you have very good problems and can hire people on the spot and give them a future we can get people in science and engineering. That doesn't address the overall issue of the number of scientists and engineers available, we have to work that, and in fact, there is legislation out to take a look at that as a whole of government approach, but it really is a very complex problem. Create the scientists and engineers and then let us hire them quickly.

Bob.

Dr. LEHENY. What I would add is that DARPA, of course, has a rather small workforce of its own. We do most of our research through contracting.

And to specifically answer your question about your part of the country, we recently visited the University of Indiana at Indianapolis and spent half a day meeting with some of the senior faculty there who described to us the kinds of research that are being done on the campus there. We were very impressed by the facilities that we saw and the quality of the research described to us. And we left them with information about how to access us, there are already people in the university being supported by DARPA in some of our programs. We encourage them to make further use of the availability of our research funds and further their programs.

All our programs are competitively solicited so anyone in your district who has an interest in receiving support from DARPA for technical research that they want to engage in, we welcome them to contact us with their ideas and we will certainly take them under consideration.

Mr. JAGGERS. Sir, I would add the authorities given to the lab, lab demo, section 219, 1108, those kind of things definitely make it easier to hire and better situation for the laboratory of science and technology community, in the Air Force that is 3,000 scientists and engineers in laboratory.

What concerns me, is that we have hundreds of thousands of Science, Technology, Engineering and Mathematics (STEM) scientists and engineers outside of the laboratory too. We have weather officers, half of our pilots have STEM background, without those authorities. And beyond the laboratory environment makes it difficult. My concern is some day in the future we might not be able to get those manned as we would like with STEM personnel.

Mr. ELLSWORTH. That would be my concern too. Thank you all very much, Mr. Chairman. I yield back.

Mr. SMITH. Thank you. Mr. Conaway.

Mr. CONAWAY. Well thanks, sir, I appreciate you being here. This is a 50,000-foot question, but maybe start with Dr. Shaffer, how does the system prioritize between immediate needs like the hearing loss program and the prosthetic program and the arms versus the 20-year out, pie in the sky, what-if kind of needs? Who sets those priorities, how do you allocate the resources against that?

And how do you split that up between the various services and their cadre of great scientists?

Mr. SHAFFER. Sir, that is a tough question, I wish there was a magic formula, there is not. All of us wrestle with the priorities between the near and the far term. Right now Secretary Gates will go around the third floor and he wants to make sure that we understand and we all understand we are a nation at war. Anything that we can do to push technologies from our laboratories, out to hands of the warfighters, that technology makes a difference is our number one priority. Beyond that, and this is where the difficulty comes in, while Secretary Gates's clearing has given us that mandate, Secretary Gates also gave us the mandate to increase basic research to keep the overall knowledge base going.

So at the end of the day, it is through the very hard work of going through the priorities, the alternatives of everybody at this table working with program analysis and evaluation, working with the requirers, working with the combatant commanders, we do our very best to hit that balance, but there is no magic formula. Everybody works as hard as they can to optimize payoff for the research that we have.

Dr. KILLION. And to follow up to what Mr. Shaffer says, I think it is important to recognize you don't make that distinction in my investment in 61, 62 and 63 between what is invested necessarily in near term versus far term other than basic research farther away in terms of maturity than advanced technology. It is really about the fact that we maintain a workforce of skilled individuals who understand technology and understand the Army and its needs, that is both in its labs and with our partners and universities in the industry. It is because you have those people who have that understanding and knowledge about the technology that they can then take that knowledge and use it to solve problems, they can come up with a solution.

You can go back to the gentleman in the laboratory who is working on materials and say, we just discovered a problem with this particular type of armor, why is it failing the way it is, what can I do to fix that problem? And because they have that knowledge and the methodology that they can use to bring to bear to the problem, they can come up with the solution and answer to the question and come up with an alternative.

Mr. CONAWAY. Let me ask this then, the weight of body armor bothers all of us, soldiers wear it, Marines wear it, airmen wear it. I guess Navy guys, who decides that we are going to take on the task of providing effective equipment, but lowering the weight? How do you decide where that project goes? How do you focus it?

Dr. KILLION. We have a systematic program within the Army, it is a partnership between the Army Research Laboratory that does fundamental research in that area, materials research, Natick, and the Program Executive Office (PEO), which was actually managing the soldier program in terms of looking at okay, what do I do to redesign, to incorporate new materials into such a system to provide better protection. It is driven by the threat that you have to compete up there.

Mr. SHAFFER. But I would like to amplify a little bit, sir. We have a process and the representatives of the group called the De-

fense Science & Technology Advisory Group (DSTAG) are sitting at this table, along with Dr. van Tilborg, we go out and scan the horizon and look for hard problems.

This morning, our council of colonels at our direction came in and said we are going to take on in a very deep dive look at the weight restrictions on dismounted infantry. So all of us are going to go out to our programs, focus the technology that we can to reduce the weight of dismounted infantry men, and we will do that over about a two- to three-month period to affect the program budget review.

Mr. CONAWAY. Let me ask this: You have the Army guys doing it, and some Navy scientists doing it for the Marine Corps, and some Air Force scientists doing it for the Air Force.

Mr. SHAFFER. And DARPA.

Mr. CONAWAY. And DARPA. Of course. Why have they not all duplicative doing the same thing? How do you focus it so that you have the right synergy of enough minds going that you get the weird idea that really works and you don't have everybody doing the exact the same thing over and over.

Mr. SHAFFER. That is exactly why we bring together the technology focus teams under the DSTAG. That technology focus team to reduce the weight on the soldier will actually be reduce the weight on everybody. There are airmen out there walking around, Marines and Navy people, that will have representatives from all of us and our laboratories coming together and showing each other and comparing technologies and looking for those most promising option. So that team, the technology focus team, will represent the entire department. And internally deconflict, because everybody we have in those teams wants to do what is right for the deployed forces. And they will share and trade information. You know, it is remarkable what happens when bureaucracy gets out of the way and people who want to make a difference get together and start working.

Mr. JAGGERS. For instance, sir, Air Force is not in the body armor business, that is an Army shop. However when you come up with a hard problem like that, the Air Force is into lightweight composite materials for aircraft. And we can bring skills and competencies to bear on that Army or bigger larger warfighter challenge. And we get the right people hooked up with the Army to provide support in that regard. It is that—the particular materials inside the body armor vests.

Admiral CARR. In the interest of the Marine Corps, we are certainly working closely with the Army. I would say the cross talk is very good.

Mr. CONAWAY. Thank you very much.

Admiral CARR. That is a problem we all face. The magnetic attraction is pull investment forward so you can help out programs. And we need to keep fertilizing those distant fields not just for the technology but as Dr. Killion said, scientists that are out there.

Mr. SMITH. Thank you, Mr. McIntyre.

Mr. MCINTYRE. Thank you, Mr. Chairman. Can't let the comment go without Indiana basketball without recognizing our North Carolina basketball. The Tar Heels were at the White House last week.

And speaking of that, Dr. Joe DeSimone from the University of North Carolina, I know, has worked with DARPA on nanoscience

and nanotechnology, and that was recognized as the Tar Heel of the year in North Carolina, the citizen of the year for his work in this area being so involved with DARPA.

I notice on page 45 of the report that you have given us that you state DARPA is also exploiting advances in nanoscience and nanotechnology or matter manipulated at the atomic scale. Can you tell us which one may be more comfortable describing exactly how this nanotechnology is making a difference at the atomic scale with what you are doing in DARPA?

Dr. LEHENY. Let me try. When we talk about nano scale, what we are talking about are dimensions, the typical atom is on the order of a nanometer. So we are talking from the size of an atom to a few hundred atoms. What we know is those size scales, nature allows us to manipulate forces, like electromagnetic forces light, in ways that are difficult to do that—in much larger scales.

For example, by capturing light more efficiently, we can make a more effective photodetector. And it is possible to do that using nanoscale structures. Because what the nanoscale structure does is it essentially takes the photon, which has a dimension on the order of a micron, which is many hundreds of nanometers, and channels it into the material that is actually going to convert the photon into an electron or a whole, which can then be measured electrically. Very much the way that an antenna; for example, if you think of the old television antennas that we had on the roofs of our house, that guides the electromagnetic energy down into your TV set, where it is detected. The elements in your TV set detecting that electromagnetic energy are much smaller than the wavelength of the radio frequency (RF) signal that you are detecting, and it is the guiding properties of the antenna structure that brings the energy into your TV set, where it can be detected. At the nanoscale we can make objects that will guide light in the same way that your antenna guides an RF signal into your receiver, and therefore more efficiently detect the light. And the kinds of light that we want to detect are infrared light, short wavelength light, visible light, through all kinds of sensing applications.

Mr. MCINTYRE. The research is fascinating, and I am glad that DARPA is once again at the forefront of using nanotechnology to our advantage. Can you also tell me how DARPA is coordinating its cybersecurity research and planning activities with other relevant federal agencies, agencies like the National Science Foundation (NSF) that fund unclassified research?

Dr. LEHENY. Coordination is a difficult concept, because both the NSF and DARPA have very different missions. The NSF of course, its primary mission is to educate and advance our understanding of the world that we live in, whereas DARPA's mission is a mission to advance the utility of that understanding. So in some respects we are orthogonal in our approach to how we deal with advancing the science and technology. And in cyber technology it is just another example of that. We coordinate, to the extent that we do, largely at the present time through the OSTP National Cyber Initiative activities. And as we go forward with this cyber range activity, we will be of course creating a test facility that will be open to researchers who are supported by the NSF, as well as other researchers.

Mr. MCINTYRE. That is good. Thank you, Mr. Chairman.

Mr. SMITH. Thank you. Mr. Murphy, you have anything?

Mr. MURPHY OF PENNSYLVANIA. Great. Thanks, Mr. Chairman. Gentlemen, thanks so much for your testimony today and your service to our country.

There was an article in the Los Angeles Times on April 26th which cited that the Department of Defense is the single largest energy consumer in the United States. Last year it bought 4 billion gallons of jet fuel, 220 million gallons of diesel and 73 million gallons of gasoline. And when gas prices skyrocketed last summer, the Department of Defense energy tab increased from about 13 billion per year in 2007 to 20 billion in 2008. The Army alone had to make up a half a billion dollar shortfall in its energy budget. You know, we often get our oil from countries that obviously don't have America's best interests at heart. And when a $10 rise in the price of a barrel means $1.3 billion increase in the Pentagon's energy costs, this is more than an environmental issue, it is a national security issue.

What is there in the fiscal year 2010 budget to increase research and development of alternative fuels so that our vehicles of war are not dependent upon traditional logistic fuels?

Mr. SHAFFER. Sir, I will go ahead and start that, but each of the groups here are doing some things in alternative energies or fuels. I have been very fortunate, because I have had the chance to lead the Department's Energy Security Task Force. In the last 3 years, our investment in research and development, not just science and technology, but research and development in energy security, has risen from $400 million to about $1.2 billion. You have to take a look at energy as a very holistic thing. And we have a number of efforts, from improving our efficiency of turbine engines for our aircraft, to making lighter weight vehicles for our Army for the next generation of vehicles, to using fuel cells, to trying to get to a deployable system that will generate nearly as much energy as it takes in from outside sources, alternative sources, solar, wind, and that type of thing.

Specifically on alternative fuels, our single largest contribution in the past year has been a DARPA effort that went on contract—Bob, I should let you do this—but in December or January to turn algae and other biomasses into jet fuel. But Dr. Killion has some small efforts around and in some of his laboratories. Admiral Carr has efforts primarily out at China Lake. And the Air Force has done a tremendous amount for synthetic fuels using Fischer-Tropsch.

So the Department as a whole is looking at alternative forms of fuel. And that is coordinated through the Energy Security Task Force, which has representatives from S&T, logistics, fuel distributors, et cetera. Other guys?

Dr. LEHENY. If I could just inject something, at DARPA the approach we are taking, and we are spending this year over $55 million and about the same budgeted for next year, the approach that we are taking is a broad one. In the area of alternative fuels based upon crop oils and plant-derived oils, the problem is, and to make it as simple as possible, if you have ever taken a bottle of olive oil and put it in your refrigerator, you know that it turns to sludge because of the way that the oil condenses at low temperature. So

one of the challenges for taking vegetable-derived oils and using them for jet fuel, for example, is to ensure that those oils remain—the viscosity of the oil is adequate at the low temperatures that they have to operate. And so what we are doing is we are investing in research to crack the molecules of the oil to create molecules that are more like the jet fuel molecules, that therefore in effect convert these plant-derived oils into oils that can be used as a fuel.

Mr. MURPHY OF PENNSYLVANIA. How many years do you think we are away from seeing that technology put to use?

Dr. LEHENY. I would hesitate to put an exact number on that, but I would think that we are between three and five years of being able to deliver an efficient process for being able to convert these plant-derived oils into usable jet fuel.

Mr. MURPHY OF PENNSYLVANIA. I don't know if this—if I could have a quick follow-up?

Mr. SMITH. Sure.

Mr. MURPHY OF PENNSYLVANIA. Mr. Killion with the Army, I know that article in the Los Angeles Times that talked about Fort Irwin and how they utilize—and they call it, instead of the footprint they usually call it the boot print—those solar panels that we utilize for vehicles transporting troops at Fort Irwin, and give energy and obviously down to control the environment, air, is that ready to go out into the field in places?

Dr. KILLION. Well, it depends upon what you mean by out in the field. We tend to use these like electric vehicles as something that would be used domestically on a base to substitute for gasoline-powered vehicles or driving materials around, delivering materiel, doing work at a base. It isn't something that we are prepared to deploy in a combat environment as such. But as Al says, we are also looking at ways of reducing the demand that is associated with those tactical and combat vehicles that are deployed, as well as the energy footprint of our installations. There are a lot of initiatives that the Army and I know the Navy are pursuing in terms of demonstrating capabilities at those installations, be they solar, be they geothermal, wind power, to substitute for demand that is on the grid that is using hydrocarbon-based fuels really as an energy source today.

Admiral CARR. It is not just a fuel question.

Mr. SMITH. If the two of you could do it fairly quickly, we are a bit over time here. We want to give other members a chance. Go ahead and do it, just quickly if you could.

Admiral CARR. Thank you, Mr. Chairman. I was going to say it is not just a fuel question of course. I am an operator, I come from the fleet, so I think in terms of my beloved kill chain. But it is that whole chain, from generating to storing to distributing and how you use them. And to just pluck one ship application, we have developed with the Naval Sea Systems Command a device to recover energy from the reduction gears in DDG–51 class ships. And what this allows you to do is to store a little bit of energy so you don't have to run the same number of generators all the time to get you through those spike voltage demand periods. And by turning off a generator, now you have just reduced your fuel consumption. So there are many things across that whole chain that we are looking at. And I work closely with Rear Admiral Phil Cullom, who chairs

the Chief of Naval Operations' (CNO's) Task Force Energy for the Navy. And we work very closely together with him.

Mr. SMITH. Mr. Jaggers.

Mr. JAGGERS. In 20 second or less, at the Air Force we have three major things going on. One is $75 million of the economic stimulus that is devoted towards energy and energy projects. We have hundreds of millions in the core S&T budget. And we also have a 6.4 effort to certify synthetic fuels in our fleet, in all engines in our entire fleet. We have two main strategic goals. One is to increase the supply of alternative sources of fuel, synthetic fuels being one, but also batteries and power storage devices and that sort of thing. And the other piece of that strategy is to reduce demand, making our engines more efficient, making our aircraft drag ratio higher, and improving—and lighter aircraft, making those more energy efficient as they fly.

Mr. MURPHY OF PENNSYLVANIA. Thank you, Mr. Chairman.

Mr. SMITH. Thank you very much. We will go back through. I had one general question. You know, much has been made of the transition towards counterinsurgency, irregular warfare, away from the traditional big conventional fights. I am a big believer in that. I think that is where we are headed. It has many implications certainly, some of them which were mentioned in your opening testimony in terms of Intelligence, Surveillance, and Reconnaissance (ISR), cybersecurity, different issues.

Can you give us an example as you have been putting together your budgets over the course of the last two or three years and you looked at this issue, we need to do more on unconventional threats, what you have plussed up and what you have plussed down, stuff you have started doing, stuff you said you know what, we are going to move off of this and we are going to move in direction? Can you give us some concrete examples of how that shift has affected all of your budgets and your approach?

Mr. SHAFFER. I will start, but again I am going to turn to my colleagues, because they also have the day-to-day tactical view. About two years ago then-Director, Defense Research and Engineering (DDR&E) John Young called the S&T execs and myself and Dr. van Tilborg together, and we sat down and looked at, given the new realities of the QDR, irregular warfare, where do we want to invest more? As I said, that has led to about a 10 percent shift in our investment over the last three budget cycles.

Where we have given things up are first off, any inflation adjustments went to the irregular warfare. But we have decreased some of our research into platforms in the conventional weapons systems. In fact, I worry from time to time that we may have gone too far with conventional weapons systems, so we have stood up another deep dive team just to make sure we have that right. But in effect we are trading in some of the larger conventional type things for nonkinetic effects across the board.

And I would turn it over to the gentleman on my left to give specific examples.

Mr. SMITH. Sure.

Dr. KILLION. Well, your comment about conventional is an interesting one, because in speaking to the Vice Chief of Staff of the Army, General Chiarelli, he will tell you that there is nothing like

an M–1 to provide a sense of peace on a street in Baghdad. And so it certainly has an influence——

Mr. SMITH. If I might say about that, just quickly, you know, there are a lot of, you know, old traditional technologies that could in fact be absolutely critical to a counterinsurgency approach. So I understand that. It is not so much about is it snazzy and new versus old and tired. It is a matter of where do you need to spend the money to actually fulfill this mission.

Dr. KILLION. And actually, if you look at how our budget has shifted over the last decade, I would tell you significantly more in force protection, which is critical in those environments, particularly for tactical vehicles. Things like the MRAP and so on, where we have invested to provide better protection to our troops than we traditionally have. And in Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR), so we are monitoring what is going on in those environments. New investments in areas like network science and neuroscience, where we are really developing basic research that enables us to do better understanding what is going on in the environment, understanding the social and cultural behavior in the environment, preparing our troops more effectively through training mechanisms and through mission rehearsal capabilities that we didn't have before. Providing the kind of language translation capabilities that Dr. Leheny was talking about. Those are all investments that I have seen rise over the last decade that are really supportive of operating in those environments.

Mr. SMITH. Admiral.

Admiral CARR. We already have, one of the 13 Navy focus areas has been irregular warfare for about 2 years. So we are looking very closely at that. And one of my five departments is dedicated to this particular area as well. So already had significant focus there because of our linkage with the Marine Corps and support of them. We had been thinking in many ways in this direction.

Mr. SMITH. And you within your department, do you do stuff to support SOCOM as well? Because certainly the Navy, both in terms of the SEALs and the Special Boat Teams, they do a lot of work in this area.

Admiral CARR. We do. It is not dedicated support. We all support SOCOM in our different ways, sir. Social networking is an important element that has increased recently. We are looking very closely at understanding the mechanisms there. Autonomy and trying to get unmanned autonomous systems forward that can provide that persistent surveillance and push decisions forward is sort of irregular warfare in reverse. And we have the infantry immersive trainer that helps train Marines for combat in Iraq and in those unusual scenarios, which has been very successful. In fact, we are looking to expand another one of those.

Mr. SMITH. The danger of the five-minute question period when you have five witnesses is that it always takes more than five minutes. We have votes come up here quickly. I want to make sure that I give others a chance here. So I will let Mr. Miller take another round.

Mr. MILLER. Thank you, Mr. Chairman. Three votes coming up. I have some more questions I would like submitted for the record, and I will yield my time to Mr. Conaway.

Mr. CONAWAY. Thank you. Playing back on the energy theme, Dr. Killion, you mentioned, and maybe the Admiral did as well, that you are working to reduce the footprint on the bases and in forts and other places. It seems to me that commercial research is being done around the world to try to actively get that done. So to the extent that we are spending money on that, we are telling the rest of the world that we have got every other research program fully funded, that we don't need to spend those dollars there?

Dr. KILLION. Let me be clear about that when I talked about that. A lot of the work at the bases is actually not funded in S&T per se. It is taking advantage of that commercial technology and applying it in an installation environment and looking at how that can benefit us.

Mr. CONAWAY. That is fine. Okay. One of the strategic risks of energy is supply. And while crude oil is a nasty word in some parts of the world, in Texas it is not. Reservoirs typically have, after the initial production, secondary sweeps, tertiary productions with carbon dioxide. It is about 50 percent of the reserves left in place. We have got extensive oil shale reserves in this country and extensive oil sands in Canada, as well as coal. Are you guys doing any research that would say how do we exploit those given resources that are under our control to be able to use them while we develop whatever that algae-based jet fuel that is going to fly our jets in the 23rd century will do? Are you guys doing any basic research on how do you get additional oil out of that rock in Pennsylvania and in Texas, where half of it is still in place?

Mr. SHAFFER. Sir, we are not doing any research into how to get more of the oil out, but we are working with the Department of Energy to understand where they are going and how they are making progress. The more important question for the Department of Defense is what the Air Force has done, is certifying our engines with alternative fuels, fuels derived from other sources, because each fuel has a slightly different makeup. And you have to make sure that all the seals and the pistons and the rings and the moving parts work okay. So what the Air Force has done to me that is quite remarkable is certify their jet engines and their aircraft using synthetic fuels.

Mr. CONAWAY. Synthetic based from what, coal?

Mr. JAGGERS. In a number of areas coal. This actually is what Mr. Shaffer is talking about is the Fischer-Tropsch process. And it is really——

Mr. CONAWAY. Still fossil fuel-based.

Mr. JAGGERS. It is a blend, a 50–50 blend of——

Mr. CONAWAY. And the section 526 restrictions don't allow you to purchase that fuel once your—the oil sand fuel that would come from Canada, you can't buy it, can you?

Mr. JAGGERS. And we are trying to characterize that right now. We know we have the fleet certified on the 50–50 blend Fischer-Tropsch. The environmental footprint sources for this particular 50–50 blend is all being evaluated at this time.

Mr. CONAWAY. But you couldn't buy it if it was done, could you?

Mr. JAGGERS. We could buy it overseas, but you can't buy it in the Continental United States (CONUS), yes.

Mr. SHAFFER. Section 526 does present some restrictions on what we can do.

Mr. CONAWAY. Okay. I yield back, Mr. Chairman. Thank you.

Mr. SMITH. Thank you, Mr. Conaway. Does anybody else have any follow-up? Gentlemen?

Mr. MURPHY OF PENNSYLVANIA. I have a quick one.

Mr. SMITH. We have a few minutes. It is all yours. Mr. Murphy.

Mr. MURPHY OF PENNSYLVANIA. Gentleman, in my district I represent the Eighth District of Pennsylvania, which is Bucks County, northeast Philadelphia, and a small slice of Montgomery County. We have several large landfills. And we are already seeing great success in our waste-to-energy conversion projects, producing enough energy to power 70,000 homes in my region. Waste-to-energy conversion could be particularly important for military bases, especially in deployed settings and war zones. And not only is waste disposal a logistical hurdle at many of these locations, but the use of generators and supply lines for the fuels they require is one more target for the enemy to attack.

Does the Department of Defense have any waste-to-energy research and development funding in the fiscal year 2010 budget? And you know, if any of you or all are interested, I would love to bring you up to Bucks County and give you a tour of it, because we are very proud of what we do.

Mr. SHAFFER. Sir, we will send one of my team up to Bucks County and take a look at your company's capabilities. I don't know if there is any specific money within the fiscal year 2010 budget for waste-to-energy. I do know that in the American Reinvestment and Recovery Act, the Energy Security Task Force coordinated the $300 million worth of R&D across the Department. Embedded in that is I want to say it was 7.5 million, and if that is not right we will get back to you, but $7.5 million to advance—it is called tactical waste or garbage-to-oil or something like that—advance that capability.

That investment is through Defense Logistics Agency. But it follows an investment that we made last year through the Power Surety Task Force, which operates out of Fort Belvoir and the Army, where we actually deployed two of these tactical systems forward to Iraq. They are not robust enough yet. They didn't have the waste stream that we want, the efficiency, but yet we do have research. And if your folks have something to bring to the table, that would be huge.

Mr. JAGGERS. Sir, and I don't know what the total amount is, and I think Mr. Shaffer is going to get that for you, but $6 million for sure is in the Air Force portion of the stimulus. And that is going to an anaerobic bioreactor that basically does that, converts the landfill into energy sources. And the broad area announcement, the solicitation for ideas and proposals is going out very soon, it hasn't gone out already. So we will be looking for some proposals from Pennsylvania.

Mr. MURPHY OF PENNSYLVANIA. Great. Thank you, gentlemen. Mr. Chairman, I yield back the remainder of my time.

Mr. SMITH. I just have one more area before we adjourn. You have done some work, as was mentioned, on human terrain teams, cultural development, sort of understanding the enemy, if you will, or actually that is not so true, understanding the areas where we are working counterinsurgency. And then there are also communications issues around that, sort of develop the message and then deliver it.

This is a major issue in Afghanistan and in Pakistan right now, that we are losing the Public Relations (PR) war. I know some efforts have been implemented here recently. I know Ambassador Holbrooke is very focused on this issue. But can you sort of pull this together for me in terms of how closely you work with the various different other agencies and different groups, whether it is, you know, United States Central Command (CENTCOM), Ambassador Holbrooke's people in terms of how you are providing, first of all, the cultural training and development in that area, and then on the messaging piece, looking at technologies. I know there has been a lot of technology to help us better use bandwidth, which has a lot of different implications, but in particular making sure that our troops have the communications equipment.

For instance, in Afghanistan, frankly, that is shortwave radios, as I understand it. Most folks there can't read. And that is where they get most of their information. And that is where the Taliban, you know, they are on the radio even before the incident happens putting out a line of propaganda.

How have you pulled all of those things together and who are you coordinating with on that?

Mr. SHAFFER. Yes, sir, I will start this, but again I know that all of my colleagues have some work in the area. I don't think that you have seen, so we will make sure, I hope—well, I wish you would have seen, but in April we sent up a very detailed report on the Department of Defense efforts in strategic communications.

Mr. SMITH. I have not seen that. I will track that down.

Mr. SHAFFER. We will get that to the staff and get that to you.

Mr. SMITH. Okay.

Mr. SHAFFER. But that effort was pulled together by an organization in DDR&E called Rapid Reaction Technology Office. RRTO works with all the services, but more importantly works with the intelligence agencies, works with the United States Agency for International Development (USAID), works with Department of State, works with the combatant commanders to focus our S&T efforts to see how we can best make a difference in strategic communication. And it really was a whole, basically a beginning-to-end look of how do we shape the message, how do we get the message out there, how do we measure the impact? And it is an S&T focus area, and an area of incredible importance to CENTCOM.

Mr. SMITH. Were you satisfied that that work is being implemented, that the people in the field who are going to use it are following up and making the best use of what you have developed?

Mr. SHAFFER. I can't look you in the eye and tell you that the answer to that is yes, sir. What I know is there is a huge demand signal from CENTCOM and the commanders in the field. I can't tell you they are all using it correctly. But part of the package and part of the S&T effort is training and making sure that our troops

understand how to use strategic communication. We are all growing in this together.

Mr. SMITH. Okay. Anybody else have a comment on this area?

Mr. MCINTYRE. If I can just ask a quick question?

Mr. SMITH. Sure.

Mr. MCINTYRE. Just a clarification, pages one and two of the report, thank you, Mr. Chairman, next to the last paragraph it says on page one, another unique feature of DARPA is that the agency has very limited overhead and no laboratories or facilities. Yet on page two it then talks about, in addition to the technical offices, DARPA has staff offices, which includes facilities, information resources and security. So I would like someone to clarify whether you have offices and facilities or not, since we have two contradictory statements. And if so, where they are located?

Dr. LEHENY. It would be helpful, which report are you reading from, sir?

Mr. MCINTYRE. The strategic plan.

Mr. JAGGERS. The one that DARPA passed out.

Mr. MCINTYRE. It is your publication, sir.

Dr. LEHENY. Let me just find the language so that I don't answer the wrong question. On page two you say—I think what we are trying to do is point out the fact that we don't have laboratories or facilities associated with actually conducting research. Obviously, we do have a building in which our program managers reside. And within that building we have space set aside that is secure.

Mr. SMITH. But you contract out the research.

Dr. LEHENY. We contract out—about 97 percent of our budget is contracted out. And I believe that you may find described in this report.

Mr. MCINTYRE. Are you permitted to say where your office is?

Dr. LEHENY. Oh, sure. We are over in Arlington, just across from the Virginia Square Metro Center.

Mr. MCINTYRE. Okay. So your reference to having no facilities, you are talking about facilities of your own to do the research.

Dr. LEHENY. We may need to correct the way we describe what we do.

Mr. MCINTYRE. Okay.

Mr. SMITH. They don't just meet at Starbucks every morning. Who knows? We will take that contracting out to its logical extension.

Mr. MCINTYRE. Thank you. Thank you, Mr. Chairman.

Mr. SMITH. Thank you all very much. Thank you for your work. Look forward to working with you on the markup this year, and as we go forward. We are adjourned.

[Whereupon, at 12:00 p.m., the subcommittee was adjourned.]

A P P E N D I X

MAY 20, 2009

PREPARED STATEMENTS SUBMITTED FOR THE RECORD

MAY 20, 2009

Statement of Terrorism, Unconventional Threats and Capabilities Subcommittee Chairman Adam Smith Hearing on DoD's FY10 Budget Request for S&T Programs

May 20, 2009

Subcommittee will meet to discuss the Fiscal Year 2010 National Defense Authorization Budget Request for Department of Defense Science and Technology (S&T) programs.

"This hearing provides us with an opportunity to review the status of current S&T programs and discuss possible reforms to the acquisition process. We have some exceptional witnesses here today and I would like to thank them for attending and lending their expertise to this important discussion. We welcome you and your thoughts.

"The Defense Budget outlined by Secretary Gates recognizes that the threats we face today and the emerging threats of the future require us to make adjustments to our defense spending, including S&T programs and priorities. S&T programs are essential to maintaining our technological superiority and we must ensure they aim to confront the enemies we face today and in the future.

"Furthermore, Secretary Gates articulated three strategic goals to be supported through the FY2010 defense budget request: Take care of our people; develop the right capabilities for today and tomorrow; and reform the procurement, acquisition, and contracting process. With this hearing, the committee looks forward to hearing how the Department plans to shift their S&T policies and investments to meet these strategic goals.

"Unquestionably, improvements have been made to adjust our thinking and approach to meet these changing, irregular threats, but much more must be done. This subcommittee will continue to evaluate our defense spending and priorities and solicit feedback from the professionals who implement these programs.

"Again, I thank the witnesses for being with us today and look forward to discussing this important issue."

Miller Opening Statement for Hearing on Fiscal Year 2010 Budget Request for Department of Defense Science and Technology Programs

May 20, 2009

Washington, D.C. – U.S. Rep. Jeff Miller (R-FL), Ranking Member of the House Armed Services Subcommittee on Terrorism, Unconventional Threats and Capabilities, today released the following prepared remarks for the subcommittee's hearing on the Administration's Fiscal Year 2010 budget request for science and technology programs at the Department of Defense:

"In his April 6th press conference, Secretary Gates provided us our first glimpse into the significant investment decisions he was proposing to the President and that would later be reflected in the Fiscal Year 2010 budget request. The Congress will have many questions for the Secretary and Department officials over the coming weeks as we are finally getting to see the details of what was only a conceptual framework until last week when the budget was finally released.

"During his press conference, Secretary Gates indicated that the Department of Defense would undergo a reshaping of its priorities to transform the way it does business and to better meet today's challenges. I think it is undeniable that we face many, and varied, challenges, both in the threats we face and in the way we provide for the nation's defense, and therefore I am adamant about taking both a prudent and practical approach to our consideration of this year's budget request. Our job is complicated, however, by the fact that we only have Fiscal Year 2010 figures with which to work. We have been told that future programmatic decisions will be based on the outcome of the 2010 Quadrennial Defense Review yet there are some significant budgetary moves found in the Fiscal Year 2010 budget. All this makes me wonder what analysis supports the decisions reflected in this request and whether we have a budget that truly reflects an appropriate balance of defense investments, not just for the short-term but for the long-term.

"These are important points to keep in mind today as we hear testimony from leaders from the Department's research, development, test and engineering community. Over the past several years, the members of this subcommittee have been keenly interested in finding an appropriate balance of investments between conventional needs and increasingly important irregular warfare capabilities. Our discussion today is of particular importance as research and development has a significant impact on providing current and future capabilities to our forces. If we do not make the right, or do not provide sufficient funding, for research and development, our forces could find themselves without needed capabilities.

"In recognition of the importance of these investments, previous budgets submissions took particular care to maintain research and development funding. In fact, the Fiscal Year 2009 request provided an overall four percent increase in science and technology funding from the previous year's levels. We find in this year's budget an overall decrease in the research, development, testing and engineering accounts from the previous year—a potentially worrisome signal that we may be trading away future capability.

"I look forward to today's testimony and am very interested in understanding how the Fiscal Year 2010 budget represents the best investment we can make for our nation's security. I want to be reassured that our investments represent the most prudent and pragmatic use of limited resources and provide the best capability for the U.S. taxpayer dollar. Also, given Secretary Gates' desire to reform the acquisition process as well as congressional bills targeting acquisition reform, I would like to hear your thoughts on reform as it relates to research and engineering, which play critical roles in the acquisition process. Ultimately, we are talking about our nation's defense, and the members of this subcommittee—indeed the America public—need to know that we can, and will be able to, meet the myriad threats we face, now and into the future."

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HOLD UNTIL RELEASED
BY THE COMMITTEE

STATEMENT TESTIMONY OF

MR. ALAN R. SHAFFER
PRINCIPAL DEPUTY, DEFENSE RESEARCH AND ENGINEERING

BEFORE THE UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON ARMED SERVICES

SUBCOMMITTEE ON TERRORISM, UNCONVENTIONAL THREATS
AND CAPABILITIES

May 20, 2009

Introduction

Good morning Chairman Smith, Ranking Member Miller, members of the Committee, I am pleased to be here on behalf of the nearly 100,000 Department of Defense Science and Technology (S&T) men and women who strive to discover, develop, mature, and field the best possible technologies at an affordable price for the soldiers, sailors, airmen, marines, and civilians deployed in defense of our nation and national objectives. To meet this challenge requires us to develop the best capabilities we can from our DoD laboratories. It also requires us to partner with all elements of the national infrastructure developing advanced technologies—academia, industry, small business, and other federal agencies. Finally, delivering the best possible technology to our deployed forces, and those forces allied with us, requires us to join with partner nations when possible. Taken together, developing and delivering the best possible technology to our forces is a complex and multi-faceted effort. It is my distinct honor today to provide information to show that we are making progress toward addressing this challenge on a number of fronts.

This is an exciting time to be in DoD S&T, a time with a great deal of on-going change of focus. For the third straight year, we submitted a President's Budget Request for Science and Technology that conveys substantial change driven by the continuing shift in national security priorities to meet the requirements of fighting our current irregular military engagement. Counter-insurgency warfare and the battle against terrorists, requires the DoD to continue to expand our capabilities in diverse areas such as persistent surveillance, protection technologies, cultural and social modeling, and other non-kinetic capabilities. At the same time, the Department needs to maintain adequate conventional operational capabilities. In total, we have moved over $6 billion of S&T investment over the last three President's Budget Requests[1] to address new mission areas.

This year's budget submission was guided by four strategic principles[2]—the first stated by Secretary of Defense Gates in his FY 2009 Budget posture hearing; the other three were highlighted in Secretary Gates' April 6, 2009 speech that laid out the budget priorities for the Department of Defense.

In a February 2008, during the FY 2009 Defense posture statement, Secretary Gates specifically highlighted the need to expand basic research when he said:

> "As changes in this threat environment create strategic challenges—irregular warfare, weapons of mass destruction, disruptive technologies—this request places greater emphasis on basic research, which in recent years has not kept pace with other parts of the budget."

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[1] The $6B estimate represents the planned budget developed through the Future Year's Defense Program—effectively, the planned investment from the present through 2013 to 2015. The actual investment will likely have some modifications, but the planned investment does indicate the priorities of the Department.
[2] Throughout this testimony, we will refer to four strategic principles; these are made up of the FY 2009 priority for basic research and three strategic imperatives from Secretary Gates April 6, 2009 speech.

While Secretary Gates emphasized this strategic imperative last year, the importance also has been highlighted by President Obama, who said, in a major speech at the National Academies of Science on April 27, 2009. In this speech, President Obama said:

> "I believe it is not in our American character to follow – but to lead. And it is time for us to lead once again. I am here today to set this goal: We will devote more than three percent of our GDP for research and development. We will not just meet, but we will exceed the level achieved at the height of the space race, through policies that invest in basic and applied research..."

The three remaining strategic priorities or imperatives were defined by Secretary Gates in his speech of April 6, 2009 outlining the Department's budget priorities. This speech clearly stated these imperatives of the Department, which are:

1. Taking care of our people
2. Developing the capabilities to fight the current and future wars
3. Improving our acquisition capabilities and accountability.

The Department of Defense S&T budget submission we are discussing today addresses all of these priorities and more, building upon our budget request of the past several years, that aligns the S&T investment to Irregular Warfare challenges. We will discuss each of these principles in detail and highlight the recent accomplishments of the S&T program after we provide a macro-scale overview of the Department's S&T budget request.

The Fiscal Year 2010 Defense S&T Budget Request – Macro-scale

The FY 2010 President's Budget Request of $11.649 billion represents a strong Department of Defense continued corporate commitment to investment in S&T. This commitment continues despite a challenging budgetary environment supporting deployed military operations and other growing non-discretionary departmental obligations. Specifically, the FY 2010 request came within 0.5% of maintaining real growth compared to FY 2009. In fact, the S&T program fared well in comparison to many other discretionary accounts. For instance, the RDT&E budget categories of Advanced Component Development and Prototypes, and System Development and Demonstration both encountered over 9% real reductions.

It is perhaps more important to take a look at the recent and long term trend of DoD S&T funding; the combined growth of the DoD S&T budget request from FY 2008 to FY 2010 budget is about 4%, in real terms. From FY 2002 to 2010 the S&T budget has grown nearly 15% above inflation, or a sustained growth of nearly 2% per year. Figure 1 shows the President Budget Request, in constant dollars from 1997 to 2010 – clearly the DoD has increased emphasis on S&T. Even more telling is the long-term view of Defense S&T investment, since 1962 as seen in Figure 2. In fact, in constant dollars, and with the exception of a one year spike in 1992 due to the Technology

Reinvestment Program, the largest seven budget requests have come since 2002, and the FY 2010 request is near the top.

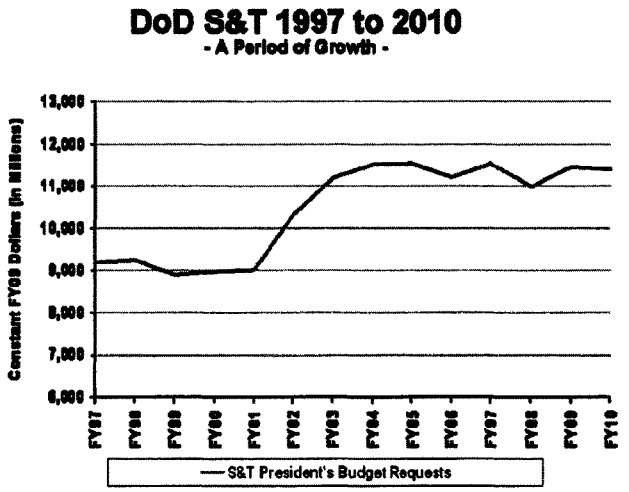

Figure 1

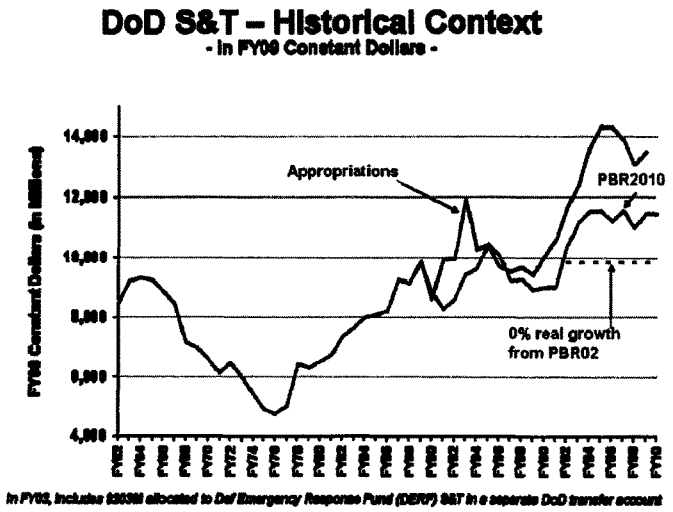

Figure 2

Table 1 shows the specifics of the FY 2010 budget, compared to FY 2009, by budget category.

Comparison of DoD Research and Engineering Requests
(President's Budget – Total Obligation Authority)

	FY09 PBR	FY09 Approp	FY10 PBR *(Constant Year FY09)*	CY Real Change from PBR FY 09
Basic Research (BA 1)	1,698	1,822	1,798 *(1,763)*	+3.8%
Applied Research (BA 2)	4,245	5,090	4,246 *(4,163)*	-1.9%
Advanced Technology Development (BA 3)	5,532	6,537	5,605 *(5,494)*	-0.7%
DoD S&T	**11,475**	**13,449**	**11,649** ***(11,419)***	**-0.5%**
Advanced Component Development and Prototypes (BA 4)	15,774	15,667	14,30 *(14,023)*	-12.5%
DoD R&E (BAs 1 – 4)	**27,249**	**29,116**	**25,955** ***(25,442)***	**-7.8%**

Table 1

FY 2010 continues the trend of moving investment from kinetic to non-kinetic capabilities. As with the past several years, the Department made a deliberate decision to increase investment in the Services relative to the Agencies and Office of the Secretary of Defense. Consequently in this year's budget request, the Services once again account for more than half of our total S&T investment. Embedded within FY 2010 budget are a number of areas of increased investment. These include:

Medical S&T (enhancements in Army, DARPA, and Defense Health Program. The Medical S&T (6.1-6.3) enhancements of $484M in FY 2010 address research needed for improvements in casualty and family medical care (DHP $95M; Services $242M; DARPA $144M; Defense-Wide $3M). This medical S&T investment builds on research in areas such as clinical approaches to poly-trauma, prosthetics, tissue, limb and organ regeneration and prevention, diagnosis, treatment, mitigation and rehabilitation of traumatic brain injury, post-traumatic stress order, and military eye injuries.

Expanded Cyber Protection (DARPA, Services). Allocates about $50M per year to fund information assurance science and technology for intrusion prevention and detection of the department's critical networks in support of the Global Development of the Force Study S&T findings.

Expanded Anti-Tamper Technology (Air Force). Funds $32.6M in FY 2010 for vulnerability assessments of critical program information, verification and validation of

protective procedures and techniques, and development of new technologies to improve anti-tamper capabilities. Special attention is being focused on making commercial-off-the-shelf components and technologies more tamper resistant.

Stand off Detection of Fissile Materials (Defense Threat Reduction Agency). The FY 2010 increase of $40M enhances the proliferation prevention of fissile materials.

Large Data Handling Capabilities (Defense-Wide) Joint Data Management S&T investment of $10M in FY 2010 supports advanced research to improve the handling of large and increasing amounts of information supporting current and emerging warfighting missions. This effort will seek new and novel ways to architect information processing pipelines and exploit other point solutions emerging within the research base. This research program will conduct independent objective quantitative assessments to demonstrate the improvements made in data management and exploitation. These assessments will explore ways in which the Department improves both in technical performance and in warfighting effectiveness.

Sociology Research (Army as Executive Agent -- project called Minerva). Adds $20M in FY 2010 for a DoD and National Science Foundation partnership to develop intellectual capital in the university-based social science research and to further establishing relationships with universities, research institutions and individual scholars to address topics in the social sciences that are of strategic importance to national security. Core Minerva funding is being executed by Army Research Office to continue growing the Department's internal capacity.

High Performance Computing Modernization (Defense-wide). In FY 2010 an increase of $10M funds continued operations at High Performance Computer Centers which increases net supercomputing capability by 50%. This will allow the RDT&E community to conduct more in-depth and a greater number of science-based simulations impacting basic and applied research, systems development and test and evaluation.

Power and Energy (Mostly Army). Energy security is a high priority focused on the S&T strategic goals of reducing platform energy consumption, developing more efficient power sources, enabling smart energy management, developing proactive thermal management, and developing and evaluating alternative fuels. The FY 2010 S&T investment funds efforts in the development of high power and high energy density components, power and thermal management technologies for platform power and higher efficiency electrical components for electronics and power generation.

Cognitive and Neurosciences (Mostly Army). Advances research in the human nervous system to develop technologies that exploit the capabilities of the nervous system structure and function to improve and optimize soldier-system performance. FY 2010 S&T funding investments in the fields of neuroscience, human factors, psychology and engineering will enhance our understanding of brain function and behavior outside the confines of standard research laboratories for development of tools to optimize information transfer between the external systems and the Soldier, identify mental processes and individual differences that impact mission-relevant decision making, and

develop technologies for individualized analyses of neural-based processing in operational environments.

Composites (Air Force). In FY 2010, about $35M will fund the Advanced Composite Cargo Aircraft (ACCA) platform to assess and validate the structural behavior and cost impact of using large out-of-autoclave composite component(s) as a primary structure. Funds are being used to validate the design tools that characterize the performance and behavior of the material, along with reliability testing of a replicate fuselage barrel section to characterize the performance of the design over time.

Changes in World-Wide S&T

As previously stated, Secretary Gates characterized challenges facing our nation and the Department of Defense, changes which have led him to personally shape the Defense Department's budget. Embedded within the changes in the worldwide geopolitical and economic landscape are significant shifts in the global science and technology landscape. These S&T changes consequently impact the Department's investment projections. There are numerous factors that, combined, make this a complicated and ambiguous time for S&T. Such influential trends escalate technological risk, and most of the trends are not something we can do anything about. Taken together, they culminate in an increased risk of technology surprise, and underlie the priority of S&T outlined by Secretary Gates. This priority, in turn, supports the need for the Department to maintain a robust S&T investment. These risk factors include, but are not limited to the following four themes:

1. **Increasing world-wide generation of scientists and engineers relative to the US and Europe**

It can easily be said, and supported with data, that the rest of the world is getting smarter. As world populations rise, the rate of doctoral degrees in the natural and physical sciences is growing in China at a rate that is increasing twice as fast as that in the US. While the number of U.S. doctoral degrees awarded in science and engineering has increased three decades in a row, virtually all of the recent growth reflects a rising number of degrees to non-U.S. citizens: 60% in engineering and computer science and nearly 45% in the physical sciences. Additionally, the ability of the US to attract the world's brilliant minds continues to fall as the rest of the world's institutions of higher learning expand and improve. According to the National Intelligence Council report "Global Trends 2025 – A Transformed World," it is educational opportunity that underpins innovation in the US along with several other key characteristics of our free market society. This is evident in two specific trends associated with education. In 2006, for the first time in history, the US fell behind the UK in ability to attract and educate foreign born scientists and engineers in country and according to the National Science Foundation the percentage of foreign born scientist and engineers that return home is continuing to rise.

2. Growth in world wide R&D investment relative to the US

According to numerous data sources and forecasts by the government and industry the Global growth of R&D spending is expected to continue despite the global economic downturn. While the US spending has slowed, Asian countries continue to grow their share of global R&D. Further, R&D spending and forecast data which show that after peaking in 2004, the amount of in sourcing funds for U.S. R&D has steadily declined one to two percentage points per year.[3] Specifically, R&D spending in China is expected to be more than 1.5% of GDP. This becomes significant because China's R&D expenditures are projected to grow at a rate of just over 6% in 2009 while the rest of the world is contracting. Fundamentally, according to National Science Foundation Science and Engineering Indicators (2006), R&D investment in the rest of the world has grown at three times the rate of the US. Despite the recognition of the US as a country with the world lead in innovation opportunity, this trend is expected to continue as a large percentage of multi-national companies have plans to build leading edge research and development facilities, not just manufacturing facilities outside the US.

3. Increasing use of commercial technology

A number of critical uncertainties in the global technology landscape are centered on the acceptance, availability and proliferation of commercially available technology. In earlier years, many high technology items were expensive and were only within the fiscal purview of military organizations and nation states with sufficient economic strength. In the last decade S&T has become commoditized and global technology distribution, linked with the formulation of global policy provides individuals, small groups, non-state actors and non-government organizations the ability to harvest commercial high technology in new ways to generate capable systems on par with military equivalent capabilities. It is interesting that the terrorists operating in Mumbai used all commercial technology to include commercial cell phones.

Several commercial technology hybrids were identified recently to have potential impact for Department consideration. These include bio-genetics, energy technology, advanced robotics and internet offshoots. In each of these the US position has become one of a high technology net importer. This means that the spectrum of technology options controlled external to the US has the growing potential to generate technology surprise and disruption due to applications and uses.

4. Accelerated pace of technology development

Given current demographic trends and the increasing quantity and quality of science and technology around the world, the rate and pace of technology development is increasing at a non-linear, almost exponential pace. Five years from now, it is projected that you will see some leading technology being developed first in India or China and

[3] "2009 Global R&D Funding Forecast", Battele and R&D Magazine Report, December 2008, Inset Chart Caption, Page 22

flowing back to the West.[4] With the acceptance of mass collaboration and the maturation of multi-country consortia, emerging technology is accelerating from the laboratory to application at an alarming rate. As an example in 2004 one of the first functional metamaterial structures able to "hide" an object went from the laboratory bench to a working prototype in less than 6 months. In Africa, due to the lack of land lines, the use of cellular devices is expected to go straight to 4G capability skipping generations of communications technology. In the area of Quantum Information Science the race to distribute quantum keys to increasing wireless distances has moved from the laboratory at a couple of meters in 2007 to a successful demonstration by Austria's Institute for Quantum Optics and Quantum Information who this month managed to send entangled photons 144 kilometers (90 miles) between the Spanish islands of Las Palmas and the Balearics.

These factors have led the Department to substantially shift our investment over the past three years as articulated on April 6th by Secretary Gates.

Secretary Gates' Strategic Principles and the Relevance to Defense S&T

Basic Research

As mentioned, the first strategic principle articulated by Secretary Gates is the importance of basic research to the future of the DoD. Over the past two budget requests, the Department has increased basic research over 16% and 4% respectively. In order to coordinate the investment, the S&T Executives of the Department developed and implemented a white paper to guide the execution. This white paper provided basic research focus areas for which we have chosen to focus our efforts around. These areas are:

- Cyberprotection and information assurance
- Network sciences
- Science of autonomy
- Information fusion and decision science
- Biosensors and biometrics
- Human sciences (including social science)
- Software sciences and materials
- Immersive sciences for training
- Power and energy management
- Counter directed energy weapons

We would now like to highlight some aspects of the current program. DoD Basic Research provides an essential source of new knowledge and understanding in science and engineering areas that underpin national defense. Today's science and engineering

[4] Beyond the Borders – The Global Innovation 1000

research leads to tomorrow's new technologies, which in turn transforms tomorrow's battlefield. In this globally connected S&T world, we need to be assured that US applies its intellectual and technological resources to keep ahead of a determined and sophisticated adversary.

Transforming the battlefield to keep the US capabilities superior means going back to the basics. The Secretary focused on Basic Research in a time of great demands on budgetary resources to meet operational and other near term purposes. That reflects our belief that the Department needs to aggressively tap into the capabilities of the research community if the U.S. military is to continue to maintain the technological superiority over potential adversaries that has been a hallmark of our national defense strategy for half a century. To cite just a few examples of the research opportunities that the increased investment in FY 2009 has enabled us to pursue:

- The computing and communication capabilities made possible by quantum physics have significant potential impact on information processing, assurance, and exploitation for the DoD. The additional resources available to this topic area have initiated research into discovering, understanding, and exploring small entangled quantum systems for their capability to sense and measure beyond fundamental classical limits. The research involves some of the most fundamental and difficult aspects of quantum physics carried out by leading scientists and institutions in a variety of physical systems, such as trapped atoms and ions, photons, superconductors, and semiconductors. The benefits for the DoD are a potential new class of capability in *cyberprotection* cryptography, sensing and metrology, such as gravity gradiometers, clocks, magnetometers, gyroscopes, detectors for very low electromagnetic radiation.

- In support of increased investment in *energy and power management* research, DoD funds research in heteroepitaxial thin film semiconductor growth that will directly contribute to power generation (solar cells) and energy conservation in communications and chip-to-chip data. The current research offers to provide a real breakthrough in the development of high conversion efficiency solar cells and lower power electronics including silicon-based optoelectronics for telecommunications and computing, areas that are very important for DoD.

- In *information assurance* major advances are being made by the Air Force in the rapid forensics of cyber attacks to enable timely and effective responses, as well as to reliably predict attacks. The Air Force also sponsors research in the active defense of cyberspace and controlled out-of-band communications, such as steganography.

- The Army Research Office's Historically Black Colleges and Universities/Minority Institutions (HBCU/MI) program supports two science, technology, engineering, and math (STEM) programs – the Core HBCU/MI program, and the Battlefield Capability Enhancement Center of Excellence (BCE COE) program totaling over $4 million annually. There have been numerous research accomplishments since the inception of the HBCU/MI Core Program in 1980 and the BCE CoE program in 2003,

including recent research into promising new materials for armor protective composites.

- The Minerva initiative, funded in the Army, seeks to increase the Department's intellectual capital in the *social sciences* and foreign area studies, improve its ability to address future challenges, and build bridges between the Department and the academic social science community. To these ends, Minerva brings together universities, research institutions, and individual scholars and supports multidisciplinary and cross-institutional projects addressing specific topic areas determined by the Department. This program will enable the Department to build long-term relationships with universities while attracting a new generation of academics interested in working on issues of interest to defense policymakers.

While these are just a few examples, the basic research investment portfolio as a whole is well focused in areas with the highest potential for long-term military benefit. Therefore, while DoD's investment is a relatively modest 5% of the total Federal basic research investment, it complements other Federal programs and provides the major source of funding in selected disciplines or subdisciplines. In relation to the total Federal investment in basic research performed by universities, DoD provides 65% of the total in electrical engineering and 85% of the total in mechanical engineering.

It is important that the Department maintains a vigorous program of world-class basic research in universities, other private-sector organizations, and DoD laboratories. Basic research performed in universities is especially important because it is an integral part of the education and training of scientists and engineers for the nation's defense workforce. DoD supports more than 9,000 graduate students in defense-critical fields, largely through the Basic Research program.

Investment in basic research should continue to be a high priority for the Department.

Taking Care of our People

In his April 6th speech, Secretary Gates cited the first priority as "Taking Care of our People." In his speech, Secretary Gates highlighted areas such as enhanced medical care; research and development; improved housing; and so forth. Several of these are elements have clear aspects that are firmly in the S&T realm, including:

1. Medical R&D and Wounded Warrior
2. Training Initiatives[5]
3. Science, Technology and Mathematics Education and Workforce Shaping[6].

[5]Not specifically cited in taken care of our troops in Secretary Gates' speech; but, we content they meet the intent

[6]Not specifically cited in taken care of our troops in Secretary Gates' speech; but, we content they meet the intent

1. Medical R&D and Wounded Warrior Activity:

The most significant way that the S&T community is addressing Secretary Gates charge to "take care of our people" is medical research and development. About 18 months ago, in recognition of the exceptional importance and urgency of improvements in combat casualty care, the Department conducted an extensive review of medical research and development. This review was jointly chaired by the Office of the Director, Defense Research and Engineering (ODDRE), the Joint Staff and the Assistant to the Secretary of Defense for Health Affairs. This review used the Joint Force Health Protection Concept of Operations to focus the effort. Wounded warrior focus areas of Traumatic Brain Injury (TBI), Post Traumatic Stress Disorder (PTSD), prosthetics, eye injury and other deployment and battlefield injuries, provided a key context for the assessment. A JFCOM-led capability assessment had identified over 200 gaps in Joint Force Health Protection. Of these gaps, about 30 percent (69 of 229 were assessed as having medical R&D solutions and only 1 of these R&D-relevant gaps was adequately addressed by the FY 2009 budget. The assessment resulted in the justification for a medical R&D budget increase. The majority of the increase in the FY 2010 budget request was placed in the Defense Health Program (DHP). In addition to the DHP increase, a program reallocation from within the Defense Advanced Research Projects Agency (DARPA) and additions to the Army and Navy RDT&E budgets results in the approximately $500M aggregated increase in the Department's medical R&D portfolio. The increase is wholly assigned to emergent capability gaps directly applicable to wounded warriors and to associated requirements from Congressional directions over the past two years.

The increase to the Department's medical R&D funding request will be used to advance the state of medical science, technologies, and practices in those areas of most pressing need and relevance to today's battlefield experience. Early emphasis will be on psychological health, traumatic brain injury, prosthetics and rehabilitation, restorative eye-care, poly-trauma and supporting medical information and training systems. These areas align with direction that Secretary Gates gave to the Department in June 2008. Research projects will be selected for funding using a competitive process where Department of Defense researchers, industry and academia will submit proposals for specific research and development projects. By using this process, the most promising and expedient medical solutions will be developed and fielded for the Joint Force. The program has a significant new allocation of budget in the 6.4 category for technology transition, clinical applications, and product development. This allocation in a new DHP advanced capability development and prototyping (6.4) program element will ensure that the results of many years of core medical science and technology and the recent large allocations in the supplemental appropriations have resources for transition into medical practice. The governance of this expanded medical R&D will be through the established mechanisms of the Armed Services Biomedical Research Evaluation and Management (ASBREM) Committee which is chaired by the DDR&E and co-chaired by the Assistant Secretary of Defense for Health Affairs. This Committee was recognized by Congress some 15 years ago as the venue for cross-Department coordination and cooperation of

medical R&D. We are committed to sustaining and strengthening the ASBREM Committee's governance role.

In addition to the focused wounded warrior initiative, it is important to recognize the progress made through DDRE-managed programs over the past several years. One highlight comes from the Office of the Secretary of Defense (OSD) Manufacturing Science and Technology (MS&T) Prosthetic and Orthotics Manufacturing Initiative (POMI) which addresses the medical practice at Walter Reed and The Center for the Intrepid at Fort Sam Houston, Texas military medical installations where our nation's most deserving receive care. The POMI effort will characterize and combine new resin materials for increased durability and comfort with new automated manufacturing processes to provide custom composite sockets that can be repeatably produced. Today, fit and performance rely on a hand-made labor intensive process with a prosthesis craftsman, resulting in each socket performing uniquely from provider-to-provider. The new processes will minimize the labor intensive fit-make-fit adjust-fit-adjust cycle for each socket and enable replacement sockets to be produced exactly like the original socket, ensuring consistent comfort from socket-to-socket. Prosthetic devices are then secured to the wounded warrior through use of a custom socket. The tasks included in the POMI initiative were selected as strategic investment focus areas through a road mapping process in partnership with Walter Reed, the Center for the Intrepid, and the Telemedicine and Advanced Technology Research Center. Clearly, these advances present advantages to a much wider population of civilian beneficiaries.

Another example of advances for medical R&D comes from the DoD Foreign Comparative Testing program, a program that seeks out potential solutions from our allies for rapid testing, acquisition, and fielding. Testing of an expeditionary airfield light duty mat system produced by Deschamps, France, enabled the 1st Marine Expeditionary Force and the Army's 10th Mountain Division to establish stabilized landing areas for medical evacuation, and forward ammo and refueling points for rotary-wing aircraft operations. Over 30 systems have been procured by Army, Marine Corps, and the U.S. Special Operations Command for Overseas Contingency Operations. An upgraded matting system is currently being tested to withstand exhaust heat for V-22 employment; when fully deployed in 2010, these mats should enhance combat casualty care across the Department.

The S&T program in FY 2010 demonstrates a strongly enhanced commitment to taking care of the medical needs of the forces we deploy – a force called "our greatest strategic asset" by Secretary Gates.

2. Training Initiatives:

Another way we can support Secretary Gates' priorities to take care of our people is to prepare them for the environmental and operational conditions in forward mission areas. S&T funding supports the Department's efforts to analyze complex cultural and insurgency environments, to experiment with new operational concepts attuned to these

mission conditions, and to devise the doctrine, procedures and training that safeguard our people on foreign and dangerous assignments.

At the foundation of training enhancement is integrated live, virtual, and constructive (LVC) modeling and simulation environments that emulate joint war-fighting conditions across a network of interoperable sites and participants to meet the training needs of the combatant commanders and the Services. The Defense Modeling and Simulation Coordination Office (MSCO), a subordinate office within DDR&E, leads a Defense-wide effort for developing, testing, and maintaining standards for LVC training environments. The LVC environments meld existing operational and strategic applications with live forces and those training in simulators to create a more robust and realistic experience, and allowing our forces to train more realistically before deployment. From networked scenario solutions to unite geographically segregated units for combined pre-deployment training, to immersive environments for cultural awareness and rules of engagement indoctrination. LVC technologies enable more effective mission preparation while managing risk to our warfighters.

Recent M&S Senior Steering Committee (M&S SC) funded training projects have focused on improving the spectrum of distributed training environment capabilities and tools. The Joint Data Alternatives addresses the need for rapid scenario data generation, and will effectively support a variety of training, testing, planning, mission rehearsal, and decision support events. The Architectural Roadmap has recommended a series of actions promoting greater commonality and more efficient environments, leading to reductions in integration costs for distributed M&S. Additionally, the Training for Aviation in Urban Operations addresses today's pressing need for representing urban environments to train and prepare our forces for the conduct of attacks on ground targets with more precision and less collateral damage. These examples of Departments M&S activities are helping the Services and COCOMS train the forces in a networked, distributed environment in which they will fight.

Demonstrations bridge developmental efforts and pragmatic employment of technologies. Training demonstrations are becoming a more important part of our Joint Capability Technology Demonstration (JCTD) Program. In FY08, we initiated the Future Immersive Training Environment (FITE) JCTD project in response to an emergent combatant commander need. This project is delivering integrated, immersive technologies to build training realism and enhance our soldiers' and marines' preparation for Irregular Warfare. We expect this JCTD to deliver FITE JCTD Software; open architecture standards; immersive visual projection (helmet mounted for individual soldier use or wall mounted); specialized sound system (hearing the bullets pass your head, on which side, etc.); Haptic vests (special vest to provide pain and body sensations during uncomfortable immersive situations/environment); olfactory system (smell generator); individual position and weapon tracking system (to provide soldier orientation during virtual and augmented reality training environments) in 2010. These serious training enhancements deliver improved mission capabilities with consequent conservation of travel expenses and time.

We also take care of our people by focusing experiments on understanding the anticipated scenarios of the future to allow the forces to train better. Executed in partnership with United States Joint Forces Command, the Joint Experimentation Program is the Department's pathfinder in developing the doctrines and operational concepts foundational to Irregular Warfare. Joint Experiments are formulated in response to priorities set by combatant commander customers and Service partners with current subjects reflecting the urgent shift to augmenting conventional warfare capabilities with a comprehensive set of Irregular Warfare force constructs and employment options. The overarching Irregular Operations Joint Operating Concept and associated Joint Integrating Concept ("IW JOC & JICs") are under development as Joint Experimentation projects. These efforts will yield the authoritative DoD framework for irregular and complex operations including Foreign Internal Defense (FID), Counter Insurgency, and unconventional warfare developing a greater representation of Irregular Warfare, which allows us to better take care of our people.

3. Science, Technology, Engineering, and Mathematics (STEM) Workforce

A final way the S&T program can be used to take care of our people is to enhance Science, Technology, Engineering, and Mathematics (STEM) Education. As highlighted in the President's speech to the National Academy of Sciences on April 27, 2009, and I'll paraphrase, we are called upon to use our knowledge of science to engage a new generation of scientists and engineers, to enhance teacher preparation and training, and to support inventive approaches to develop new and innovative ways to attract experienced scientific professionals into the classroom. But by expanding our STEM education programs, we provide avenues for returning service members and their families while reducing the stress on today's civilian and military force.

The education of a new generation in the STEM disciplines in the context of a very competitive world is one of the key challenges of our country, and for the Department of Defense, and the undergirding for our future national security. DoD scientists and engineers account for nearly 50 percent of the entire workforce of Federal scientists and engineers—and we take care of our people by improving the ability to shape the workforce of the future.

It is important to recognize that STEM and outreach have a number of individual programs across the Department and the DDRE staff is involved in improving the Department-wide transparency of STEM programs. I wish to highlight a relatively new but I think successful program initiated in 2006 by Congress: the National Defense Education Program (NDEP). NDEP currently has three major initiatives. The first is the Science, Mathematics and Research for Transformation (SMART) Program which is an undergraduate and graduate scholarship-for-service program. Over the past year, we have transitioned nearly 40 SMART students into the DoD laboratory workforce and funded several hundred of new and continuing SMART students.

The second initiative is the National Security Science and Engineering Faculty Fellowship or 'NSSEFF' Program which is a prestigious faculty award Program.

NSSEFF, which began in 2008, is funding 18 top-tier university researchers to conduct unclassified, long-term basic research in areas that underpin future DoD technology development.

The final program is the pre-college math and science program, or PEP, which is engaging and developing students' interests in math and science through inquiry-based activities and LabTV webisodes that introduce our scientists, engineers and cutting edge technology to the K-12 students throughout the country. To date, PEP has provided professional training for hundreds of teachers as well as providing support for our laboratory scientists and engineers (S&Es) in the classroom partnership initiative. Our S&Es and teachers work collaboratively in engaging students in real-world problems.

In FY 2010, SMART will continue to transition students into the Army, Navy and Air Force laboratories and build our near term workforce. PEP will, among other things, expand to nearly 25 States and continue to engage DoD S&Es with students and their teachers. Also in FY 2010, we will issue a new NSSEFF Broad Agency Announcement and make new awards. Although relatively young, NDEP has been received positively from the local to national level. Further, it has been a positive force in the Department as it is a DoD-wide program in which all three Services have been active partners.

In summary, taking care of our people is a cornerstone of the Department. While this is most closely aligned with Medical S&T, there are other areas that provide depth to our forces' understanding of their present (training) and future (STEM) challenges. Taken as a whole, we believe this demonstrates some success, although there is much left to do.

Developing the Capabilities to Fight the Current and Future Wars

The second priority highlighted by Secretary Gates in his April 6, 2009 speech is to "institutionalize and enhance our capabilities to fight the wars we are in today and the scenarios we are most likely to face in the years ahead. What this means practically is that we need to continue the shift of investment capabilities from kinetic to non-kinetic capabilities to meet the special challenges of Irregular Warfare. As outlined in the 2006 Quadrennial Defense Review, and reaffirmed by Secretary Gates, the DoD needs to continue to develop capabilities in a number of new technology areas supporting Irregular Warfare capabilities.

In order to demonstrate how the Department's S&T program supports development of new capabilities, we would like to highlight some recent and future efforts in the following areas:

1. Intelligence, Surveillance, and Reconnaissance
2. Large Data Processing
3. Command and Control and Network Sciences
4. Cyber Protection
5. Social Modeling
6. Irregular Warfare Modeling and Simulation / Joint Experimentation

7. Energy Efficiency for Forward Deployed Forces
8. Other Irregular Warfare S&T Efforts

1. Intelligence, Surveillance, and Reconnaissance

The Secretary of Defense has noted that contemporary warfare, and especially information-based warfare, requires increased intelligence, surveillance, and reconnaissance (ISR) support for our warfighters. To meet this need, the Secretary established the ISR Task Force in 2008. However, the Department's S&T program has been involved in bringing about new ISR capabilities throughout the current conflict.

For instance, ISR has been a focus of the JCTD program – and its precursor Advanced Concept Technology Demonstration (ACTD) program -- for several years. JCTD projects have demonstrated and transitioned both ISR platforms and sensors. For example, the Predator and Global Hawk unmanned air systems grew from Service S&T and early DARPA and Service experiments culminating in ACTDs to demonstrate the capability. Today, our JCTD program is investing in the next generation of unmanned platforms for ISR. An example is the Global Observer, a hydrogen powered, high altitude vehicle capable of carrying multiple sensors simultaneously on missions lasting 10-14 days. Global Observer is under construction now, and is expected to begin flight testing by October of this year. Another is Zephyr, a low-cost, solar-powered vehicle capable of carrying small payloads 5-7 days at high altitude. Zephyr was flight tested in 2008, including a flight of over 82 hours with a communication relay payload, an unofficial world endurance record for fixed wing unmanned aircraft. All of these platform advances could help fill persistent ISR gaps while potentially saving valuable resources. Finally, DARPA has just initiated the Integrated Sensors is Structure (ISIS) program, a program to determine if we can build and fly an extended duration "balloon" at high-altitudes with integrated sensors. This is roughly a four year program, but could revolutionalize current tactics, techniques and procedures.

The ACTD/JCTD program has also been at the forefront of developing sensors that operate in new and expanded domains. Such systems as Hyperspectral Collection and Analysis System ACTD, MAGNUM Polarimetric Imager ACTD, Foliage Penetration Radar JCTD, Airborne Weapon Surveillance System ACTD, and Joint Multi-Mission Electro-optics System JCTD are carried by our ISR platforms today. We continue to develop new concepts, ranging from complex multi-sensor turret systems aboard both manned and unmanned platforms, to miniature hostile fire detection, localization, and classification systems for small unmanned air platforms. One current project integrates multi-spectral and other sensors in a small turret, and includes on-the-fly multi-spectral processing for automated target alerting of concealed targets.

Current technology involving commercial satellite Synthetic Aperture Radar (SAR) imagery is limited by resolution, polarization, and global surveillance coverage. The Rapid Reaction Technology Office (RRTO) is leading the development and testing of the first real-time, low-cost SAR capability for battlefield commanders in small dispersed units. This system should allow us to detect minute changes in terrain,

infrastructure and other human activity, including troop and vehicle movement. The Synthetic Aperture Radar Coherent Change Detection (SAR CCD) capability is intended to produce immediately actionable intelligence by collecting and downlinking in near real time, SAR imagery using a tactical unmanned aerial system (UAS) at a cost of less than $500K per sensor package. Today, no tactical SAR platform with real-time CCD capabilities exists. The initial assessment of the SAR CCD technology demonstrated the ability to detect small (millimeter) changes in terrain left by footprints, vehicle tracks, digging and other human activities. These small changes were often discernable via the SAR but not with the human eye at ground level.

The RRTO also focuses on maturing ISR technologies that support Irregular Warfare needs, not only in support of current challenges in Iraq and Afghanistan, but in anticipation of different environments where we may operate in the future. The RRTO uses funds from the OSD Quick Reaction Special Projects program – a program that allows us to develop and demonstrate novel capabilities within a year to 18 months. The agility of the QRSP program allows the Department to meet emergent needs of the warfighter, and is a vital element of the overall DDR&E investment strategy. This program has placed a special emphasis on ensuring ISR capabilities in development are demonstrated in operational conditions before deploying. In the past, RRTO has helped prepare new capabilities for use in the field by sponsoring test beds and operational experiments at the Yuma Joint Experimental Range Complex, a venue to evaluate how well newly developed capabilities work in a simulated urban environment; and, on Stiletto, a maritime test vessel used to provide developers a way to inexpensively assess operational capabilities of maritime-related systems. Future technology developed by RRTO includes the Pelican heavier-than-air aircraft demonstration, which could ultimately provide a long-endurance lift capability by 2015.

The Foreign Comparative Testing Program is also sponsoring a project with the Defense Intelligence Agency using the commercial, Italian produced COSMO-SkyMed, a constellation of four SAR satellites that provide rapid revisit, 24-hour, global coverage of the Earth. If successful, this will increase the amount of imagery data, at a higher resolution, in a quarter of the time it takes today to get the same image from other satellites. The net result could be more timely tactical support to commanders on the ground. In short, the combination of UAV and space-based SARs should provide an incredible advancement to ISR capabilities.

Taken all together, the collective offices of the DDR&E have worked effectively with the Services to deliver a number of novel ISR demonstrations.

2. Large Data Processing

With the successful ISR demonstrations we have just talked about comes a significant challenge. Data streams amounting to terabytes of information, with the prospect of even bigger data sets in the future, now represent a realistic challenge that must be addressed. Without improving our ability process data and extract actionable intelligence, we run the risk of becoming data bound and information starved. This is

similar to highways—when highways have too many automobiles on them, the system stops working, and people don't move. Similarly, when data saturates communications architectures, finding the actionable information becomes nearly impossible. In recognition of the need to improve data handling capacity, the ODDR&E has identified several promising technical approaches for dealing with extremely large data sets, including techniques such as cloud computing, compressive sensing, dense correspondence algorithms, and topological data analysis. Our FY 2010 budget requests $10M to focus research efforts in this important area; while this is a small investment, we believe it is sufficient, and will pay major dividends.

The JCTD program also invests in novel processing advances to enable our warfighters to make best use of existing ISR information. Some illustrative programs include (1) new processing of data collected by satellites to isolate particular targets, such as the Signals Intelligence Processing ACTD which delivered new algorithms in 2007; (2) the Extended Space Situation Awareness which leverages missile defense and other sensors to improve awareness and tracking of space objects, transitioning in 2010; and (3) the Comprehensive Maritime Awareness JCTD that automatically collects and correlates information from hundreds of sources to assist maritime security analysts in both DoD and DHS, which transitioned to the Navy and US Coast Guard in 2009.

Finally, any improved capacity for handling large data requires experimental data sets. The RRTO has sponsored two major projects, with the Services and other government agencies, to develop very large test data sets—project Bluegrass and Thunderstorm.

Conducted in the Summer of 2008, Bluegrass amassed a significant (50TB) database of electro-optical and ground moving target indicator information collected in urban and rural environments. This database containing ground truth target tracks has been made available to numerous users in the defense community to assist in developing a multitude of ISR related capabilities.

Building on Project Bluegrass we developed a Multi-Intelligence ISR test bed to facilitate development and evaluation of ISR capabilities in a real world environment known as Thunderstorm. DDRE partnered with the Joint Interagency Task Force-South (JIATF-S) to conduct exercises two to three times a year. For each spiral, a set of challenge problems are designed to encourage technology development that will help DoD and JIATF-S "unravel the networks" associated with global threats to national security. Data gleaned from the multitude of sensors and analyses during Thunderstorm will help us in our joint mission to deny drug trafficking organizations (and terrorists) access to funds, supplies, and transportation resources.

The first Thunderstorm spiral will be executed from 9-22 Jun 09 focusing on solutions to pressing issues plaguing operations in and around Central and South America, and Africa. Exercise scenarios, which will involve DoD and interagency partners, will help define techniques to stop high speed boats and detect self-propelled semi-submersible vessels.

As part of Thunderstorm, we are also supporting ISR-related programs. RRTO is sponsoring the use of a low-cost mobile satellite ground station located at JIATF-S's Key West compound, combined with Israel's TECSAR Synthetic Aperture Radar satellite to demonstrate a streamlined, yet decentralized, approach for a theater commander to task and receive satellite images.

3. Command and Control and Network Sciences

Building upon our successes in ISR and data handling capabilities, we are also focusing on improving the command and control and network capacity to move data among dispersed operations.

The DDR&E Networked Communications Capability Program is designed to streamline DoD programs as well as to provide additional capability for today's warfighter. This program in conjunction with the Services has:

- Created and demonstrated a joint federated networking testbed, owned and operated by the government. This testbed is used to develop new network operations (NETOPS) technologies to integrate tactical networks and ensure that NETOPs technologies are "born joint."
- Demonstrated an airborne data and voice relay for small tactical units. DDR&E will demonstrate this recently prototyped package to both SOCOM and CENTCOM this year for possible immediate transition to support the war effort.
- Transitioned several technologies to existing programs of record (JTRS, WIN-T) to enable multiple users to simultaneously receive data and voice. The transition of this technology to different programs will ease integration and promote interoperability once these systems are fielded.

In response to an Urgent Need, DDR&E led the fielding and delivery of a new radio network. The Netted Iridium capability has been developed, delivered and fielded; this capability is a new type of beyond-line-of-sight network for disadvantaged users for use in Afghanistan and Iraq. Forty-four production-ready prototype radios and associated Iridium-based gateway networking technology are currently fielded, and 500 production radios will be delivered by the Army over the next year. This lightweight radio (<2 pounds) ground network provides voice and high capacity data for ground networks for people up to 100 nm apart, regardless of the terrain. The success of this DDR&E-led development is due to the close partnership of the Joint Staff, CENTCOM, and the US Navy (Dahlgren).

Effective command and control requires precise position, navigational timing data. The High Integrity GPS (iGPS) program is developing and demonstrating technologies that enable orders of magnitude improvements in the warfighter's positioning, navigation, and timing (PNT) anti-jamming (AJ) capabilities. The program exploits features currently available in the commercial Iridium satellite constellation and is an augmentation to the current and future GPS constellations. The focus is on the

development of technologies that (a) utilize ranging data from the rapid angle motion of the Iridium satellites for geo-location, (b) enable coherent integration of the GPS carrier phase signals for up to a 30dB increase in anti-jam performance, and (c) demonstrate satellite spot beam control to provide enhanced PNT capabilities in dense canopies, mountains, and urban canyons. Field tests with brassboard hardware in a moving vehicle have successfully demonstrated a two orders of magnitude increase in GPS AJ with decimeter position precision. Oversight of the iGPS program is led by the Deputy Under Secretary of Defense for Science and Technology and executed through Office of Naval Research by Naval Research Laboratory. SOCOM is providing input on user needs and assisting in field testing.

4. Cyber Protection

During the last year, DDR&E has championed the DoD's increased S&T efforts to address military cyberspace security. Prompted in part by calls from Congress and Executives from both the current and previous administrations, the DDR&E staff has implemented a $100 million per year investment increase. The program has a number of objectives, to include:

- Identified gaps and initiated new science and technology research executed by the Components to build technologies to defend our critical military networks from cyber attacks
- Championed DARPA's new efforts in cyber security and information assurance
- Reinvigorated DoD's science and technology efforts in all dimensions of cyber warfare.
- Actively engaged with the Office of Science and Technology Policy to lead interagency coordination to identify and develop leap-ahead technology for national security
- Enabled many small innovative companies to develop solutions for DOD cybersecurity challenges through the Small Business Innovation Program

While the details of the specific projects are classified, we are dramatically increasing our attention on this important area.

5. Social Modeling

As noted previously, we have initiated a social modeling basic research program called Minerva. To complement Minerva, we have the more mature OSD Human Social Culture Behavior (HSCB) program.

In its first year, HSCB modeling program rapidly established a foundation for success and begun delivering new initial capabilities to DoD users. The program is comprised of a Senior Level Users Group, an Integrated Project Team, and five technical working groups. A test bed for technology integration experiments and operational feasibility demonstrations has been established at the Army Geospatial Center. Building on this foundation, the program has moved quickly to identify and support cutting edge

research to develop computational models of social, cultural, and behavioral factors, and model-driven tools that can be transitioned to DoD programs of record. Funded work has already yielded some high impact success stories; Sentia Corporation's Senturion influence models were instantiated in PACOM/SOCPAC planning; Carnegie Mellon University researched and enhanced social network analysis tools that were transitioned to USSOCOM; and the US Army Corps of Engineers applied the Measuring Progress in Conflict Environments framework to the Haiti Stabilization Initiative.

Another novel JCTD, called Mapping the Human Terrain (MAP-HT) is providing tools for collecting and processing social and cultural information in 2009 and 2010, enabling appropriate consideration of social and cultural factors in military decision making. Using manual techniques available to date, this capability has proven to be especially useful in operations in Iraq.

6. Irregular Warfare Modeling and Simulation/Joint Experimentation

DoD is supporting our ability to fight in new situations such as Irregular Warfare by investing in high-priority modeling and simulation (M&S) activities that enhance our warfighters' training and understanding of the adversaries, neutrals, and the physical and social surroundings. High-level tasks funded for FY 2009 include coordinating the development and dissemination of tools for Irregular Warfare and managing our priority standards. Specific projects are encouraging collaboration, supporting efficiency and reuse, and reducing duplication.

We have already established the M&S Irregular Warfare Senior Coordination Group (M&S IWSCG) to fund projects in an area where we are underinvested and potentially vulnerable. This group is leveraging the existing DoD M&S governance structure to enhance visibility, collaboration and coordination of IW M&S. The M&S IWSCG is coordinating the development of tools, data and services that will allow us to address current and future IW challenges.

We are establishing the M&S standards that will allow the warfighter to access needed tools efficiently, easily, and quickly for timely applications when and where needed. Also, our work creating a standardized synthetic environment (through the Environmental Scenario Generator) provides the IW planners and analysts M&S-ready databases representing the air, sea, land, and space environments uniformly across the mission space.

Research, Development, Test & Evaluation funding underwrote the Department's earliest efforts to analyze and understand the emergent world of Irregular Warfare and continues to propel innovative concepts and capabilities into the hands of today's warfighters and peacekeepers. The Joint Warfighting Analysis Program (JAWP) delivered seminal studies outlining the need and form of new military capabilities evolving into today's Irregular Warfare roadmaps. Direct analysis support to theater commanders conducting Operations IRAQI FREEDOM and ENDURING FREEDOM produced a series of strategic and operational benchmark references including

"Indigenous Forces in Irregular Warfare," "Iraqi Terrorist Perspectives," and "Global War On Terrorism - Horn of Africa Lessons." Current DDR&E-funded JAWP efforts develop concepts and capabilities to fill gaps that senior officers identify as important and that joint force commanders struggle to perform: sustaining distributed deployed basing, planning economic campaigns, planning indigenous population influence, and countering police/security force corruption.

Other programs supported with RDT&E programs provide pivotal capabilities empowering a new generation of joint operations. The Joint Fires Integration and Interoperability Team (JFITT) troubleshoots technical and procedural issues in the demanding realm of joint close air support producing mission-tailored tactical capabilities such as cockpit-to-ground target designation links and integrated sensor sources for target detection and engagement. Other DDR&E programs executed in partnership with USJFCOM such as Joint Integration and Interoperability (JI&I) and Joint Systems Integration Command ("JSIC") are the main resource accounts for joint command and control capabilities amalgamated from Service solutions.

7. Energy Efficiency for Forward Deployed

As evidenced by the increased emphasis on energy security activity in the DoD, the Department-wide S&T investment in energy related technologies continues to increase in importance. Energy consumption affects both tactical operations and strategic decisions of the DoD. In response, the Department developed and is coordinating an energy security that contains four primary goals—the first two of which apply to the S&T investment of the DoD. They are:

- Increase operational capability by increasing energy efficiency, and
- Assure supply of energy

While the topic of technology for energy security has recently been the subject of several hearings, we would still like to highlight a few key activities.

In the summer of 2006, then Major General Rick Zilmer, commander of the deployed Marine forces in Al-Anbar Province Iraq, issued a Joint Urgent Operational Need (JUON) statement that said "reducing the military's dependence on fuel for power generation could reduce the number of road-bound convoys.... Without this solution [renewable energy systems], personnel loss rates are likely to continue at their current rate." In response to this request, the Army Rapid Equipping Force (REF) established the Power Surety Task Force to determine what could be done to address this need. They discovered there were few "turnkey" ready capabilities applicable to the harsh operating conditions at a forward operating base.

When Maj Gen Zilmer discussed the need to reduce the fuel demands of forward operating bases, he did so because the Army (and forward deployed ground forces in general) use more fuel to operate ground generators at forward bases than they use for any other system, including helicopters and ground vehicles. According to a 2008

Defense Science Board study, the total amount of fuel consumed by generators has jumped from 26 million to over 350 million gallons to operate bases in Iraq and Afghanistan. This usage rate led to the Net Zero JCTD, which is sponsored by the US Central Command, which will demonstrate prototypes of technologies (wind, solar, other renewables) over a 3 year period that could, collectively, use less energy than they create. The JCTD will determine which, if any, should be recommended for inclusion in sustainable design efforts in DoD installations and tactical bases. By reducing demand, providing efficient distribution, and using alternative energy sources, the FOB should be able to minimize fuel consumption, and ultimately save lives through the reduction in the number of fuel convoys required.

While petroleum demands at ground sites have increased, aircraft engines are still the DoD's greatest single consumer of energy; they consume over 50% of all energy used in the DoD. The Air Force is developing technologies with industry to increase jet engine efficiency. The Highly Efficient Embedded Turbine Engine initiative is developing a high-pressure ratio, high temperature core turbine technology, with the potential to reduce specific fuel consumption up to 25% over today's turbine engines. The current schedule includes a rig test in FY 2010. These technologies are applicable to all turbine engines and could be used in commercial aircraft.

Another project I would like to mention is the DARPA-led effort to develop and test various feed stocks for synthetic jet fuel that would have the same energy density as current petroleum-based fuels. DARPA initiated a $100 million program to further development of affordable algae-based synthetic fuels (synfuels), with the goal of driving the cost to $2 per gallon in 18 months. In December 2008, DARPA awarded two contracts to determine the state of the art. If successful, the DARPA solution could lead to carbon-neutral assured source of domestically produced JP-8 jet fuel, providing stability to the price volatility of fuel.

In addition to aircraft, we have on-going projects throughout the Department to address fuel consumption associated with the mobility of our ground forces. The Army's Tank and Automotive Research and Development Center (TARDEC) in Warren, Michigan is $40 million program centered around the ground vehicle Fuel Efficient Demonstrator (FED). The FED is testing the feasibility and affordability of achieving significant decreases in fuel consumption (30 to 40%) in a tactical vehicle while maintaining or increasing mission capability. This program is integrating potentially high-payoff fuel efficient technologies, like efficient propulsion and drive trains, and advanced lightweight materials in new and innovative designs, and will test prototypes over the next two years.

A final area of interest is batteries. We mention this because of the recently completed "Wearable Power Prize". Currently one of the more significant limitations for our irregular warfare ground operations is available power. A typical dismounted warrior on a four-day mission carries between 20 and 50 pounds of batteries and rechargers. The DoD has invested in the research and development of many energy technologies including, secondary batteries, air-breathing batteries, solid oxide-, direct methanol- and

hydrogen- fuel cells with great success. The Wearable Power Prize competition captured these investments and extended the technology towards a more system-centric focus where the integration of the power technologies with material and power management techniques were demonstrated.

The competition was announced in the summer of 2007 resulting in over 169 teams registering to win the $1M prize for a wearable system that produced 20 watts average power continuously for 96 hours and weighed less than 4 kg (8.81 pounds). Ultimately, 20 teams, of which 35% were from non-traditional backgrounds without a previous relationship with the DoD and without corporate affiliation, participated in the capstone event at the Marine Corps Air Ground Combat Center in Twentynine Palms, California.

At the conclusion of the 96 hour test phase, five teams had completed the competition metrics with remaining power to spare. The top three winners, as determined by the lightest weight, were the DuPont/Smart Fuel Cell team's methanol fuel cell hybrid weighing 8.29 pounds followed by Adaptive Materials Inc and the Jenny 600S team at 8.35 and 8.51 pounds respectively. The top three teams were awarded $1,000K, $500K and $250K.

Many of the component technologies featured in the competition were already known to the DoD and variants are being funded through mechanisms such as the Program Executive Office (PEO) structure. Other approaches are in various stages of R&D. In this sense, the competition validated DoD's investment in technology components while offering novel approaches to the integration of materials and components. The competition produced prototype systems that show great promise for dramatically reducing the weight of the power systems warfighters must carry while performing their critical missions.

The Defense Acquisition Challenge (DAC) program creates innovation, serving as an "on-ramp" to companies who may not be major DoD contractors. DAC testing enabled a non-traditional defense supplier to provide Army soldiers with a methanol fuel cell power system for a small, advanced, high-power, light-weight, wearable power source for use in military operations. This device offers a revolutionary new power source for individual soldier use during military operations, up to 80 percent lighter than conventional power sources, with the potential to extend a soldier-mission to 72 hours. Initial units are currently deployed for limited Army evaluation in Afghanistan.

8. Other (Irregular Warfare) S&T Efforts:

While we have thematic investments, I would like to close by discussing a few additional significant efforts. The Department's S&T investments in directed energy systems have achieved, in recent months, tactically significant laser power in electric laser devices. In a cooperative effort and with funding from the Army, the Air Force, and the Department's High Energy Laser Joint Technology Office, competitive contractor development of high power electric lasers has demonstrated greater than 100 kW power,

for long durations (>300 seconds per shot at 100kw demonstrated frequently), and with excellent repeatability. The laser-on time since February of this year has exceeded 120 minutes, sufficient for "kill" 1400 targets. This advancement in electric laser technology enables attendant advances in applications for battlespace awareness, force protection and force application missions. In addition, the Department's High Energy Laser Joint Technology Office (JTO) continues to press associated advances in optics, solid state devices, controls, lethality studies, and advanced concepts to ensure this technology is brought to sufficient technical readiness to transition to the battlefield.

The Department's rotary wing vehicle S&T portfolio is supporting the warfighter today by providing advanced technologies for current and development systems. For example, the recently completed Rotorcraft Drive Systems for the 21st Century (RDS-21) program developed two different concepts for advanced drive systems that are starting to provide benefits in DoD aircraft. One of these concepts is now in production in the AH-64 Apache Block III. The other concept is in development for the CH-53K program, providing greater power at lower weight. Continued improvements in drive system weight, power, and durability are being sought in the on-going Enhanced Rotorcraft Drive System program. At the same time, our S&T program is leaning forward by participating in the Capabilities-Based Assessment (CBA) and planning effort called out in Section 255 of the Duncan Hunter National Defense Authorization Act for FY 2009. My staff is leading a team of S&T experts from across the Department and NASA to develop the requested S&T plan, and the team has recently developed a capabilities-based framework to help them integrate their efforts and communicate with the teams working on the CBA and Strategic Plan, and ultimately lay a solid foundation for the future of vertical lift for the Department and the Nation.

The Joint Technology Office on Hypersonics (JTOH) works with the Services and agencies to support a series of major flight test activities. The X-51A Scramjet Engine Demonstration program will test the Air Force/DARPA hydrocarbon fuel-cooled scramjet engine in flight operating from Mach 4.5 to greater than Mach 6, with 4 tests currently planned in FY 2010 starting with the first flight in October 2009. The DARPA/Air Force Falcon Hypersonic Technology Vehicle (HTV-2) program will flight test two boost-glide vehicles demonstrating technologies to achieve significant downrange, large cross-range, and accurate navigation, with the first flight planned for late this summer and the second flight early in 2010. The Navy/DARPA Hypersonic Flight (HyFly) program looks to flight test dual-combustor ramjet technology for missile applications at speeds up to Mach 6. After two flight test failures in 2007 and 2008 due to technical difficulties, DARPA recently added funds for an additional flight in 2010. Finally, the Navy's Revolutionary Approach To Time-critical Long Range Strike (RATTLRS) program looks to flight test high-Mach turbine propulsion technology at flight velocities greater than Mach 3 for missile applications. The propulsion system has experienced technical difficulties in ground test, but the Navy is exploring options to pursue flight testing in 2010. Collectively, these flight test activities will demonstrate the maturation of technologies we have been working on for several years and provide the foundation for future efforts in combined cycle propulsion and advanced vehicle concepts. In addition, these flight tests define a backdrop for a number of studies that are

considering potential requirements for high-speed and hypersonic technologies. The JTOH is currently updating its roadmaps in accordance with the 2007 John Warner National Defense Authorization Act.

Improving our Acquisition Process

The third and final priority highlighted by Secretary Gates is improving our acquisition process and accountability. There have been numerous "blue ribbon" studies pointing to the challenges facing our acquisition program. There are several areas of potential improvement where the DDR&E team can play a key role:

1. Technology Maturity Assessments
2. Rapid Acquisition
3. S&T Integrated Priority List
4. Agile Information Tools
5. High Performance Computing
6. Manufacturing Technology

1. Technology Maturity Assessments

A fairly consistent theme in a number of troubled acquisition programs is lack of technical maturity in that program. Acquisition programs such as the Space Based Infra-Red Satellite System, Future Combat System, Transformational SatCOM, Airborne Laser, and others all had technically immature components or critical technologies at Milestone B. The Department addressed this challenge in the recent revision to DoD Directive 5000 series by directing expanded use of technology reviews and technology maturity assessments at or before Milestone B. In the current system, if we are surprised by immature technologies at Milestone B, we have a failure of the process. To minimize these surprises, we have dramatically expanded the use of Joint Analysis Teams and Defense Support Teams to specifically address focus areas in the technology base or early acquisition programs.

Technology Readiness Assessments (TRAs) have been used by USD (AT&L) to support of DoD acquisition decision-making and to certify technology maturity at Milestone B by USD (AT&L). TRAs have been very effective in the identification of technology readiness issues prior to acquisition decision points, thereby focusing attention on mitigating any such deficiencies. In many cases, immature technologies have been identified that led to additional technology testing and validation in operationally relevant environments. Also, TRAs have often clarified ambiguities in system requirements and needed capabilities that might otherwise cause serious problems during program execution. Lessons on how to conduct more effective assessments are being continually learned from past assessments, and are captured in the TRA Desk Book to assist current and future acquisition programs.

Complementing the formal Technology Maturity Assessments are defense support teams (DST) and joint analysis teams (JAT). In December 2008, the Office of the

Secretary of Defense mandated two new categories of these two teams. The DSTs and JATs are comprised of world-class Government and contractor technical experts from the technology development and management disciplines. The DSTs and JATs leverage the unique expertise and understanding these individuals possess in the disciplines of science, technology, engineering, manufacturing, and program management. The teams' roles span from giving advice and assistance to program managers and engineers in resolving complex technical challenges with major DoD acquisition programs, to defining strategies and roadmaps for the development of technologies or mission capabilities for the entire defense enterprise. The differences between the two types of teams are primarily attributed to the breadth and scope of each team's charter and tasks. DSTs focus on solving a specific technical problem that could assist high-risk, troubled programs in getting back on track; whereas JATs look at cross-cutting activities that impact multiple programs and requirements. DSTs and JATs that are completed or underway now number in the dozens. Many programs and DoD investment areas are benefiting from the support team concept. We will highlight four recent teams for which DDR&E was chair or co-chair responsibility.

- Electromagnetic Aircraft Launch System (EMALS) DST - established to assess the development maturity of the EMALS program and its ability to support the CVN 78 production schedule. The DST identified eight findings with actionable recommendations for the Navy to implement to reduce schedule risks; the program risk has been reduced.

- Networked System Security Certification (NSSC) JAT - established to address the acquisition challenges associated with evolving (security) certification requirements. The NSSC JAT recommendations for improvements were accepted by the USD(AT&L), who directed that they be implemented immediately with progress reported back to him within 120 days.

- Nuclear Defense (ND) JAT - established to explore DoD mission, authorities, guidance and options related to nuclear defense and to make recommendations on investment strategies and management approaches. The ND JAT recommendations led to guidance from the USD(AT&L) to endorse Assistant to the Secretary of Defense for Nuclear, Chemical, & Biological Defense Programs as the principal advisor for global nuclear defense and to establish a global nuclear defense steering committee and permanent working group to develop and implement the recommendations of the JAT.

- F135 JSF Engine DST - As the Congress is aware, the F135 engine suffered two blade failures in the 3rd stage low pressure turbine during testing in late 2007 and early 2008 for powered lift in support of STOVL operations. These failures were traced back to high cycle fatigue and linked to a phenomenon known as mistuning. Mistuning is a difficult problem that has been researched since the 1960s, but in the last several years the Department, working with the gas turbine industry and academia, has made great strides in understanding this complex issue. The F135 JSF DST consists of experts from the Air Force and Navy and an

external independent review team. The team worked with the program office and Pratt and Whitney to identify the most probable root cause and applied their understanding of mistuning to establish a plan to resolve the issue while minimizing redesign and the subsequent cost and schedule impacts. The program is now implementing this plan and looks to fly STOVL operations later this year.

2. Rapid Acquisition

The two key components of rapid acquisition are the generation of urgent operational needs and the corresponding acquisition processes used to fulfill those needs. The 2009 NDAA directed two studies in these areas. First, Section 801, Assessment of Urgent Operational Needs Fulfillment, asked the Secretary of Defense to commission a study to assess the effectiveness of the processes used by the Department for the generation and fulfillment of urgent needs. Secondly, Section 253 directed the USD (AT&L) to perform an assessment of technology transition programs in the Department of Defense to determine if consolidation of these programs into a more unified effort would be beneficial. We are generating these two assessments as we continue to improve our processes in ways that adapt to a changing threat within the context of budgetary realities.

3. S&T Integrated Priority List

Finally, the S&T community can enhance the Department's acquisition process by improving early identification and dissemination of warfighter priorities that can be addressed with S&T. In our effort to decisively address the current war, validated joint military capability requirements drive responsible resource decisions. S&T development and technology transition for tailored capabilities stand a significantly higher probability of success when we can rely on validated, well-defined, high-priority military needs. DDR&E works with the Joint Staff J8 and Combatant Command (COCOM) Science Advisors to identify COCOM technology requirements and accelerate responsive technology into the acquisition process. The S&T Integrated Priority List (STIPL) ensures that COCOMs influence S&T program and resource decisions. In coordination with the Joint Staff, these STIPLs provide a critical input for determining overall Department technology needs to resolve approved COCOM capability shortfalls. While STIPLs may not reflect a complete list of COCOM technology needs, they are a key reference lens to focus the full force of the Defense S&T Team. After following this effort through its first cycle, I can tell you that this is an exciting and promising avenue to not only keep our warfighters on the cutting edge of technology but also reinvigorate the S&T community.

4. Agile Information Tools

Another improvement we have made for the Department is coordinating a free flowing exchange of ideas. Just as the warfighter requires new capabilities and tactics to meet the challenges of the 21st century battlefield, the DoD technology and acquisition communities need new tools to bring about strategic change in the DoD acquisition

process. Recognizing this need, and responding to needs articulated by of the USD (AT&L) and the DoD Chief Information Officer (CIO), the Defense Technical Information Center (DTIC) developed DoD Techipedia, a suite of services and processes that should speed technological innovation; increase awareness of new technologies across DoD; encourage collaboration and expand the pool of technology providers. The goal is to provide better capabilities to the warfighter faster and at less taxpayer expense through enhanced collaboration.

DoDTechipedia uses wiki, blog, and Web applications to bring together DoD researchers, technologists, and program managers. The DoDTechipedia Suite of Services currently has three interrelated components:

- DoDTechipedia Internal Wiki (https://www.DoDTechipedia.mil) is a collaborative wiki and blog application restricted to employees and contractors of the DoD and other Federal agencies. This wiki provides a living knowledge base that improves research awareness, reduces duplication of effort, and encourages Federal agency collaboration.
- DefenseSolutions.gov (http://defensesolutions.gov/) is a publicly available Web site aimed at non-traditional technology providers that have not done business with DoD in the past. The site encourages them to submit solutions to needs in selected technology areas.
- Defense Solutions is an information management system pilot project focused on streamlining the process for disseminating idea submissions to program managers' areas for evaluation.

Since October 2008, over 6,000 new users have registered for DoDTechipedia and have viewed more than 160,000 pages, participated in blogs, and added or edited almost 8,000 pages. DefenseSolutions.gov, which launched in February 2009 with a single technology area, has since received 44 proposed technology solutions, 14 undergoing further review and 6 being pursued. Usage and impact are expected to grow as marketing efforts increase awareness and DoD barriers to participating in social networking activities are addressed. By expanding collaboration, we also expect more scientists and engineers from "the digital generation" will be attracted to government service. By challenging the status quo within the defense community, DoDTechipedia is encouraging a more open and innovative capability development process.

Finally, we are examining how to extend the DoDTechipedia to a public site. There are policy issues to work through to include sensitivity/classification of an aggregated unclassified data. As we work through these issues, we hope to extend the site for greater application.

5. High Performance Computing

We can improve acquisition processes by expanding the use of common support tools. Our investments in science-based modeling and simulation through the HPCMP and Service-based computational science projects are paying off in major capability gains

and cost avoidance. In fact, we increased the investment in the DoD's High Performance Computing Modernization Program (HPCMP) in FY 2010.

A recent study documenting the impacts of all HPCMP investments shows a return on investment of better than 6 to 1. Improvement in the accuracy of our ocean simulations will soon provide our submarine commanders with near-real time knowledge of the impact of the ocean conditions on the performance of their sonar, allowing much greater situational awareness. The use of science-based models and supercomputers improved armor designs for faster delivery to our ground forces. Much of the recently deployed armor improvements in use today in Iraq and Afghanistan benefited from these high-end simulations. Our process for certifying the airworthiness of different combinations of stores (bombs, external fuel tanks, missiles, and pods) that hang on fighter aircraft has been fundamentally transformed through the use of HPCMP assets. Today, science-based simulations form the core of this critical process are used throughout DoD to assure the flight safety of different store combinations on different combat aircraft. Multiple stores combinations have been approved and used in Iraq and Afghanistan, and were approved much more quickly and safely than previously possible, using high quality models running on the high performance computers.

In FY 2009, we embarked on a new effort called Computational Research and Engineering for Acquisition Tools and Environments (CREATE) program which aims at transitioning supercomputer models and simulations, commonly used in the research community, into tools that can be routinely used by the systems development or acquisition community. The CREATE program, an element of the HPCMP is working to replace the existing DoD design paradigm for major systems that rely on extrapolation of historical data and experimental testing with a new paradigm that exploits science-based computational tools. Developing and deploying tools through CREATE should be an important step needed to improve our acquisition processes. Our engineering community needs modern tools they can use to make better, less risky choices earlier in the design process. Many industries and government agencies - Goodyear Tire, Whirlpool, and the US nuclear weapons design program - are replacing or have replaced their experimentally-based development methodologies with newer modern systems and engineering approaches. These modern approaches are based on the iterated use of computational engineering tools applied in "design-mesh analyze" cycles that lead to building and testing the end product, enabling industries and government agencies to produce and deliver better products much more quickly and less expensively. The Department needs to do the same. The CREATE program is building science-based models and simulation tools focused on supporting the development of ships, air vehicles, and radio frequency antennas (integrated with platforms). CREATE is a long-term investment that will initially integrate and upgrade existing science-based research tools to make them more appropriate for engineering applications. In the long run, CREATE will introduce highly scalable, coupled multi-physics software applications that will exploit next generation supercomputers and future high-end workstations.

6. DoD Manufacturing S&T Program

Other, more traditional, S&T programs continue to lower risk in all phases of acquisition. The Department's ManTech Program facilitates technology transition through significant reductions in cost and cycle time, increased reliability, and increased return on investment.

In FY 2009, we increased the defense-wide ManTech S&T investment which has a long history of lowering risk in all phases of our acquisition programs, and serves as a link between technology inventions and industrial applications giving the program a unique position within the defense industrial base and broader strategic security environment. Further, the GAO has concluded in successive annual weapon system reviews, that entering production with immature manufacturing capabilities, like entering development with immature technology, is a significant contributing factor to cost and schedule overruns.

The ManTech Program's core focus on closing manufacturing technology capability gaps and reducing risk is therefore an important part of the Department's solution to its growing affordability and acquisition timeline challenges. Identifying production issues early and providing timely solutions, the ManTech Program reduces risk and positively impacts system affordability by providing solutions to manufacturing problems before they occur. A few recent examples will help illustrate.

- The Army ManTech Program improved fabrication processes, explosive loading technologies, and developed an affordable and repeatable assembly method resulting in $33M cost avoidance and MEMS S&A use in precision-guided artillery.

- The Navy has a goal to ensure that the VIRGINIA Class Submarine (VCS) program is affordable; the cost to build one submarine must be less than $2B and must be completed in less than 84 months. Navy ManTech is currently investing in over 60 projects focused on cost reductions to support the VIRGINIA Class Submarine affordability goals. A recent example of the Navy ManTech investment and its significance to the VCS is the adaptation of the Laser Projection System, an image projection technology for locating attachments and penetrations on the interior hull of the submarine, previously a labor-intensive process using paper templates and manual measurements. VCS is saving nearly 8,000 labor hours per ship for electrical, heating/ventilation/air conditioning and stud installs.

- The Army ManTech Uncooled Focal Plane Array Producibility Manufacturing Technology Objective improved producibility of the high resolution, uncooled IR sensor technology in order to affordably field advanced uncooled IR sensor technology to meet Future Combat System requirements. High sensitivity, high-resolution (640x480), uncooled infrared (UCIR) sensors are too expensive for the sensors to widely proliferate throughout Army systems. Additionally, there is a

very large mismatch between production capacity and current and future force projected requirements (>12,000 packaged UCIR FPAs per year). Measured yields have improved from less than 10% to over 50% and cost is reduced from $16K to $2K per focal plane array, enabling proliferation of new, affordable sensor technology.

DMEA

Finally, in FY 2009, DDR&E assumed responsibility for the Defense Microelectronics Activity (DMEA). The DMEA provides a vital service as the joint DOD center for microelectronics acquisition, transformation, and support; advancing future microelectronics research, development, technologies, and applications to achieve DOD's strategic and national security objectives.

DMEA applies advanced technologies to create or add performance enhancements in response to the newest Irregular Warfare threats and to modernize aging weapon systems. Program Managers use DMEA for assistance with resolving microelectronics technology issues in weapons systems. DMEA quickly presents them with appropriate solution options to not only keep a system operational but also elevate it to the next level of sophistication or to meet new threats.

DMEA employs in-house engineering capability to rapidly design, develop, and demonstrate microelectronics concepts, advanced technologies, and applications horizontally throughout the DOD. The contractor capabilities are primarily obtained through the Advanced Technology Support Program (ATSP), an Indefinite Delivery/Indefinite Quantity (IDIQ) contract with a $4.7 Billion ceiling. In a matter of weeks, ATSP provides government organizations streamlined access to commercial state-of-the-art technologies and engineering capability through leading defense industry resources within a fully competitive environment. DMEA provides essential systems and specialized government engineering oversight when contractors are used. DMEA and the ATSP contract can be utilized to provide the warfighter with improved operational readiness, new capabilities, and dramatically enhanced performance through the application of advanced technologies and sophisticated engineering techniques.

DMEA has developed the in-house one-of-a-kind Advanced Reconfigurable Manufacturing for Semiconductors (ARMS) foundry to produce specialized microelectronic devices, such as Application Specific Integrated Circuits. The ARMS can be "flexed" on demand to fabricate integrated circuit (IC) devices on multiple commercial manufacturing processes with different feature sizes and technologies. This flexibility satisfies the DMEA mission to provide microelectronics solutions, and results in a "just enough, just in time" ability to provide analog, digital and mixed signal integrated circuits, hybrid and multi-chip module products. In support of DODI 5200.39 - Critical Program Information (CPI) requirements, DMEA can provide trusted products from our in-house capability. DMEA is also accrediting all parts of the commercial

trusted supply chain (e.g., design, aggregator/broker, mask and wafer fabrication, packaging and test services) to allow acquisition of CPI trusted products in a variety of process technologies and geometry node-sizes for specialized government applications, both classified and unclassified. Over the past 20 years, DMEA has supported the DOD and federal organizations with thousands of tasks using a highly streamlined competitive acquisition process resulting in over $5.5B in cost avoidance.

Summary

In conclusion, the DoD S&T community has adapted and will continue to adapt to the needs of the warfighter as guided by the four strategic principles laid down by Secretary Gates. The basic research portfolio is expanding to meet President Obama's challenge of leading worldwide S&T efforts and Secretary Gates' direction. DoD S&T investments have been tailored to the Irregular Warfare fight in which we now find ourselves. By expanding our S&T program to better take care of our people, to develop capabilities both for the current fight and any future conflicts, as well as working on specific S&T issues to improve our Department's acquisition process, the S&T community stands ready to provide combatant commanders the tools necessary to carry out their respective missions around the world. Our measure of success will always be the ability for our soldiers, sailors, airmen and marines to maintain a technological advantage on the battlefield to ultimately prevail in combat. We appreciate the opportunity to provide this update on the status of the DoD S&T enterprise to the committee, and the privilege to support our warfighters.

STATEMENT BY
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BEFORE THE
SUBCOMMITTEE ON TERRORISM,
UNCONVENTIONAL THREATS AND CAPABILITIES
COMMITTEE ON ARMED SERVICES
UNITED STATES HOUSE OF REPRESENTATIVES

ON
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Mr. Chairman and Members of the Subcommittee, thank you for having me here today to discuss the fiscal year (FY) 2010 Army Science and Technology (S&T) Program and the significant role we play in supporting the Warfighter today, while developing the technologies that drive the Army's transformation. We appreciate the members of this Committee for your sustained support of our Soldiers currently at war, and for funding the investments that will provide our future Soldiers with the equipment and capabilities to defend America's interests and those of our allies around the world.

The Army's S&T investment strategy is shaped to foster innovation and accelerate/mature technology to enable Future Force capabilities while exploiting opportunities to rapidly transition technology to the Current Force. The S&T program retains flexibility to be responsive to unforeseen needs identified through current operations. We have rapidly responded to a broad range of these needs. Our Fiscal 2010 budget priorities are in line with Secretary Gates' recently announced objective to "reshape the priorities of America's defense establishment." I would like to take the opportunity today to focus on some important areas of investment for our program: Force Protection, Lightening the Soldier's Load, Force Health Protection, Power and Energy, Battle Command and Basic Research.

Force Protection

Army S&T transitions to Operation Iraqi Freedom and Operation Enduring Freedom have significantly reduced Soldier and vehicle weight burdens while increasing protective capability. Vehicle armor upgrades for advanced IED defeat, fuel tank hardening, and crew protective opaque and transparent armors have all stemmed from Army S&T investments that have been accelerated and deployed on the Mine Resistant Ambush Protected (MRAP) armored vehicle. In FY08, for example, Army S&T responded an OSD/DDR&E request to develop near-term options for armor enhancements at reduced weight for MRAP vehicles. A number of solutions were quickly developed that increased protection against the largest threat and reduced

package weight by one-third. This effort resulted in over 50% (8000) of MRAP vehicles outfitted with enhanced, reduced weight armor by December 2008, using Army S&T designs and engineering.

Additional vehicle transition successes in reactive armors, ceramic armors, and transparent armors (both in materials and manufacturing efficiencies) have been notable and have transitioned to several military-use vehicle prime contractors.

To further individual soldier protection systems, Army S&T is pursuing improvements in body armor component fabrics and materials through two technical design paths. The first path will provide increased levels of protection at equal weight and/or in better, flexible configurations. The second path will provide the same level of protection at significantly reduced weights. For both designs, performance enhancements will be achieved through advances in high performance ballistic fiber and textile technologies, transparent polymers, composites, and materials systems integration. For example, Army S&T efforts are currently focused on improving the high performance ballistic fiber technology needed to obtain a 50% increase in textile material strength to reduce soft body armor weight by 40-50%. In addition, new ceramics technology and manufacturing techniques are being investigated, to include silicon carbide materials and the ability to form ceramic materials into complex shapes.

Lightening the Soldier's Load

Army S&T is seeking to optimize our future investments to mature both vehicle and soldier protection and efficiently reduce weight burdens as collective systems. In the area of enhanced soldier protection and lighter-weight loads, we are continuing efforts to lighten soldier helmets and body armor through manufacturing technology and advanced material solutions. We are developing new protection enhancements and weight reduction for body armor applications with efforts to address protection for the head, face, torso and extremities, focusing on fragmentation protection, protection from small arms threats, and blast protection for the thorax area of the body. For example,

improved transparent armor materials that provide enhanced fragmentation protection have been demonstrated with a weight savings of 20%.

S&T investments contributing to soldier weight reduction above and beyond helmet and body armor are approached in a holistic method to address personnel load issues. Exploitation of advanced materials and manufacturing processes allow for 10-20% weight reduction of individual components with an overall weight savings estimated at 20 lbs, while increasing the capability in the areas of advanced fibers for carrying equipment (rucksack and utility systems), powered equipment and battery weight reduction (efficient batteries, night vision, communications and sight augmentation systems), combat ration packaging efficiency, and weapon/ammunition modernization. As the emphasis on deployed forces is placed more on light infantry type operations, continued investment and maturation of materials and processes to lighten the load on individual Soldiers is paramount to a target goal of achieving true fighting load weights for all Soldiers regardless of specialized weapons or communications.

Force Health Protection

Our investment in medical S&T provides the basis for maintaining the physical and mental health of Soldiers as well as enhancing their performance. We are currently researching novel methods for screening and treating for Traumatic Brain Injury, by identifying physical and functional changes in the injured brain, and countering the post-injury inflammation. Battlemind, the U.S. Army's psychological resiliency building program, prepares Soldiers for the psychological rigors faced during deployment and improves the Service Members' ability to transition home. The Army is currently developing and validating advanced group-level Battlemind Training to further reduce deployment-related psychological problems, including symptoms from combat-related Post-Traumatic Stress Disorder (PTSD). For Battlefield Trauma Management, a primary focus is to address the single greatest potentially preventable cause of combat – internal hemorrhage. This requires an integrated approach which includes controlling bleeding, replacement of lost fluid volume, cells, and clotting capability, and providing fluids and adjuncts to maintain adequate delivery of oxygen to critical tissues.

Army S&T is also a core partner in the Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC) program, a component of the DoD Blast Injury Research Program Coordinating Office. JTAPIC links the DoD medical, intelligence, operational, and materiel communities to facilitate the collection and integration of data and information to improve our understanding of vulnerabilities to threats. This enables the development of improved Tactics, Techniques, and Procedures (TTPs), requirements and materiel solutions to prevent/mitigate combat injuries. The JTAPIC program routinely integrates data from combat incidents and analyzes this data in to actionable information.

Finally, in FY09 the Army initiated a research program on suicide, working with the National Institute of Mental Health. The Army suicide prevention efforts are focused on prevention, early intervention, screening, treatment, and quality of life for all Service Members and their Families. This important work will continue in FY10.

Power and Energy

The Army continues to focus on developing and demonstrating technologies to reduce power consumption and increase energy efficiency. The Army Science and Technology power and energy strategic goals are to reduce platform energy consumption, develop more efficient power sources, enable smart energy management, develop proactive thermal management, and develop and evaluate alternative fuels.

The Army was a significant contributor in manpower and knowhow to the operation and success of the recently completed DoD Wearable Power Competition (WPC). The WPC's two primary goals were to bring in non-traditional DoD performers with their innovative power source ideas, and the successful completion of a 96 hour test of a wearable power source weighing less than 8.8 pounds. To the Army's credit, the three winning Wearable Power entrants have had previous Army S&T investment.

The Army is executing $75 million in research, development, test, and evaluation from the American Recovery and Reinvestment Act for near term energy efficient technologies. Power generation efforts include research in portable and flexible solar

arrays for Soldier and tent powering applications and research in generating power from the waste heat of generators. Efforts to reduce energy consumption include research and demonstration of advanced silicon carbide components that require less cooling to operate and research in an intelligent power distribution system that is reasonable to tactical applications.

Battle Command

Army S&T is working on advancements in information transport and on enabling improved collaboration for the Warfighter. For information transport at the tactical level, Army S&T is investing in lower cost, more capable satellite communications antennas for current and planned satellite constellations. Additionally, S&T is developing the software application for existing radios to better utilize the limited RF spectrum in military operations. Research and development is underway to more seamlessly share information across functional domains. This will allow more timely interaction and sharing of information across intelligence, planning and battle operations.

Basic Research

Fundamental to realizing superior land warfighting capabilities is the discovery of new fundamental knowledge through high-risk/high-payoff basic research in areas highly relevant to the Army mission. To accomplish these goals we have increased our focus on seven areas that are likely to yield extraordinary capabilities for our Soldiers – autonomous systems, network science, immersive environments, neuroscience, biotechnology, nanotechnology, and quantum information science.

In fiscal year 2009, Secretary Gates set the vision for the Minerva Research Initiative (MRI), a new university-based social science research program for all the services. MRI focuses on areas in the social sciences of strategic importance to U.S. national security policy which have not received substantial Department investment in the past. MRI research will pursue understanding of the internal military-political dynamics of repressive regimes, the vulnerabilities of regimes and institutions to various kinds of influence and instability, the nature of crowd dynamics, the potential to influence public

opinions and attitudes in diverse cultures, cultural effects on network security and military operations, the influence of technology on military capabilities of potential adversaries and allies, and other intersections of social-cultural issues with military activities. The Army science and technology community is fully supportive of the MRI objectives and is actively soliciting proposals focused on social science and cultural issues affecting US military warfighting capabilities and we are increasing our investment in this area.

Within basic research, we are making major progress in many areas. One particular example is power and energy-related science with the ability to "grow" batteries through genetically engineered organisms. Dr. Angela Belcher at MIT, whose work is supported by the Army and through the Army-sponsored Institute for Collaborative Biotechnologies at the University of California, Santa Barbara, is at the forefront of research enabling biologically inspired, virus-based assembly of battery components. For the first time, MIT researchers led by Dr. Belcher have shown they can genetically engineer viruses to build both the positively and negatively charged electrodes of a lithium-ion battery. This technology will lead to future batteries that are far more compact and powerful than anything available today and at much lower cost. This is one of many exciting new discoveries that will reap major benefits for our Soldiers well into this century.

Science and Engineering Workforce

To maintain technological superiority now and in the future, the Army needs to hire top quality scientists and engineers into the Army Laboratories and Research, Development, and Engineering Centers. This is especially daunting given that the Army must compete with the other Services as well as the private sector to obtain its future workforce. We have taken important steps to attract and retain the best science and engineering talent. Our laboratory personnel demonstrations have instituted initiatives, such as pay banding to enhance recruiting and reshaping of the workforce. These initiatives are unique to each laboratory allowing the maximum management flexibility for the laboratory directors as well as allowing them to be competitive with the private sector. The Army is also instituting direct hire authority at our labs, and we would like to

thank the Committee for their strong support on this issue. Finally, we have long recognized that a scientifically and technologically literate citizenry is our nation`s best hope for a diverse, talented, and productive workforce. To pursue this goal, we leverage the numerous resources across our programs and the Department of Defense (DoD) to engage America`s youth in science, technology, engineering, and mathematics.

Defense Acquisition Reform

Army Science and Technology supports current efforts in Congress and within the Department to reform the acquisition system. Because of our position so early in the material development process, the Army S&T program is well positioned to leverage our flexibility in support of any major weapons system acquisition reforms undertaken through consultation between Department of Defense senior leadership and our Congressional stakeholders.

Conclusion

The S&T portfolio contributes to addressing the Army's critical challenges and restoring balance in our forces through the four imperatives: Transform, Sustain, Prepare, and Reset. It has and will continue to enable the success of our force modernization efforts and to exploit technology opportunities through spin outs (Transform). Emerging medical technologies enable improved care for our wounded Soldiers and will enhance their future quality of life (Sustain). Advanced training technologies will accelerate the preparation of our Soldiers and leaders to operate in complex 21st century security environments (Prepare). Technology insertion opportunities and advanced training can contribute to resetting the force to prepare for future deployments and other contingencies (Reset).

With the continued support of Congress, the Army will be able to maintain funding for a diverse S&T portfolio that is adaptive and responsive to unanticipated needs of the current fight while still achieving the desired capabilities for the Future Force.

The Army's scientists and engineers are expanding the limits of our understanding to provide our Soldiers, as well as our Joint and coalition partners, with technologies that

enable transformational capabilities in the ongoing Overseas Contigency Operations to ensure that the Army remains a relevant, ready and victorious land component of the Joint Force. The Army S&T community is the "engine" of change for the Army's transformation.

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HOUSE ARMED SERVICES COMMITTEE
TERRORISM, UNCONVENTIONAL THREATS AND CAPABILITIES SUBCOMMITTEE

STATEMENT OF
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CHIEF OF NAVAL RESEARCH

BEFORE THE
TERRORISM, UNCONVENTIONAL THREATS AND CAPABILITIES SUBCOMMITTEE
OF THE
HOUSE ARMED SERVICES COMMITTEE
ON
THE FISCAL YEAR 2010 BUDGET REQUEST

MAY 20, 2009

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Introduction

It is an honor to appear before you to report on Science and Technology (S&T) efforts within the Department of the Navy and discuss how the President's FY 2010 Budget Request supports the Navy and Marine Corps.

The Naval S&T challenge is to support a Navy and Marine Corps capable of prevailing in any threat environment. In recent months, ONR has engaged in a direct, unprecedented, hands-on partnership with the Chief of Naval Operations and the Commandant of the Marine Corps. We are unanimous in thinking that in order to address critical challenges facing the Navy and Marine Corps of today and tomorrow, the Office of Naval Research (ONR) must: 1) focus on S&T areas that provide the biggest payoff for the future, 2) be innovative in our thinking and business processes, and 3) improve our ability to transition S&T to acquisition programs. The President's FY 2010 Budget requests $1.8 billion in the Naval S&T portfolio to accomplish these goals.

S&T Strategic Plan

Earlier this year, an updated Naval Science and Technology Strategic Plan was approved by Navy and Marine Corps leadership. It reaffirms alignment of Naval S&T with current Naval missions and future capability needs – and continues to ensure S&T has long-term focus, meets near-term requirements, and makes our course clear to decision makers, S&T partners, customers and performers. The Strategic Plan identifies 13 key areas where S&T investment will have high payoff in supporting Navy and Marine Corp requirements. Those areas are:

Naval S&T Strategy Focus Areas

- **Power & Energy**
- **Maritime Domain Awareness**
- **Operational Environments**
- **Asymmetric and Irregular Warfare**
- **Information Superiority & Communication**
- **Power Projection**
- **Assure Access and Hold at Risk**
- **Distributed Operations**
- **Naval Warfighter Performance**
- **Survivability and Self-Defense**
- **Platform Mobility**
- **Fleet/Force Sustainment**
- **Total Ownership Costs**

Executing the Strategy

We execute Basic Research (6.1) thru Advanced Technology Development (6.3) funds by dividing S&T into three areas – Discovery and Invention (D&I), Innovative Naval Prototypes (INP), and Future Naval Capabilities (FNC).

Discovery & Invention

Discovery and Invention (D&I) is basic research (6.1) and early applied research (6.2) in areas where we have unique requirements or support capabilities essential to the naval mission. Investment in these areas is necessary to ensure we maintain technical advantages for our Naval forces. D&I develops fundamental knowledge, provides the basis for future Navy/Marine Corps systems, and sustains the Defense Scientist and Engineer workforce.

Approximately 40% of our S&T investment is in D&I. This reflects our desire, as well as that of congress and the President, to maintain a robust investment in basic and early applied research. We rigorously assess impact on Navy/Marine Corps missions and potential for innovative performance in order to invest those resources in the best research areas and projects. This builds the foundation of our S&T portfolio by developing a broad base of scientific knowledge from which INP, FNC, and quick reaction efforts are generated. Approximately 60% of basic research is executed with academic and non-profit performers.

In 2008, motivated by growing concerns that maintaining the status quo represented a significant risk to national security, Secretary Gates initiated a DoD-wide increase in basic research funding. These funds enhanced our ability to maintain technical advantages relative to global innovation in areas such as the science of autonomy, information assurance, information fusion and decision sciences, energy and power management, and social/cultural modeling.

Also in 2008, an external panel of university, industry, and DoD experts continued their review of our entire D&I portfolio, to assess research performance with respect to S&T quality, program plan, and Naval impact. The panel evaluated overall portfolio direction, whether there were promising research areas in which we had not invested, and opportunities for collaboration with other organizations and agencies. The panel reaffirmed overall performance as strong; while encouraging expanded collaboration. We plan to continue external peer review of our D&I investments, annually reviewing approximately one third of the portfolio.

An important component of D&I is the Defense University Research Instrumentation Program (DURIP), designed to support university research infrastructure essential to high quality Navy research. This instrumentation program complements other Navy D&I programs by supporting the purchase of high cost research instrumentation necessary to carry out cutting-edge research. ONR awarded 68 grants for this purpose in FY 2007, 92 in FY 2008, and 82 in FY 2009.

Another D&I component is ONR's Basic Research Challenge Program, designed to stimulate interdisciplinary research investments in high-risk emerging scientific and technical fields. In 2009, ONR selected the following research topics: 1) Irreducible Uncertainty and the Limits of Predictability in Ocean-Atmosphere Modeling, 2) Elastomeric Polymer-by-Design to Protect the

Warfighter against Traumatic Brain Injury by Diverting the Blast Induced Shock Waves from the Head, and 3) DNA-based Molecular-scale Nanoelectronics Fabrication.

One of the largest contributions made through D&I investments is development and sustainment of the S&T workforce. Through the Independent Laboratory In-house Research (ILIR) and Independent Applied Research (IAR) programs, ONR sponsors cutting edge research and furthers the education of scientists and engineers at our Warfare Centers. We provide education and research opportunities to undergraduate and graduate students, fellows, future faculty members and researchers. This is achieved through specific programs, such as the Naval Research Enterprise Internship Program (NREIP), which expose students and researchers to work done at Naval laboratories, as well as other research opportunities.

Through the University Research Initiative (URI) and Young Investigators Program (YIP), ONR gains access to researchers with an understanding of, and willingness to investigate high priority topics of interest to the Navy that intersect multiple technical disciplines.

In addition to supporting external research, ONR supports internal research within the Navy's corporate laboratory, the Naval Research Laboratory (NRL). This support, known as the NRL base program, develops S&T to meet the needs identified in the Naval S&T Strategic Plan and nurtures the world class skills and innovation that exist within our in-house laboratory.

In addition, we support Historically Black Colleges and Universities and Minority Institutions (HBCU/MI) with education and research partnerships. Through a variety of demonstration, apprentice, award, and graduate programs, we encourage young men and women to consider and explore S&T careers in academia, the Naval labs, and industry.

Innovative Naval Prototypes

Innovative Naval Prototypes (INP) represent approximately 10% of the S&T budget. They focus on high risk, high payoff, game changing opportunities emerging from the D&I portfolio that can significantly impact naval capabilities if we can mature the technology.

INP efforts are often discontinuous, disruptive, radical departures from established requirements and operational concepts. As such, they are approved and overseen by the Naval S&T Corporate Board consisting of the Assistant Secretary of the Navy (RD&A), Assistant Commandant of the Marine Corps and Vice Chief of Naval Operations. The goal is to prove the concepts and mature the technology within 4-8 years, allowing informed decisions about reductions in technological risk to govern transition into an acquisition program.

We have met major milestones in all four current INPs:

We have developed and tested a more powerful lab gun in our Electromagnetic Rail Gun INP. Within twelve months, our Electromagnetic Rail Gun program has doubled current state of the art muzzle energy. Additionally, the program has a series of technical objectives scheduled this year to validate progress towards completion of Phase I in FY 2011.

The Tactical Satellite (TacSat) INP will be completed in FY 2010. Four satellite payloads have been delivered for launch. Ocean Data Telemetry Microsatellite Link payloads were integrated on TacSats 3 and 4, with the Comm-X communications package as the primary payload on TacSat 4. Most technology, and some personnel, transitions to the Operationally Responsive Space program office in New Mexico.

In August 2008, the Persistent Littoral Undersea Surveillance (PLUS) INP conducted a major Autonomous Underwater Vehicle (AUV) trial off the coast of Hawaii with thirteen unmanned undersea vehicles, powered and gliding, working collaboratively to demonstrate autonomous sensing and onboard processing of undersea targets.

In the Sea Base Enablers INP, last year's CNR testimony reported selection of three concepts for further design and model testing. In 2008, we completed a set of multi-ship tests to characterize relative motions between vessels, evaluate ramp excursions, quantify forces and structural loads, and correlate results with computer predictions and analytical models. Results were provided to each of the three contract design teams for incorporation into their technology development.

Additionally, we plan to establish two new INP programs in FY 2010:

The Free Electron Laser (FEL) INP will enable the Navy to fight at the speed of light by bringing high power laser technology to sea for ship defense. This project will develop a laser for use in the maritime environment, consistent with Navy plans for an all-electric ship. The FEL provides intense beams of laser light tuned to atmosphere-penetrating wavelengths, allowing us to assess the potential of laser-based shipboard defense strategies.

The Integrated Topside INP will provide Navy with the ability to dominate the electromagnetic spectrum through the development of multifunction apertures for all classes of ships. Over and above development of highly flexible, multi-beam, multi-function apertures, we are developing: 1) open architecture for Radio Frequency (RF) equipment, in addition to computer hardware and software that will enable multiple industries to contribute to development of affordable new systems and upgrades, and 2) modular systems that enable the same technology to be scalable across all Naval platforms to significantly reduce logistics, training, and maintenance costs.

Future Naval Capabilities (FNCs)

Our Future Naval Capability (FNC) program is the most critical component of our transition strategy. FNC investments were restructured in 2005 to better align this "requirements-driven, transition-oriented" portion of the S&T portfolio to Naval Capability Gaps identified by OPNAV and Marine Corps Combat Development Command (MCCDC).

As opposed to high-risk/high-payoff INP projects, FNCs involve near-term projects. FNCs are included in the portion of our budget focusing on Acquisition Enablers (approximately 30% of our overall budget). The FNC process delivers mature technologies to acquisition sponsors for timely incorporation into systems and products that deliver new capabilities to the warfighter.

FNCs are based on earlier D&I investments, where technology has matured to the point that it can achieve a Technology Readiness Level (TRL) of 6 or better within 3-5 years. FNC projects are selected annually to address specific capability gap needs, with final prioritization approved by a 3-Star Technology Oversight Group (TOG) representing OPNAV/USMC, U.S. Fleet Forces Command (USFF), Assistant Secretary of the Navy (ASN-RDA) and ONR.

All approved technology products are required to have Technology Transition Agreements that document the commitment of the resource sponsor, acquisition program, and ONR to develop, deliver and integrate products into new or upgraded systems that can be delivered to the Fleet/Force. Every FNC product's progress and transition status is reviewed annually. Products that no longer have viable transition paths are terminated with residual funding used to solve unexpected problems with existing projects, or start new projects in compliance with Navy priorities.

There are 158 FNC projects in various stages of their 3-5 year development. Nineteen are expected to complete in 2009 and transition in 2009/10. The FY 2010 budget request continues funding for remaining projects and initiates an additional 23.

FY 2009/10 transitions include: automated battle management aids for ballistic and cruise missile defense, a low cost imaging seeker that provides terminal guidance for weapons directed at moving targets, an expeditionary vehicle obstacle avoidance system to mitigate threats from improvised explosive devices (IEDs), and electromagnetic armor that improves survivability and mobility of combat vehicles.

We plan to complete 21 additional projects in FY 2010 to transition in 2010 /11. They include: swimmer detection/targeting capability that helps defend harbor and near-shore infrastructure against asymmetric threats, weapon fuse improvements for standoff assault breaching of mines buried in shallow water and surf zones, the capability to perform precision navigation and mark assault lanes in mined environments, and a closed loop ventilation system for casualties that can be used in the evacuation process.

The critical measure of FNC success is whether our projects meet technology requirements and exit criteria, and whether acquisition sponsors have transition funds in their programs to accept and integrate FNC products. Products with planned transition funds usually transition after risks are mitigated, a definitive plan is finalized, and required funding is programmed. As shown in the table below, we have had good success in this effort. We expect equally strong performance in 2009.

FNC Transition Summary	FY05		FY06		FY07		FY08	
	# Products	% Plan	# Products	% Plan	# Products	% Plan	# Products	% Plan
Products Planned to Complete	30		26		35		32	
S&T Completed or near complete with Manageable Risk	28	93%	25	96%	35	100%	32	100%
S&T Completed or Near Complete and Transition Funds Programmed	20	71%	24	92%	27	77%	20	63%
S&T Completed or Near Complete and Transition Funds Planned	4	14%	0	0%	5	14%	10	31%
S&T Completed and No Transition Funding	4	14%	1	4%	3	9%	2	6%

Increases and Decreases in FNC Funding Levels

FNC investments focus on the most pressing capability gaps identified each year. This generates year-to-year movement in funding levels for associated Program Elements (PEs). As FNC investments mature and develop technology products over a 3-5 year period, the Technology Readiness Level (TRL) of underlying products moves from 6.2 to 6.3 PEs. The first year is predominantly 6.2; the final year is predominantly 6.3 – with a mix of 6.2/6.3 in-between. As products deliver and transition to Advanced Component Development and Prototypes (6.4) and Engineering and Manufacturing Development (6.5) funding, new FNC products do not necessarily start in the same PEs as those completed. Although resulting changes may appear to be program growth, they actually reflect realignment of funds in response to successful technology transition – coupled with reprioritization and start of new efforts based on evolving Naval needs and requirements.

Current S&T Program Highlights

The Naval S&T portfolio includes a range of projects either entering the fleet or poised to do so in a short time. I include examples of these efforts with respect to the direct impact they will have on Sailors and Marines, both today and in the future.

Manpower, Personnel, Training and Education

In FY 2010, ONR's Capable Manpower FNC is focused on developing innovative, technology-based products to support Navy/Marine Corps Human Capital programs. These include human systems integration, manpower, personnel, and training products that provide new approaches to selection, classification, training, distribution, assignment, and job performance to ensure future combatants and sea-service components are staffed for optimal readiness.

Force Utilization Through Unit Readiness and Efficiency (FUTURE) and Personnel Integration of Selection, Classification, Evaluations and Surveys (PISCES) programs blend behavioral research and economic theory in a virtual experimental environment. These programs, combined with an integrated Total Force career span assessment system, will help deliver products, tools, and information enabling attainment of goals outlined in Navy's *Strategy for Our People 2016*. Additionally, PISCES will expand and incorporate assessments of knowledge, skills, abilities, and personality to improve person-to-job fit.

A program to develop and demonstrate validated, effective, adaptive training system components to enhance individual and team training for submarine navigation and piloting skills will be extended to training for personnel manning surface ship combat information centers.

A Human Systems Integration program is underway to enable advanced design methods and tools supporting rapid, spiral, human-centered design processes to support the total life cycle of complex naval systems. Further, Capable Manpower is studying methods to improve officer and crew situational awareness in increasingly stressed tactical and strategic operations, as well as developing information architecture to improve decision making in submarine attack centers.

Infantry Immersion Trainer

The Infantry Immersion Trainer (IIT) is a revolutionary training system that prepares Marines and Sailors for deployment to today's battlefield environment. The facility uses virtual reality, physical structures, holograms, pyrotechnics, and live role players – simulating a Southwest Asian village in the midst of combat – to give troops necessary skills to win and survive in battle. Equipped with laser-tag-like weaponry, Marines, Navy Corpsmen, and Army soldiers, walk through realistic dwellings and alleys – including sounds and smells – encountering civilians and enemy combatants. The IIT confronts warfighters with a range of possible scenarios requiring split-second decisions and action. High-tech simulation provides a safe, yet realistic, training environment for learning how to prevent fatal errors before being exposed to real threats.

IIT software-based systems allow for rapid improvement of training delivery, and the simulated scenarios can be tailored to suit mission or individual needs. Repeatable and scaleable scenarios increase skills in less time. The first IIT facility opened in 2007 at Camp Pendleton; a second is planned to open at Camp Lejeune in 2009. The IIT system incorporates ONR technologies, DARPA initiatives in game-based simulators, as well as technologies sponsored by the Army Research Development and Engineering Command's Institute for Creative Technologies at the University of Southern California.

Marines in Operational Environments

When the Commandant of the Marine Corps visited ONR in August, 2008, he made clear that while the "Marine Corps has recently proven itself in sustained operations ashore, future operational environments will place a premium on agile expeditionary forces, able to act with unprecedented speed and versatility in austere conditions against a wide range of adversaries."

Marines must be two-fisted fighters – able to destroy enemy formations with scalable air-ground-logistics teams in major contingencies, and equally able to employ superior Irregular Warfare (IW) skills honed in on-going conflicts. ONR has taken the lead in rebalancing traditional and IW capabilities by providing quantifiable technical advantages to warfighters in Afghanistan and Iraq. While IW favors indirect, asymmetric approaches, it may employ the full range of military and other capabilities, in order to erode an adversary's power, influence, and will.

In implementing *Marine Corps Vision and Strategy 2025*, Marine Air-Ground Task Forces (MAGTF) of the future, either from the sea or in sustained operations ashore, must be leaner in equipment. ONR initiatives will help reduce the load of dismounted Marines and Sailors through new materials and technologies that are much lighter, while providing enhanced protection in combat.

Persistent intelligence, surveillance and reconnaissance technology will provide tactically relevant information in all phases of a broad spectrum of operations. It will enhance situational awareness and understanding – enabling real-time decision making that provides proactive, predictive capabilities for Asymmetric and IW, as well as traditional encounters.

The use of unmanned aerial cargo vehicles to rapidly move logistics on a distributed battlefield and complete casualty evacuation, as well as revolutionary robotics to enhance ground logistics delivery, are future capabilities equally applicable to IW and traditional warfare.

ONR has been in front of efforts to improve survivability for the Marine Corps current and future family of tactical vehicles. Efforts to develop optimized fiber composite materials, amenable to advanced high volume fabrication techniques, and active protection systems for vehicles against rocket propelled grenades and missiles help make Marine Corps forces more agile, lethal, mobile and survivable.

Large Scale S&T Demonstrations for Protection of Ground Forces and Systems

Major integrated technology demonstrations will investigate dramatic new capabilities in the Protection of Ground Forces and Systems. The demonstrations are wide ranging, encompassing technologies for pre-detonation of Improvised Explosive Devices (IEDs), personal protection materials, personal power generation, micro power sources, and augmented reality.

The integrated demonstration program will be a broad, multi-year effort to both investigate technology integration, as well as spur application of more fundamental technologies for force and platform protection. The integration of safer ways to remotely detonate IEDs will require additional power – while technologies to enhance the protection capacity of equipment that mitigates effects of blast, blunt trauma, ballistic and directed energy attacks on individuals will require new materials and nanomaterials.

Additional sources of advanced power systems for dismounted Marines/Sailors will be embedded in the demonstrations. Power systems include advanced batteries, fuel cells, and personal power. Augmented reality will demonstrate fusion of organic and individual borne sensors with existing datasets to provide enhanced decision systems and situational awareness. These demonstrations will result in multiple broad phased force protection applications and technologies – with immediate utilization of all fielding successes.

Operational Adaptation

Operational Adaptation (OA) is intended to identify, develop, and demonstrate S&T solutions for future conflict. These conflicts, sometimes called "hybrid complex warfare" or "hybrid complex operations" may include any or all elements of conventional, irregular, disruptive, or catastrophic threats. Recognizing that adversaries are adaptive, rather than try to predict the exact threat and counter that prediction, OA provides warfighters with capabilities to develop and sustain a tempo of adaptation and decision-making that is superior to any adversary's ability to match. OA anticipates fighting on turf that favors the enemy and is intended to help warfighters orient rapidly, become pro-active earlier, and dominate adversaries with increasing effectiveness.

Unlike large-scale mechanized formations in the industrial age, today's adversaries try to hide by submersing themselves within complex environments. OA includes the ability to understand "human terrain" – to distinguish between adversarial/non-adversarial populations. Affordable, scalable, persistent surveillance is vital to OA. Our forces have capability gaps in maintaining

surveillance over large areas with the persistence and resolution needed to identify threat activity and provide timely indications and warnings. These gaps are caused by limits of current sensor technologies, and by manpower requirements associated with operating individual systems and data interpretation. Several ONR projects are directed towards overcoming these limitations.

Utilization of improved sensors necessitates understanding the resulting data. Where mechanized warfare required understanding the physical characteristics of weapons platforms and their employment, hybrid warfare requires that we understand human phenomena. ONR utilizes the social sciences to investigate solutions to problems in human, social, cultural and behavioral arenas. These solutions will help develop a better understanding of "human terrain" phenomenology, apply that phenomenology in operational contexts, and design or modify technologies that will enable us to make better use of affordable, persistent surveillance products.

We are not just studying the problem. ONR has an aggressive program to demonstrate results to operators, get feedback, work out the bugs, and transition successful technologies to the field. This capability will also exploit automated system cues for human intervention as appropriate.

During FY 2010, ONR will conduct an Integrated Technology Demonstration to address operational gaps that preclude adequate warning of non-conventional hostile activities through affordable, autonomous, persistent, pervasive littoral surveillance. Success metrics associated with this demonstration include achieving sufficient advanced warning of hostile intent and actions to enable our forces to respond at the time and place of our choosing – rather than awaiting an enemy attack and then reacting to it.

Improvised Explosive Devices (IEDs)

Working with the Joint IED Defeat Organization (JIEDDO), ONR funds research efforts aimed at attacking IED networks and devices, and enhancing training for our forces. In conjunction with other agencies, ONR is investing in prediction efforts involving terrorist activity associated with bio-forensic profiling to trace place of origin, factory location, support networks, placement, and dynamic analysis of suicide bombing. These projects anticipate future threats, and put us in a better position to respond to changing conditions.

Sponsored by D&I investments, scientists at Columbia, Drexel, University of Miami, and other organizations working in ONR's Automated Image Understanding (AIU) program developed computational methods and algorithms for recognizing hundreds of object categories and human activities including tracking and analysis of human behavior. The intent is to develop an automated means for identifying people and behavior to highlight potentially threatening situations as they emerge. AIU is a critical capability for many DoD missions including, situational awareness, persistent and adaptive surveillance, and autonomous operations.

Detection efforts are geared towards enhancing our ability to achieve persistent surveillance of battlespace – understanding, identifying, and locating signatures associated with manufacture, transport, and placement of IEDs. Near-term initiatives include the Advanced Technology Development efforts to neutralize IEDs through improved countermeasures as well as locating

and directly attacking the device. Long-term S&T includes bio-inspired sensing systems for detection and tracking of explosive components in ports, coastal, and ocean environments.

It is important to remember that IEDs are mines. ONR's advances in countering IEDs are 100% compatible with Countermine Warfare in any environment. Threats posed by IEDs and mines are one of the reasons ONR is developing technologies to separate warfighters from hazardous missions, while providing increased economy of force. Efforts are underway to develop novel man/machine interfaces to enhance crew capability and situational awareness – with the ultimate goal of developing unmanned, autonomous systems to displace the operator from the battlespace.

Medical Research related to IEDs and Hearing Loss Prevention

ONR continues work with the medical community to better understand the effects of IEDs and develop tools to connect event and medical data. Force Health Protection Advanced Technology Development efforts include modeling human responses to blast, ballistic, and blunt trauma, as well as modeling physical and cognitive effects of blast exposure and conditions arising from traumatic brain injury.

Another area of emphasis is reducing hearing damage to personnel in high noise environments. We are working with medical and acquisition communities exploring multiple approaches to reduce noise, attenuate noise that still exists, monitor and assess exposure, develop advanced personal protective equipment, and develop enhanced warnings and procedures to ensure exposure does not become damaging. A suite of technologies developed under the FNC program are now transitioning to the warfighter as part of the acquisition sponsor's Flight Deck Cranial program of record. We are working on treatment, including ground-breaking pharmaceutical interventions for situations where potentially damaging exposure does occur.

Naval Undersea Medical Research

Undersea Medical Research is a National Naval Responsibility. ONR is regarded as a world leader in the field, with investments to: 1) further our understanding of health threats to undersea warfighters, 2) develop novel mitigation strategies for decompression sickness, arterial gas embolism, and oxygen toxicity for disabled submariners and divers, and 3) assess other health challenges associated with undersea deployment. Products from our Undersea Medicine Program, such as the development of non-recompression strategies for the mitigation of decompression illnesses, the elucidation of biological mechanisms that govern oxygen toxicity, and understanding the epidemiological consequences of undersea deployment will improve efficiency, flexibility, and safety of manned undersea operations.

Vertical Lift

In recognition of the important role of rotorcraft in current and projected combat operations, humanitarian relief, and other missions, ONR continues to invest in vertical lift technology. The current program includes research into enabling technologies and new concept vehicle systems for automated resupply of distributed Marine Corps and Navy ground forces, and options for a future Joint Multi-Role aircraft.

Technologies of particular interest and in development are durable composite structures and modeling of ship/air wake interactions, including air vehicle dynamic interfaces. Investments to enable future high speed vertical lift aircraft are being leveraged through partnership with the Army and Defense Advance Research Projects Agency (DARPA) in the Joint Heavy Lift (JHL) program. Ship compatibility attributes of a potential future JHL are being investigated.

ONR continues its commitment to the rotorcraft community by partnering with the Army in applied research investment via the National Rotorcraft Technology Center (NRTC). These investments not only show benefits from the synergy of collaborative planning and execution, but are cost shared by the Center for Rotorcraft Innovation, an industry-academia consortium.

Our long-term vision for Vertical Take Off and Landing (VTOL) aircraft combines improved mission effectiveness, increased affordability, maintainability, reliability, and unprecedented levels of aircrew safety and survivability. To achieve these breakthroughs we will join with the Army in the Vertical Lift Research Center of Excellence, with participation from Navy labs, NASA, and innovative performers from academia.

Power Projection and Time Critical Strike

Revolutionary Approach To Time Critical Long Range Strike (RATTLRS) is a Navy, Air Force, NASA, and OSD interagency cooperative program, to develop a high speed non-afterburning turbine, Mach 3 flight demonstration program for a future expendable high speed strike weapon. The most significant challenge facing this high risk program is mitigating unanticipated vibration encountered during turbine engine tests.

The Long Range Anti-Ship Missile (LRASM) is a joint Navy/DARPA demonstration program that will significantly advance anti-ship missile technology by demonstrating survivability while penetrating advanced air defense networks – and achieve robust lethality through precision targeting. A LRASM flight test is expected in FY 2012.

Affordable Platforms

Cutting edge technologies are of little value if unaffordable. Affordability factors and cost reduction technologies are embedded throughout the S&T portfolio. ONR efforts such as the Navy Manufacturing Technology (ManTech) Program and the Enterprise and Platform Enablers FNC contribute to affordability in acquisition programs and throughout the lifecycle of systems and platforms. This includes using operations research, modeling and simulation, and computer sciences to reduce costs and improve the caliber of training and skill maintenance technologies. Affordability technologies are being developed for a wide variety of new sensors including biosensors with chemical/biological utility, Anti-Submarine Warfare sensors, and persistent surveillance sensors being developed as part of ONR's Operational Adaptation initiative.

The CNO's directive on affordability and cost-cutting in shipbuilding led to a major restructuring of the Navy ManTech portfolio in 2006. This reemphasis led ManTech to focus on shipbuilding solutions that cut acquisition costs. Currently, ManTech continues to focus on technologies that

reduce costs of processing and fabrication for composites, electronics and metals, shipbuilding and repair technology, and technical engineering support for DDG 1000, CVN 21, Littoral Combat Ship, and VIRGINIA Class Submarines.

Among ongoing cost reduction efforts, ONR is developing ultra reliable materials and sensors that incorporate condition-based, zero maintenance capabilities. This includes research into the development and manufacture of durable alloys, thermal barrier coatings, ceramic matrix composites, and other promising materials. These could provide major cost savings in areas such as maintenance of ship topside surfaces, high performance airfield pavements, and a variety of motors and turbine engines. We are also researching airframe and ship anti-corrosion technologies, as well as technologies allowing non-destructive examination and inspection.

Future Power Systems

ONR continues to invest in advanced technologies for high efficiency electrical systems and equipment to meet increasing electric power requirements for advanced weapons, launchers and defensive systems aboard ships and submarines. Our S&T focus is on technologies and system architectures that increase power and energy densities and efficiency. These efforts directly support NAVSEA's Electric Ship Office *Next Generation Integrated Power Systems Roadmap*, and the Navy energy strategy to reduce the amount of fossil fuel used by our fleet.

In concert with the Defense Department and Navy Task Force Energy focus on energy security and reducing the amount of fossil fuel used by our forces, we continue to invest in the Naval Future Fuels effort investigating the impact of new fuel formulations on Naval machinery. In FY 2009, congress added $20M for Alternative Energy Research. We are using this funding to evaluate energy positive structures, advanced solar and wind technologies, ocean thermal technologies, and to address the system integration impacts of intermittent, renewable alternative energy sources on power grids. Finally, ONR continues to support research in fuel cells, methane hydrates, and other alternative sources of energy.

Automated Image Analysis

In the 1980s, ONR initiated research in the mathematical and computational foundations for processing, analysis, and understanding of imagery/video. ONR's basic research resulted in the development of wavelet-based compression algorithms that became the industry standard. More significantly, Navy put ONR-developed compression algorithms on the F/A-18 video pod. ONR is further developing a mathematically rigorous framework for automating image analysis. One example is partial-differential-equation (PDE) based image registration and enhancement tools. The resulting image analysis and exploitation tools have been used to support operations in Iraq. This effort continues with a focus on automatically understanding entities/activities in imagery and video to address information overload, a problem which must be solved if we are to be able to have responsive persistent, pervasive surveillance of the battlespace. Industry began adopting PDE-based tools in 2000 for enhancement and detection of abnormalities in medical images.

Modular Open System Architecture

Modular and open system architecture enables the Navy to affordably procure and integrate complex systems. By assembling similar components to provide a range of cost/capability trade-offs, modular system architecture can be used across all classes of ships. Open architecture enables affordable upgrades for introducing new technical advances to respond to new threats.

An example is the multi-function Electronic Warfare-Electronic Sensing (EW-ES) system ONR delivered to Program Executive Office – Integrated Warfare Systems (PEO-IWS). The system met operational requirements with scalable, open system architecture. The contract required the use of open interfaces and determined capability as a function of the number of receiver elements and channels. In addition, a third party provided components for some system elements. This allowed the PEO to not only use results of the S&T program for DDG-1000, but use underlying subsystems to develop the scaled back-fit for all ships in the Navy requiring EW-ES capability.

Similarly, the Affordable Common Radar Architecture program developed an architecture for all future radars in which the system is divided into frequency independent subsystems (radar control processor, human-machine interface, digital signal processor, digital beam-forming subsystems) which only need be developed once. They can then be used for all radars regardless of frequency and frequency dependent subsystems. The decomposition of radar into independent subsystems with open, well-defined interfaces enables Navy to procure the best components from any company and affordably upgrade only those elements which are necessary.

This experience led ONR to bring together a team of all major system integrators, along with key acquisition components, to develop Naval Radio Frequency (RF) modular system open architecture for the Integrated Topside INP. This will enable Navy to use modular construction to procure RF communications, moderate to low power radar, and electronic warfare capability across all ships with common RF hardware. This will reduce developmental acquisition, training and maintenance costs, and enable affordable upgrades due to open architecture.

This approach clearly involves acquisition challenges since various RF capabilities are currently funded by different Navy resource sponsors and acquired by different PEOs. In addition, the open subsystem construct may face Testing and Evaluation requirement challenges when only some subsystems are upgraded. I believe we can successfully address these challenges.

Marine Mammals and the Environment

Significant S&T efforts are dedicated to effective and responsible stewardship of the marine environment, and this includes the impact of national security requirements and activities on fish and marine mammals. Navy is the worldwide leader in marine-mammal research, with ONR spending approximately $14 million annually to understand how marine mammals may be affected by sound. Navy investments represent a majority of funding spent on this research in the U.S., and nearly half spent worldwide.

As previously reported, the Navy collaborates with universities, institutes, industry, conservation agencies, and independent researchers around the world to better understand what combinations

of ocean conditions, geography, and sonar usage could potentially impact marine mammals and the environment. Congress has been generous in support of these programs and I look forward to continued partnership in achieving the goal of better protecting the marine environment.

As we testified last year, we used capabilities of Marine Mammal Monitoring on Ranges at the Atlantic Undersea Test and Evaluation Center (AUTEC) in our Behavioral Response Study. The second phase of our Behavioral Response Study last summer gained new information on beaked whale responses to sonar signals and other environmental sounds. Suction cup affixed tags allowed us to follow the animals' change in foraging and swimming response. Another phase is planned for this summer in the Mediterranean Sea. We have also begun to establish a passive acoustic monitoring network around the perimeter of the Hawaiian island of Kauai to monitor humpback, sperm, and other whale migrations as they approach naval training ranges.

Lastly, our Marine Mammal Veterinary Health S&T effort directly supports Navy's Fleet Marine Mammal Systems activity, in turn providing critical support for perimeter defense, platform and swimmer protection missions. Through identification of marine mammal specific-pathogens, development of improved diagnostic tests for infections, toxin exposure and other causes of disease, and strategies for bolstering immune responses, our program is not only helping Navy animals but will facilitate National Oceanographic and Atmospheric Administration (NOAA) health assessment surveys of marine mammal populations.

Understanding the Sea

As we operate in-on-above the ocean, understanding and prediction of the marine environment, as a coupled system of atmosphere and ocean, is critical for Naval operations. Our research has concentrated on currents, acoustic properties, and storms in the Western Pacific. We are completing a study of the Kurishiro Current using a small fleet of undersea gliders continuously cycled into the current's flow for the past eighteen months. Our studies are finding new sources of acoustic variability and incorporating them into prediction systems. Last summer, we completed a study of how typhoons create deep, cool wakes in their paths that affect upper ocean acoustic properties. In addition, a decade of S&T in ocean modeling came to fruition as a new hybrid coordinate model became operational at the Naval Oceanographic Office.

Highly capable research vessels are critical to the success of our basic and applied programs in ocean sciences. Since 1972, ONR has partnered with the National Science Foundation and other agencies in the University National Oceanographic Laboratory System (UNOLS) to allow joint scheduling and operations of a fleet of research ships used by academic oceanographers. The partnership continues with procurement of the next generation of Ocean Class research vessels. Last year's budget funded a Phase I award for the Functional Design by the Program Executive Office (PEO) Ships. Phase I design studies are being completed, and a request for proposals to support competitive selection of operating institutions for the ships is about to be issued. Plans call for two ships to be built starting in FY 2011 and FY 2012, with lead ship delivery in FY 2014.

Conclusion

Thank you for the opportunity to discuss Naval S&T. The FY 2010 President's Budget request is about prevailing in today's threat environment and building a strong, flexible Naval force in the future. Building that force requires careful S&T investments to protect the nation and our warfighters. To achieve that goal, we continue moving toward greater integration of capabilities, more effective partnership between research and acquisition, and a clearer vision of how to achieve shared goals with DARPA, Army, Air Force, and other DoD research organizations.

We must monitor, assess and leverage emerging S&T in a global environment. The worldwide movement of technology and innovation demands that we be able to take advantage of emerging ideas and science wherever they originate, and we have an aggressive worldwide presence to ensure we do that. Our S&T partnerships in 70 countries, 50 states, with 900 companies, 3,300 Principal Investigators, 3,000 grad students, and 1,000 academic and non-profit entities puts us in good stead to maintain our technological edge. ONR Global offices in London, Tokyo, Singapore and Santiago, Chile help us stay on the scene and abreast of emerging S&T trends around the world.

We continue to focus the majority of our investment on external performers – those outside the Naval R&D system - in order to tap into the full spectrum of innovative thinking and discovery. Nevertheless, we need to nurture the world class skills and innovation that exist within our lab system, especially at the Naval Research Laboratory (NRL). Congressional authorization and direction to move ONR into the Lab Demo personnel system provides welcome assistance in our ceaseless effort to attract world-class scientists to become part of our organization. ONR has published its first internal business plan, establishing internal organizational goals aimed at aligning our efforts with the S&T Strategy and guiding needed organizational improvements.

For all of these reasons, I believe the state of our S&T investments is sound, represents careful stewardship of taxpayer dollars, and will significantly enhance the safety and performance of our warfighters as they serve in defense of the United States, today and in the future. Thank you for your support.

DEPARTMENT OF THE AIR FORCE

PRESENTATION TO THE HOUSE ARMED SERVICES COMMITTEE

SUBCOMMITTEE ON TERRORISM, UNCONVENTIONAL THREATS AND CAPABILITIES

UNITED STATES HOUSE OF REPRESENTATIVES

SUBJECT: Fiscal Year 2010 Air Force Science and Technology

STATEMENT OF: Mr. Terry J. Jaggers, SES
Deputy Assistant Secretary
(Science, Technology and Engineering)

May 20, 2009

NOT FOR PUBLICATION UNTIL RELEASED
BY THE ARMED SERVICES COMMITTEE,
UNITED STATES HOUSE OF REPRESENTATIVES

INTRODUCTION

Mr. Chairman, Members of the Subcommittee, and Staff, I am pleased to have the opportunity to provide testimony on the Fiscal Year 2010 Air Force Science and Technology (S&T) Program.

The Air Force S&T Program is a subset of the larger Research and Development (R&D) enterprise and is poised to discover, develop, and demonstrate technologies that are sufficiently mature to transition into legacy systems and new system developments. This enterprise provides new and advanced warfighting capabilities plus the technical and intellectual capital essential for future capabilities – it is also one of the critical elements in maintaining a viable national industrial base. Coupled with this enterprise, the concept of prototyping is also essential to securing future warfighting capabilities and maintaining the industrial base. Government and industrial design teams need a structured environment in which to practice and maintain their expertise and the Air Force helps provide this environment through our support of robust, full-scale and sub-scale prototyping that is broadly based on anticipated future capability needs. S&T is also essential for acquisition excellence by ensuring technology is delivered at the right maturity level, at the right insertion date, and with the right performance to meet the needs of acquisition programs. Towards this end, advanced systems engineering planning for future concepts is strengthening the acquisition process by reducing risk and enhancing technology transition.

For the past two years, I have spoken extensively about adapting Air Force S&T to the security environment identified in the 2006 Quadrennial Defense Review and shifting investment emphasis from traditional or conventional threats to address new threats, such as terrorism. Balancing investments to prepare for a wide range of future contingencies is a challenge that involves maintaining military superiority against near-peers with traditional threats, while

addressing terrorists with unconventional weapons and tactics. The Air Force S&T Program continues to address this challenge by shifting investments among a broad portfolio to attain a balance between near-term capability support, sustainability of existing systems, operations requiring more efficient fuel usage, enhanced manufacturing capabilities, and revolutionary technologies that address far-term warfighting needs.

AIR FORCE S&T FISCAL YEAR 2010 PRESIDENT'S BUDGET REQUEST

The Air Force Fiscal Year 2010 President's Budget Request for S&T is approximately $2.2 billion, which includes $2.0 billion in "core" S&T efforts with the remaining funds supporting devolved programs to include High Energy Laser efforts and the University Research Initiative. These investments sustain a strong and balanced foundation of basic research, applied research, and advanced technology development to provide demonstrated transition options to support future warfighting capabilities. This year's budget request includes an increase of $98 million or almost four percent real growth over the Fiscal Year 2009 "core" request. This healthy increase reflects the continued strong support of Air Force leadership for its S&T Program.

In keeping with Secretary Gates' objective to reshape our defense establishment priorities and, given the current budget environment, the Air Force has started the process to reduce the number of Advanced Technology Demonstrations and refocus this funding on basic and applied research, and on early advanced technology developments. While supporting current warfighting operations when needed, we are taking a longer term view of where we want to invest current resources to be ready for the next system deployment and to ensure our S&T Program is postured to address both the traditional and unconventional threats with which we might be faced. In

addition, we are focusing on sustaining legacy capabilities during these times of austere budgets and fewer new system developments.

AIR FORCE GUIDING PRINCIPLES FOR S&T

In 2005, the Air Force established five principles to guide the S&T Program. They continue to be sharpened and are providing a comprehensive framework for our larger R&D strategic planning. The following five guiding principles reflect the current order of Air Force S&T priorities:

- **Value and Protect People** – Recruiting, developing, mentoring, and retaining the best and brightest Scientists, Technologists, Engineers, and Mathematicians in the S&T community is my number one priority.
- **Maintain Stability and Balance in the Portfolio** – Keeping the right balance is always a challenge and we continually assess these goals to ensure the right investment is in place to quickly respond to the threats of today and anticipate the challenges of tomorrow.
- **Focus Technology Development on Air Force Strategic Priorities** – Our S&T Program focuses technology investments on winning today's fight, while modernizing our air, space, and cyber inventories for the future, and is a foundation for recapturing acquisition excellence.
- **Transition Technology to Warfighters and System Developers** – Finding new and improved ways of transitioning technologies directly to the warfighter in the field and into our weapon systems acquisitions is an area that receives special attention as evidenced by the stand up of a new Technology Transition Office within Headquarters Air Force last year.

- **Honor Commitments with Our Partners** – Whether our commitments are with others in the Air Force, our sister Services and Defense Agencies, the Office of the Secretary of Defense, industry, academia, our allies, or Congress…Air Force S&T will deliver on our commitments.

Addressing these five S&T guiding principles is essential to maintaining a well-rounded S&T Program that supports Air Force priorities and core functions.

FISCAL YEAR 2010 S&T INVESTMENT HIGHLIGHTS

This budget request focuses investments to mature the technologies needed to address the modernization and development plans for the future. We continued to shift S&T investments from traditional areas to support unconventional warfare. A specific goal of the 2008 Air Force Strategic Plan is to bolster the Air Force core function of Intelligence, Surveillance, and Reconnaissance (ISR) support to the joint warfighter, emphasizing irregular warfare scenarios. The S&T Program is developing unprecedented proactive ISR technologies to create a universal situational awareness through a layered and flexible sensing architecture. Air, space, and cyber ISR technologies are being developed that will respond to the Commander's current and future requirements to collect, process, and distribute knowledge and information.

We have also increased investment in technologies, such as meta-materials, to decrease antenna aperture size and mass, increase gain and bandwidth, and reduce loss and power required. Persistent surveillance research and technology development being conducted will allow all-weather, day-night, continuous tracking of vehicles in an urban environment and dismounts showing anomalous behavior, such as Improvised Explosive Device deployment, while providing infallible forensics to track backward from any event.

In the space domain, we continue to highlight ISR research and develop technologies that are more responsive to the warfighter and ensure a space situational awareness. The ability to detect, track, and identify, as well as provide on-demand, highly detailed characterization of individual space objects and near-real-time, high-fidelity forecasts of space environmental effects are all prevalent space situational awareness challenges we are addressing. Defensive counterspace activities also continue to be emphasized in this year's budget and the Air Force is developing technologies to detect, understand, and mitigate the threats in the space environment across the full-range of natural and man-made sources. Such technologies include real-time proximity sensing, threat warning, nuclear detonation remediation, and survivable space electronics.

We also increased investment in smaller, plug-and-play types of satellites that offer more responsive construction and launch. Our microsatellite activities have led to new satellite acquisition concepts, leveraging small satellites to deliver essential ISR and communications capability to the warfighter faster.

ISR in the cyber domain is becoming paramount in maintaining our technological superiority and mission assurance in every domain. The goal is not to wait until after a cyber attack occurs and then analyze what happened, but to conduct ISR activities in real-time and provide feedback to adaptive defense measures to permit us to fight through any attack. We recently transitioned a prototype cyber operations center to the Air Force Network Operations Center. The prototype integrates real-time data sources, such as internet health and router data, and displays the data to create a multi-level situational awareness picture of Air Force cyber assets.

In order to modernize our air and space inventories, we continue to shift resources to address medium- to long-term risk. Energy efficient technologies are expected to yield big gains

in fuel consumption. We are leading the evaluation of alternative fuels that may lead to greater fuel efficiency and significantly reduce our dependence on oil. The Air Force is qualifying synthetic fuel based on domestic sources to ensure a stable energy supply regardless of political uncertainties in oil-producing countries or supply disruptions. The Highly Efficient Embedded Turbine Engine project is developing fuel efficient engine technologies for future ISR, tanker, mobility, manned and unmanned combat air vehicles. The Adaptive Versatile Engine Technology (ADVENT) project is developing technologies that allow efficient engine operation over a wide range of flight conditions. ADVENT is a variable-bypass ratio turbofan engine technology concept that allows efficient engine operation at both subsonic and supersonic speeds. These technologies are expected to improve fuel efficiency by at least 25 percent, substantially increase range and loiter times, and decrease vehicle size. Additionally, the Efficient Small Scale Propulsion program is developing fuel efficient engines for unmanned air systems.

Other modernization activities in which we have increased investment are sustainment technologies and composite materials. We are developing novel technologies to assist in prolonging the life expectancy of our aircraft systems, and conducting research and developing technologies to decrease the cost of sustaining our systems. Not surprisingly, our strong commitment to composite aircraft structures, materials, and manufacturing techniques continues.

Game-changing technologies where we have a focused investment include directed energy, hypersonics, cyberspace, and highly accurate, low collateral damage conventional munitions. Our directed energy activities plan to deliver precision effects and low collateral damage options for the warfighter in urban environments. An example of our game-changing hypersonics technology area is our X-51 Scramjet Engine Demonstration project, which plans to provide the hypersonic propulsion needed for an affordable, fast reaction, stand off weapon. In

support of hypersonic and space access technologies, we have also increased investment in high temperature materials' development and thermal management. Beyond the ISR cyber technologies already discussed, we continue to evolve the game-changing cyber arena. The cybercraft concept is developing technologies for a cyber platform that contains traditional-type payloads to ensure cyber command and control, attack options, damage assessment, and survivability. Game-changing precision guided micro-munitions' technologies are being developed that will provide warfighters the ability to engage high-value fleeting targets in an urban environment with low collateral damage.

Guided by Air Force strategic priorities to win today's fight, modernize our air and space inventories, and recapture acquisition excellence, and specifically, the goal to bolster ISR support to the joint warfighter, we have focused our investments to best position the Air Force to support the National Defense Strategy.

RENEWED COMMITMENT TO ACQUISITION EXCELLENCE

This year, the Air Force established a prototyping program and an early systems engineering and analysis program to support development of future weapon systems. We are also developing tools to assess the maturity of pre-program materiel concepts before they get selected as the preferred solution. We have released an Early Systems Engineering Guidebook and are developing a methodology to assess the maturity of early system concepts, with a focus on quality and sufficiency of technical planning, to get programs started right – these efforts stem from a National Research Council study we commissioned in 2007 to look at pre-acquisition systems engineering. This study also led to changes in the Department of Defense Instruction 5000.02 and to current Acquisition Reform Legislation. All of these activities will greatly facilitate risk reduction of materiel solutions during concept development, enhance transition

policy and processes, and help shrink the technology transition gap. Simply stated, shrinking this gap means a decrease in the time it takes to get matured technology into the hands of the warfighter to win today's war and into the hands of the acquisition developer to more rapidly modernize our warfighting capabilities – this is the link between Air Force modernization plans and technology development and equates to a stronger, more invigorated acquisition process.

As the Air Force Component S&T Executive, I have continued conducting Technology Readiness Assessments (TRA) on Air Force Major Defense Acquisition Programs (MDAPs) in support of the USC Title 10, Section 2366.b. statutory requirement for the Milestone Decision Authority to certify that the "technology in the program has been demonstrated in a relevant environment" prior to Milestone B approval (or Key Decision Point (KDP) B for Space MDAPs). The TRA process has proved to be highly beneficial in ensuring a program's technology readiness for a Milestone/KDP. To date, I've led approximately thirty TRAs with over twenty completed, two Manufacturing Readiness Assessments, one Program Support Review, and multiple other independent reviews. However, I am concerned about the proliferation of these specialty reviews and we are collaborating with the Office of the Secretary of Defense (OSD) to develop a synergized independent program review and assessment process that integrates multiple technical reviews (e.g., technology, systems engineering, reliability, manufacturing, logistics, and risk) into a single review process. Leveraging off our experience with TRAs and working in cooperation with OSD, we are currently assessing the Small Diameter Bomb II program's readiness for Milestone B using this integrated review process and interim feedback is highly promising.

In addition, the strength and effectiveness of Air Force warfighting capability depends on our ability to ensure the industrial base is poised to be responsive to our warfighting needs. Our industrial base activities help to increase the supply, improve the quality, and reduce the cost

of advanced materials and technologies needed for national defense. We are reducing U.S. dependency on foreign sources of supply for critical materials and technologies, and strengthening the economic and technological competitiveness of the U.S. defense industrial base. Our Technology Transition Office is performing admirably as an integrating body between developing policies, assisting in pre-acquisition systems engineering planning, and focusing the necessary resources to shrink the technology transition gap.

CONCLUSION

Guided by Air Force strategic priorities, the Air Force S&T Program is rebuilding and shaping the workforce, balancing and focusing investments to modernize our inventories for a wide range of contingencies, shrinking the technology transition gap, and honoring commitments with joint and coalition teams to win today's and future fights. While the S&T Program has many challenges, we continue to ensure the development and care for our people and focus and protect our S&T investments to maintain Air Force dominance of air, space, and cyberspace.

History clearly demonstrates the broad benefits to the Air Force of our S&T efforts in terms of military power, industrial capability, economic growth, educational richness, cultural wealth, and national prestige. The Air Force continues to show a strong commitment to the S&T Program, and maintains a diverse and ambitious portfolio. This commitment is clearly shown through the Air Force Fiscal Year 2010 President's Budget request of $2 billion for "core" S&T efforts. The Air Force S&T Program is vital to ensuring the Air Force maintains technological advantages and prevents technological surprise in a rapidly changing world.

Of course, none of this can be accomplished without a strong, robust and well-educated workforce. As already stated, recruiting, developing, mentoring, and retaining the best and brightest Scientists, Technologists, Engineers and Mathematicians – the Air Force STEM

workforce – is my number one priority. We commissioned a National Research Council study to define STEM. This study is due out this summer and will provide recommendations and a blueprint for moving forward in developing our STEM workforce. We are also in the process of developing an Air Force STEM Strategic Plan aimed at all phases of this critical workforce's life cycle. In addition, the Air Force is a key user of the National Defense Education Program and the Science, Mathematics, and Research for Transformation Program. Finally, the Air Force is planning its first-ever STEM Conference. It is a testament to Air Force leadership commitment to STEM that the Chief of Staff of the Air Force will be attending to kick off this conference.

Mr. Chairman, thank you again for the opportunity to present testimony and thank you for your continuing support of the Air Force S&T Program.

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Statement by

Dr. Robert Leheny

Acting Director
Defense Advanced Research Projects Agency

Submitted to the

Subcommittee on Terrorism, Unconventional Threats and Capabilities
House Armed Services Committee
United States House of Representatives

May 20, 2009

NOT FOR PUBLICATION UNTIL RELEASED BY THE SUBCOMMITTEE

Mr. Chairman, Subcommittee Members and staff: I am Bob Leheny, Acting Director of the Defense Advanced Research Projects Agency (DARPA). I am pleased to appear before you today to discuss DARPA's ongoing activities and our plans to continue as the engine for radical innovation in the Department of Defense (DoD).

With the change in Administration, our long-time Director, Dr. Tony Tether, left DARPA in late February. As the Deputy Director, I have been asked to serve as DARPA's Acting Director until a permanent Director is appointed. You may naturally wonder what changes are in store for DARPA. We are essentially continuing on the path we were on before Dr. Tether left. When the new Director arrives, he or she will, of course, make changes; that is, after all, a big part of the job. But one of the pleasures of working at DARPA is the strong support we have enjoyed over the years from successive administrations, this subcommittee, and other committees in Congress. So while there will be changes at DARPA, I'm confident that we will continue the mission we began more than 50 years ago.

DARPA's original mission, established in response to the Soviet Union beating the United States into space with Sputnik in October 1957, was to prevent technological surprise. This mission has expanded from preventing technological surprise for us to creating technological surprise for our adversaries. Stealth aircraft, developed at DARPA more than 25 years ago, is one among many important examples of how we create technological surprise.

DARPA conducts its mission by searching worldwide for revolutionary high-payoff ideas and then sponsoring research projects that bridge the gap between these fundamental discoveries and their military application.

DARPA is the Department of Defense's only research agency not tied to a specific operational mission: DARPA supplies technological options for the entire Department and is designed to be a specialized "technological engine" for DoD.

This is a unique role within DoD. The Department's operational components naturally tend to focus on the near-term because they must meet urgent needs and requirements. Consequently, a large organization like DoD needs a place like DARPA whose only charter is radical innovation.

Secretary Gates' Announcement and DARPA Priorities

Mr. Chairman, you asked that I address DARPA's S&T priorities in light of Secretary Gates' budget announcements on April 6th, and his objective to "reshape the priorities of America's Defense establishment." I believe the portfolio of nine strategic research thrusts DARPA is emphasizing today, which I will describe in greater detail later in my testimony, are in strong accord with the Secretary's goals:

- Robust, Secure, Self-Forming Networks
- Detection, Precision ID, Tracking, and Destruction of Elusive Targets
- Urban Area Operations
- Advanced Manned and Unmanned Systems
- Detection, Characterization, and Assessment of Underground Structures
- Space
- Increasing the Tooth-to-Tail Ratio
- Bio-Revolution
- Core Technologies

One of the first things the Secretary mentioned in his announcement was keeping our commitments to our all-volunteer force, including their medical care. For several years, our Bio-Revolution strategic thrust has included important research aimed at keeping our warfighters healthy, fit, and protected in the field; caring for them when they are wounded; and rehabilitating our wounded over the long-term. More specifically, these are:

- Protecting human assets through advanced technologies to provide combat casualty care to greatly improve the chances of our wounded surviving battlefield injury.
- Maintaining combat performance by innovative approaches to sustain the warfighter's peak physical and cognitive performance when deployed, despite the challenges of extreme battlefield stresses such as heat and altitude, prolonged physical exertion, and sleep deprivation.
- Restoring capabilities after severe injury by developing technologies to restore full function, including techniques to accelerate healing and revolutionary new prostheses for combat amputees.

For example, last month, DARPA's program to revolutionize upper extremity prosthetics was highlighted in a story on "60 Minutes" and as part of the Veterans Affairs' Research Week.

While there are many exciting things happening at DARPA, we are proudest of this work that aids our wounded men and women in uniform.

The Secretary also emphasized rebalancing DoD's programs to enhance our ability to fight the kind of wars we are in today, and will most likely continue to face in the years to come. Much of the fighting in Iraq has happened in cities, which can be one of the most dangerous, costly, and chaotic forms of combat. And our adversaries have realized that, if they are to survive the United States' superior precision strike capabilities, they either have to move, hide, or blend into cluttered environments. DARPA is responding by developing sensors, exploitation tools, and battle management systems to rapidly find, track, and destroy forces that operate in difficult terrain such as mountains, forests, and swamps, as well as those ground troops and other insurgents that abandon open country for urban terrain where whole organizations are often embedded in civilian activities. Since before the current conflicts began, DARPA has been addressing these issues in programs aimed at:

- Improved Intelligence, Surveillance, and Reconnaissance (ISR) capabilities to vastly improve understanding of what is going on throughout complex environments.
- Tagging, tracking and locating capabilities to persistently monitor targets or equipment of interest; tag, track and locate enemy activities; track and detect weapons fabrication and movement; and precisely discriminate threat from non-threat entities against severe background clutter.
- Asymmetric warfare countermeasures to develop technology to detect, prevent, or mitigate asymmetric attacks, such as suicide bomber attacks, improvised explosive device attacks, and WMD attacks – including radiological dispersal devices.
- Pre- and post-conflict capabilities to model and understand social indicators that precede the onset of hostility and conflict.
- Command, Control, Communications, and Intelligence (C3I) for irregular warfighting to develop new approaches to all-echelon C3 and new intelligence analysis tools specifically suited for irregular operations that allow warfighters to see and understand what is happening throughout the urban battlespace in real time.

A great deal of our effort is focused on improving our ISR capabilities. Our programs include developments in three general areas; sensors to find targets; sensor exploitation tools to identify and track targets; and battle management systems to plan and manage the use of sensors, platforms, and weapons throughout the battlespace. Our goal is to seamlessly layer surveillance and battle management systems using a network of platforms that includes radars and electro-

optical sensors that can scan wide areas of open or forested terrain and laser detection and ranging (ladar) sensors to obtain high-resolution, three dimensional imagery that is particularly useful in urban terrain. We are developing tools to exploit video, in all regions of the spectrum, to track elusive targets as they move around. By networking sensors together, and coordinating sensor movement and tasking, we aim to achieve wide area coverage, high resolution, high frame rates and high revisit rates.

One of the lessons of today's wars is the importance of prompt language translation at both the strategic and tactical levels to understand what is being reported and to allow our troops to work with the people they encounter. Efficient language processing with superb machine language translation technologies can remove barriers to interaction with the local population. For many years, DARPA has pursued better automated language translation, and it remains a crucial part of our strategic thrust in Increasing the Tooth to Tail Ratio. This long-term effort is yielding fruit for our warfighters today, with DARPA translation devices being used and evaluated in the field.

On the other side of rebalancing, the Secretary also pointed to the continuing need for conventional and strategic modernization to contend with possible security challenges from the militaries of other nations, including better cyberspace capabilities. While few DARPA programs could be characterized as "conventional," our strategic thrusts in Space, Advanced Manned and Unmanned Systems, and Robust, Secure, Self-Forming Networks are focused on keeping our conventional force-on-force capabilities unsurpassed.

In particular, our Robust, Secure, Self-Forming Networks thrust contains our work in cyber security, a threat area that has been receiving increasing attention. U.S. tactical and strategic networks must be reliable in any environment for extended periods and must be protected against cyber threats. DARPA has increased its efforts to develop technologies that make computers and their networks secure against the spectrum of information operations attacks, including the capability to be disruption-tolerant and to quickly self-reconstitute after attack.

As technologies are developed and deployed to successfully block overt cyber attacks, adversaries will likely attempt to insert malicious code in our networks to impede our ability to fight. The ever-growing sophistication of this threat has surpassed the ability of current

commercial markets to provide DoD with rapid and robust solutions, particularly at the hardware and component levels.

The microelectronics used in DoD systems are purchased from multiple vendors, including foreign sources. DARPA's TRUST program seeks ways to determine whether malicious features were inserted during the design or fabrication of application-specific integrated circuits or during the loading of field programmable gate arrays. DARPA is at the forefront of research in this area, addressing many of these issues in a comprehensive manner for the first time.

Cyber security threats will continue to increase in scope and sophistication. Rapid experimentation of new defensive capabilities is needed to stay ahead of cyber threat advances. In the belief that you can only truly understand what you can measure, DARPA is taking an unusual position by leading the development of a cyber test and evaluation facility. The National Cyber Range will allow realistic, quantifiable tests and assessments of cyber security scenarios and defensive technologies. The range, which DARPA will not operate in the long run, will contain thousands of real and virtual nodes to provide realistic, tailored simulations of large-scale military and Government networks, all coupled with state-of-the-art forensic tools to analyze exactly what happens. We believe rapid technical progress requires precise tools for rigorous experiments, and the National Cyber Range will provide these tools. The revolution in large-scale cyber testing created by the National Cyber Range will spur tremendous progress in making networks more secure and reliable in the face of a wide range of challenges.

Given our mission, DARPA must remain focused on the technologies of the future – both threats and opportunities. The best way to prepare for the future is to create it yourself, so that is where our Core Technologies thrust comes in. These are the technologies that will make the military systems of the future possible. They are often our most long term investments and will have payoffs against both conventional and asymmetric threats.

DARPA continues to enjoy strong support in the DoD for our mission and our current portfolio of programs. While there will always be adjustments and changes at DARPA – that's part of who we are – I believe we currently are on the right track and aligned with DoD's overall direction.

You also asked for our views on acquisition reform. As a purely S&T organization, DARPA doesn't manage any acquisition programs, so we are not well-positioned to comment on what exactly should be done and how. But, as an organization upstream of acquisition programs, reforms that make the system faster and more agile can only help us more quickly and effectively transition new technologies to the warfighter.

DARPA's Strategic Thrusts

I would now like to update you on our work in more detail by describing the strategic thrusts that currently embody our mission, and providing you with examples of what DARPA has been doing in each.

Robust, Secure, Self-Forming Networks

DoD is in the middle of a transformation to "network-centric operations" with the promise of turning information superiority into combat power so the United States and its allies have better information and can operate far more quickly and effectively than any adversary. Network-centric operations offers the prospect of fusing the typically separate functions of intelligence and operations to dramatically speed up our OODA – "observe-orient-decide-act" – loops.

At the core of this concept are robust, secure, self-forming networks. These networks must be at least as reliable, available, secure, and survivable as the weapons and forces they connect. They must distribute huge amounts of data quickly and precisely across a battlefield, a theater, or the globe, delivering the right information at the right place at the right time. They must form, manage, defend, and heal themselves so they always work at the enormously high speeds that provide their advantages, which means that people can no longer be central to establishing, managing, and administering them.

Tactical networks must locally link effects to targets and be agile, adaptive and versatile. Strategic and operational networks must globally link air, ground, and naval forces for operational maneuver and strategic strike and enable knowledge, understanding, and supply throughout the force. And there is now the opportunity to bridge the gap between these two families of networks so strategic and tactical echelons can share information and insight rapidly and effectively.

To connect tactical ground, airborne, and satellite communications platforms and terminals together, our Network-Centric Radio System (NCRS) program has developed a mobile, self-healing, ad hoc network gateway that provides total radio/network interoperability among these platforms moving in any terrain. Limited radio interoperability has plagued the DoD for decades. NCRS builds interoperability into the network itself, rather than building it into each radio–so now, any radio can talk to any other radio. Previously incompatible tactical radios can talk seamlessly among themselves and to more modern systems, including both military and commercial satellite systems. We are now taking this technology and working on commercial components and practices to make NCRS more affordable at low rate initial production quantities. Specifically, the follow-on program, Mobile Ad hoc Information Network GATEway (MAINGATE), is focused on providing this capability and more at a low unit cost ($60,000 each) in small volumes (1,000 units).

Frequency spectrum is scarce and valuable. DARPA's neXt Generation (XG) Communications technology will effectively make up to 10 times more spectrum available by taking advantage of spectrum assigned to other users, but not being used at a particular place and time. XG technology senses the actual spectrum being used and dynamically uses the spectrum that is not busy at that moment. Recently, XG conducted a series of successful experiments and demonstrations at several military locations, and various organizations within DoD are planning to transition XG technology broadly into current and existing wireless communication systems.

DARPA has been developing communication networks for cities. Urban clutter can create multiple signals from diverse reflections of the initial signal (multipath), and the result is weak or fading communications. Turning this problem into an opportunity, our Mobile Networked Multiple-Input/Multiple-Output (MNM) program is actually exploiting multipath phenomena to improve communications between moving vehicles in cities without using a fixed communications infrastructure.

MNM has demonstrated reliable non-line-of-sight communications during on-the-move field trials in urban environments. MNM successfully exploited multipath to increase information throughput and reliability while maintaining high data rates. The program also demonstrated reliable communications in the face of interference by enabling multiple signals to simultaneously occupy the same frequency band, resulting in increased capacity of that channel.

Building on XG and other technologies, the Wireless Network after Next (WNaN) program is developing an affordable communication system for the "tactical edge." The low-cost, highly capable radio developed by WNaN will allow the military to communicate with every warfighter and every device at all operational levels. WNaN networking technology will exploit high-volume, commercial components and manufacturing so DoD can affordably evolve the capability. This means the radio cost will be so low that we could throw them away after a few years of use and issue newer, more capable radios at the time of deployment – like we use cell phones in civilian life. We are working with the Army to make a "low cost handheld networking radio" for about $500 apiece a reality. In fact, we recently signed a memorandum of agreement that could lead to the Army buying large numbers of units for military use.

DARPA is bridging strategic and tactical operations with high-speed, high-capacity communications networks. The DoD's strategic, high-speed fiber optic network—the Global Information Grid (GIG)—has an integrated network whose data rate is hundreds to thousands of megabits per second. To reach deployed elements, data on the GIG must be converted into a wireless format for reliable transmission to the various units within theater. This creates problems in the timely delivery of information.

How can we connect the tactical warrior to the GIG? We need a high-speed network that robustly disseminates voice, video, text, and situation awareness information among the various military echelons and coalition forces. DARPA is combining the high data-rate capability of laser communications with the high reliability and adverse-weather performance of radio frequency communications to make such a network possible.

The goal of our Optical RF[1] Communications Adjunct (ORCA) program is to create a high data-rate backbone network, via several airborne assets that nominally fly at 25,000 feet and up to 200 kilometers apart, which provides GIG services to ground elements up 50 kilometers away from any one node.

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[1] Radio frequency

Recent ORCA tests demonstrated billions of information bits per second communicated error-free across 147 kilometers on an optical link between two mountains in Hawaii under high turbulence conditions. Moreover, the radio frequency technology maintained communications at hundreds of millions of information bits per second when clouds blocked the optical link. ORCA will perform a more complex set of air-to-air, air-to-mountaintop, and air-to-ground field trials to assess our progress.

At sea, we are working to bridge strategic and tactical maritime operations with a revolutionary new capability for submarine communications. The Navy has long sought two-way communications with submarines traveling at speed and depth. Current technology offers only one-way communications to deeply submerged boats at low data rates by using towed antennas that significantly constrain maneuvers. However, laser-based communications with submarines offers the promise of two-way communications at speed and depth without maneuver restrictions.

We are striving toward a blue laser efficient enough to make submarine laser communications at depth and speed a near-term reality. This laser will be matched with a special optical filter to form the core of a communications system that could enable a signal-to-noise ratio thousands of times better than other proposed laser systems. If successful, it will meet all the Navy's requirements for submarine communications at depth and speed, dramatically change how submarines communicate, and greatly improve their operations and effectiveness. Submarines could become truly persistent nodes for Network-Centric Operations at sea.

DARPA is building the components needed for the laboratory tests to show that an operational system is worth building. If the components prove out, the next step would be to build an actual prototype system and test it as a joint program with the U.S. Navy.

This thrust also contains our work in cyber security, which I discussed earlier.

Detection, Precision ID, Tracking, and Destruction of Elusive Targets

For many years, the DoD has steadily improved its ability to conduct precision strike against both stationary and moving ground targets. In response, America's adversaries realized that if they are to survive, they have to move, hide, or blend into cluttered environments. U.S.

combatant commanders consistently cite the need for an improved ability to find and track these elusive targets.

To provide a focused response to these challenges, DARPA is assembling sensors, exploitation tools, and battle management systems to rapidly find, track, and destroy irregular forces that operate in difficult terrain. This strategy includes small units operating in mountains, forests, and swamps; ground troops that abandon open country for cities; and insurgents whose whole organization – finance, logistics, weapon fabrication, attack – is embedded in civilian activities.

We must seamlessly layer surveillance and battle management systems using a network of platforms with capable sensors and effective weapons. For example, changes detected between images generated by DARPA's foliage-penetrating radar can be used to engage elusive targets. The radar operates at frequencies that penetrate forest canopy. Algorithms, running either on an aircraft or on the ground, compare images taken at different times to detect changes. Because radars operate in all weather and at long ranges, this technique can discover the location of potential targets over very wide areas.

We successfully demonstrated a foliage penetrating radar that detects vehicles and dismounted troops moving under heavy forest canopy. The radar, called FORESTER, was most recently installed on an A160, DARPA's revolutionary high-altitude, long-endurance, unmanned helicopter. In the initial safety test, the A160 was flown with the FORESTER antenna over various altitudes at various air speeds and antenna orientations, including with the antenna deployed at right angles to the helicopter. Significantly, no degradation in aircraft performance and handling was noted. Further testing shows the electromagnetic compatibility of FORESTER with A160. The development of the A160/FORESTER system is continuing, and we expect to transition the system to USSOCOM during this fiscal year.

To identify targets in response to these cues, DARPA developed ladar sensors that can obtain exquisitely detailed, 3-D imagery. By flying the ladar over a potential target, photons can be collected from many different angles. For example, in our Jigsaw program, photons that pass through gaps between leaves and branches can even be assembled into a composite image. The fully integrated Jigsaw 3-D laser radar system was placed on the nose of a UH-1 helicopter and used to collect 3-D imagery of a wide range of obscured targets. Based on these successful

demonstrations, the Jigsaw technology has been transitioned to the Army for continued evaluations, further development, and transition to the warfighter.

For longer distances, DARPA's Standoff Precision Identification in 3-Dimensions (SPI-3D) program is developing a 3-D ladar system to allow commanders to quickly and accurately identify and locate targets at standoff ranges. Flight tests were conducted last June using improved miniaturized components integrated into a Twin Otter airborne testbed. Test sites included both rugged terrain and urban facilities, and the flight data confirmed achievement of the 3-D imaging and location goals.

The Vehicle and Dismount Exploitation Radar (VADER) is a program with the Joint IED Defeat Organization to rapidly create a radar for surveillance and tracking of ground vehicles and dismounts from a Warrior, or similar unmanned aerial vehicle. VADER will provide all-weather detection and localization of vehicles and dismounts at high area coverage rates and will be suitable for urban operations.

VADER conducted its first test flight in April 2008 and successfully produced real-time, high-quality synthetic-aperture radar images and ground moving target indicator data. An exploitation ground system is being developed that will provide state-of-the-art vehicle tracking capabilities, automated intelligent sensor resource management, motion pattern analysis, automated change detection, and advanced dismount signature analysis. Later this year, VADER plans to deliver a radar system suitable for installation and fielding on the Warrior.

This strategic thrust also includes some of our most ambitious work to defeat the threat from improvised explosive devices (IEDs). I cannot say more about this in an open forum.

Urban Area Operations

By 2025, nearly 60 percent of the world's population will live in urban areas, so we must assume that U.S. forces will continue to be deployed to cities. Unstable and lawless urban areas give terrorists sanctuary to recruit, train, and develop asymmetric capabilities, possibly including chemical, biological, and radiological weapons of mass destruction.

Urban area operations can be the most dangerous, costly, and chaotic forms of combat. Cities are filled with buildings, alleys, and interlocking tunnels that provide practically limitless places

to hide, store weapons, and maneuver. They are hubs of transportation, information, and commerce, and homes for a nation's financial, political, and cultural institutions. Cities are densely packed with people and their property, creating an environment in which adversaries can mix and use civilians as shields to limit our military options. And insurgents don't just mix in, they *blend* in.

Warfighting technology that works superbly in the open or in the rugged natural terrain of the traditional battlefield is often less effective in cities. By moving into cities, our adversaries hope to limit our advantages, draw more of our troops into combat, inflict greater U.S. casualties, and cause us to make mistakes that harm civilians and neutrals.

The Urban Area Operations thrust is aimed at creating technology to help make U.S. operations in cities as effective as operations elsewhere by seeking new warfare concepts and technologies that would make a smaller U.S. force conducting operations in an urban area more effective, suffer fewer casualties, and inflict less collateral damage.

DARPA has several programs to vastly improve U.S. capabilities to understand what is going on throughout a complex urban environment.

Threats in urban environments pose unique challenges for the warfighter because the most common objects can have tactical significance: trashcans can contain IEDs, doors can conceal snipers, jersey barriers can block troops, rooftops can become landing zones, and so on. The sheer number of potential threats in a city means that a human geospatial analyst cannot possibly examine city-wide imagery and identify all of them in a meaningful time interval.

This is the background to DARPA's Tactical Ground Reporting (TIGR) system, a multimedia information capture/sharing system first used in Iraq in January 2007; it was so successful in Operation Iraqi Freedom, it was requested by brigades going to Afghanistan. TIGR allows small units, like patrols, to easily collect and quickly share "cop-on-the-beat" information about operations, neighborhoods, people, and civil affairs. This highly detailed patrol-level information is crucial to today's fight. Recent tests have shown that TIGR requires very little bandwidth and operates robustly even when there are frequent network disruptions, important considerations for small units operating in remote outposts in Afghanistan.

DARPA's Urban Reasoning and Geospatial Exploitation Technology (URGENT) program has developed a suite of 3-D urban object recognition algorithms to improve situational awareness for the warfighter in urban environments. URGENT algorithms were evaluated by an independent Government team in December and successfully demonstrated fully automated location and labeling of objects in urban scenes. Further, the algorithms' accuracy was equal to human geospatial analysts and more than 10 times faster. URGENT algorithms will be integrated into operational environments starting later this year.

Our UrbanScape system rapidly creates a 3-dimensional model of an urban area that allows the user to navigate and move around in a computer environment much like a video game – but one based on real data. This capability will allow troops to become very familiar with the urban terrain before beginning a mission.

In 2008, DARPA worked with the Army to evaluate and assess the prototype UrbanScape system in a complex operational training environment. Results of the evaluation concluded that the system met or exceeded all the technical objectives. The system successfully collected data for seven continuous hours, automatically processed all the raw collected data, and converted it to fully fused 3-D models that were of exceptional quality and very accurate. As a result, the system was transitioned to the Army.

Moving up from ground level, DARPA is developing ARGUS-IS, a new wide-field-of-view video sensor that significantly increases the number of targets that can be tracked. The sensor will provide more than 65 real-time, high-resolution video windows, *each one* providing motion video comparable to Predator imagery. Each video window is electronically steerable and independent and can either provide continuous imagery of a fixed area on the ground or automatically track a specified target. From a platform at an altitude of 6,000 meters, the system will be capable of imaging an area of greater than 40 square kilometers with a pixel size on the ground of 15 centimeters. Flight testing of ARGUS-IS on a manned helicopter, followed by flight testing on an MQ-9 Unmanned Aerial System, is planned for early 2010.

In the area of command and control, we need ways to control unmanned aerial vehicles (UAVs) so they are efficiently deployed and do not bunch up on one target. Technology from our Heterogeneous Airborne Reconnaissance Team (HART) program simultaneously controls

multiple UAVs to conduct autonomous, coordinated area searches, allowing warfighters to stay focused on the fight rather than having to pilot UAVs.

In November 2008, HART controlled multiple platforms performing simultaneous tasks over an infantry brigade combat team-sized area of operations. HART autonomously and simultaneously flew more than 50 UAVs and demonstrated the system's ability to reconnoiter hundreds of kilometers of roadway, support convoys and explosive ordnance disposal teams; provide persistent perimeter surveillance for forward operating bases; and rapidly provide multiplatform, multi-echelon "eyes on" support to troops. The Army is preparing portions of HART's capabilities for use in-theater.

Protecting our warfighters from asymmetric attacks is an ever-present challenge – especially in the close-quarters and congestion of cities. DARPA is developing technologies to counter asymmetric attacks, including suicide bombers and IEDs.

IEDs remain a significant threat to our forces in Iraq and Afghanistan. The jointly-funded DARPA/Army Hardwire program has developed and demonstrated several novel hybrid armor concepts aimed at protecting troops in ground tactical vehicles against armor piercing threats, fragments, IEDs, and explosively formed projectiles. All of these armor systems exploit the high-performance characteristics of low-cost, commercially-available materials, and exceed the performance of currently fielded armor at lighter weights.

One Hardwire composite armor system was integrated and tested on a prototype Family of Medium Tactical Vehicles truck cab. The integrated armor provided modular vehicle protection and saved approximately 20 percent of the armor weight on the vehicle, while significantly increasing the protection.

The DARPA Hardwire initiative provides an industrial infrastructure for development of advanced composite armors, under which Hardwire has successfully responded to a critical surge demand for armor materials. Specifically, working closely with the Army and vehicle manufacturers has resulted in rapid transition and armor procurement contracts for both the Navistar MaxxPro-Plus Mine Resistant Ambushed Protected (MRAP) vehicle and the MaxxPro-DASH MRAP vehicle: 2,243 MaxxPro-Plus vehicles up-armored with Hardwire materials are in

theater in Iraq just over two years after the start of the program, and Hardwire is currently producing armor panels for 1,222 advanced IED kits for the MaxxPro-DASH MRAP.

For several years, DARPA's Boomerang system has helped alert ground forces that they are being shot at and from where. On the strength of Boomerang's success, we turned our attention to the air.

Our Helicopter ALert and Threat Termination - Acoustic (HALTT-A) program is developing a system to alert an aircrew of hostile gunfire, and provide the location of the shooter, a caliber estimate, and the trajectories of passing bullets in real time. To-date, five complete live-fire tests have been conducted using different caliber threats in multiple flight regimes and flight profiles including hover and straight and turning flight at speeds between 30 and 150 knots. The most recent test series, conducted in February 2009, included multiple simultaneous shooters and burst fire; the test included over 1600 shots. The HALTT-A system detected 100 percent of the bullets that passed within 100 meters of the test helicopter. One false alarm was experienced. Significantly, no false alarms have been generated by outgoing fire.

There are many dimensions to operating in the complex urban theater that make training very difficult. To improve that training, DARPA's RealWorld program will let U.S. troops rehearse missions using a laptop on which they can build their own mission simulations quickly and easily. They will be able to build simulations, without programmers, saving a tremendous amount of time, money, and manpower while getting better tailored simulations.

Hundreds of beta copies of RealWorld have been distributed within DoD and to other Federal agencies. It is being widely evaluated, including in theater, and is being used to train all U.S. Air Force electronic warfare officers and A-10C pilots. RealWorld is used in the Marine Corps' Infantry Immersion Trainer, by the Defense Threat Reduction Agency for chem-bio dispersion simulation, and by the Air Force for UAV simulations. RealWorld technology is being used in a SEAL Delivery Vehicle trainer and an AC-130 sensor operator station trainer.

Advanced Manned and Unmanned Systems

DARPA has worked for many years toward a vision of a strategic and tactical battlespace filled with networked manned and unmanned air, ground, and maritime systems. Unmanned systems

provide capabilities that free Soldiers, Sailors, Airmen, and Marines from the dull, dirty, and dangerous missions that might be better done robotically, and they enable entirely new design concepts unlimited by human crews.

Our efforts have been focused in two areas: DARPA seeks to improve individual platforms so they provide new or improved capabilities, such as unprecedented endurance or survivability. In addition, DARPA is expanding the autonomy and robustness of robotic systems by more tightly networking manned and unmanned systems to improve our knowledge of the battlespace, enhance our targeting speed and accuracy, increase survivability, and allow greater mission flexibility.

Our A160 program has been developing an unmanned helicopter for intelligence, surveillance, and reconnaissance (ISR) missions, with long endurance – up to 20 hours – and the ability to hover at high altitudes. In 2008, the A160 set a world record for UAV endurance when it completed an 18.7-hour endurance flight, carrying a 300-pound payload, much of the time at 15,000 feet. The A160 will eventually fly at speeds up to 165 knots with a ceiling of 20,000 to 30,000 feet altitude for more than 20 hours, and a high hover capability of up to 15,000 feet altitude. The altitude and endurance of this UAV, combined with the ability to hover at altitude and take off and land vertically with a significant payload, will give our military a set of capabilities not currently found in any other operational aircraft.

In the past, we described the Wasp micro air vehicle, a squad-level surveillance and reconnaissance asset that enables small units to quickly see their local terrain from above. Wasp gained the distinction of being the first micro air vehicle (MAV) to be adopted by our forces in an acquisition program, the Air Force's Battlefield Air Targeting Micro Air Vehicle. Based on Wasp, DARPA's Stealthy, Persistent, Perch and Stare program is creating an entirely new generation of perch-and-stare MAVs that can fly to difficult targets, land, perch, conduct sustained surveillance, and return home.

The Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration (ACTD) program developed a back-packable, easy-to-operate, affordable reconnaissance and surveillance system organic to and operated by platoon-sized units. The MAV is capable of vertical takeoff and landing, allowing it to be deployed from nearly anywhere. It provides hover-and-stare capability

and can effectively monitor a 10-kilometer area, remaining in the air for approximately 40 minutes at density altitudes in excess of 7,000 feet. The system provides still images and full motion video from a gimbaled camera in either visible band or infrared for day and night. As part of the Joint Explosive Ordnance Disposal Taskforce (J-EOD), the Navy has been testing 10 MAV systems (20 aircraft) in theater since 2007. Based on the success of that testing, the Navy recently issued a contract to procure 90 systems for use by EOD teams in theater. Delivery of these units is expected later this year.

Just as air vehicles have moved toward increased mission complexity and increased environmental complexity, DARPA is trying to increase both the mission and environmental complexity for autonomous ground vehicles.

The Unmanned Ground Combat Vehicle – Perception for Off-Road Robotics (PerceptOR) – Integration (UPI) program demonstrated an unmanned ground vehicle (UGV) capability by putting perception and the use of terrain data for path planning on an extremely capable robotic vehicle. DARPA has begun to transition this technology to the Army and provided a prototype ground vehicle with PerceptOR vehicle control algorithms and software to the Army Tank-Automotive Research, Development and Engineering Center to use in developing a UGV control architecture and conducting vehicle design and control risk mitigation activities for Future Combat Systems (FCS) UGVs. UPI's perception and planning control and sensor algorithm suite has been transitioned to the FCS Autonomous Navigation Sensor program, the technology has been used in NASA's Mars Rover, and is being integrated into mining trucks.

DARPA held a series of prize competitions in 2004-2007 to promote the development of autonomous ground vehicles. The final event, the Urban Challenge, used what we had learned in the two open desert Grand Challenges to lay out a far more difficult challenge: autonomous ground vehicles driving at-speed in urban traffic, obeying driving rules and regulations, and interacting with other manned and unmanned vehicles, maneuvering in a mock city on simulated military supply missions.

Last November, the National Museum of American History added a display on autonomous ground vehicles, one that features the winner of our 2005 Grand Challenge, "Stanley," and one of the most innovative entrants we had, an unmanned motorcycle called "Ghostrider." The

display is well done, and I encourage you to visit it and see what this committee and others in Congress helped make happen. Getting an achievement into the Smithsonian is a signature achievement for any scientist or engineer, and we are very proud to have it there.

Detection, Characterization, and Assessment of Underground Structures

Our adversaries are well aware of the U.S. military's sophisticated intelligence, surveillance, and reconnaissance and global strike capabilities. In response, they have been building deeply buried underground facilities to hide and protect various activities.

These facilities range from caves to complex and carefully engineered bunkers in both rural and urban environments. They can be used for a variety of purposes, including protecting leadership, command and control, hiding artillery and ballistic missiles launchers, and possibly producing and storing weapons of mass destruction.

To meet the challenge posed by these facilities, DARPA is developing a variety of sensor technologies and systems – seismic, acoustic, electromagnetic, optical, and chemical – to find, characterize, and conduct post-strike assessments of underground facilities.

Our program is working on tools to answer the questions, "Where is the facility? What is this facility's function? What is the pace and schedule of its activities? What are its layout, construction, and vulnerabilities? How might it be attacked? Did an attack destroy or disable the facility?"

To answer these and other questions, DARPA is developing ground and airborne sensor systems with two-orders-of-magnitude improvement in sensor system performance, with emphasis on advanced signal processing for clutter rejection in complex environments.

Space

DARPA began as a space agency, when the shock of Sputnik caused Americans to believe the Soviet Union had seized "the ultimate high ground." DARPA's ambitious efforts are aimed at ensuring the U.S. military stays preeminent in space.

DARPA's space strategic thrust has five elements:

- Access and Infrastructure: technology to provide rapid, affordable access to space and efficient on-orbit operations;
- Situational Awareness: the means for knowing what else is in space and what it is doing;
- Space Mission Protection: methods for protecting U.S. space assets from harm;
- Space Mission Denial: technologies that will prevent our adversaries from using space to harm the U.S. or its allies; and
- Space-Based Support to the Warfighter: reconnaissance, surveillance, communications, and navigation to support military operations down on earth – extending what the United States does so well today.

The Falcon program is working to vastly improve the our capability to promptly reach other points on the globe by developing technologies for long-duration hypersonic flight. The program recently fabricated and tested a prototype carbon-carbon aeroshell, a key technology for future hypersonic vehicles. Falcon's aeroshell is both the thickest carbon-carbon laminate and the largest complex carbon-carbon shape ever made, an achievement that required breakthroughs in carbon-carbon processes and advanced nondestructive evaluation and inspection techniques.

The Space Surveillance Telescope (SST) program will demonstrate rapid, uncued search, detection and tracking of faint, deep-space objects, such as small, potentially hazardous debris objects and future generations of small satellites. SST's novel wide-field-of-view, rapidly scannable, three-mirror, 3.6-meter telescope design is the first to make use of recent advances in curved focal plane technology. The program is completing final assembly, polishing, and testing of subsystems, and components. Onsite integration of subsystems and components will begin this summer, with "first light" expected next year.

The Integrated Sensor is Structure (ISIS) program is developing a stratospheric, airship-based, autonomous, unmanned sensor offering years of persistence in surveillance and tracking of air and ground targets. ISIS will have the capability to track the most advanced cruise missiles at 600 kilometers and dismounts at 300 kilometers. It uses a large aperture instead of high power to meet radar performance requirements, making it the most powerful moving target indicator radar ever conceived.

The enormous size of ISIS requires that we develop an advanced, ultra-low-weight hull material that is flexible and structural and can incorporate the platform's electronic sensors. DARPA's researchers began with ultra high molecular weight polyethylene fibers and overcame materials

and fabrication limitations to produce a breakthrough composite laminate hull material that is robust and significantly lighter than materials currently used in lighter-than-air vehicles.

Combined with other key advances in the airship power system and radar antenna and components, the stage is now set for building a scaled demonstrator of ISIS. DARPA has signed a memorandum of agreement with the Air Force to jointly fund the demonstration phase of the program, which will culminate in a year-long flight of a one-third scale ISIS system.

Increasing the Tooth-to-Tail Ratio

Today's forces require an extensive support infrastructure that is growing even larger. The military sometimes describes the proportion of forces in actual contact with the enemy to the supporting forces as the tooth-to-tail ratio. Improved information technology can reduce the layers and amount of infrastructure (the "tail") needed to operate the computers, software applications, and networks that support fighting forces (the "tooth"). The fundamental goal of this thrust is to get more of our forces into the fight.

The major themes of this strategic thrust are:

- Cognitive Computing – reducing manpower by providing information systems that "know what they are doing" and whose functionality improves through user interactions;
- High Productivity Computing Systems – speeding up the development and deployment of new weapon systems by more complete and rapid design and testing; and
- Language Processing – improving our global operations by removing language and cultural barriers through superb machine language translation, thereby reducing the need for human translators and improving our local knowledge and interactions with the local population.

Cognitive Computing

Computer systems are essential to military logistics and planning, command and control, and battlefield operations. However, as computing systems have become pervasive in DoD, they have also become increasingly more complex, fragile, vulnerable to attack, and difficult to maintain. The computing challenges facing DoD in the future – autonomous platforms that behave reliably without constant human intervention, intelligence systems that effectively integrate and interpret massive sensor streams, and decision support systems that can adapt rapidly – will depend on creating more flexible, competent, and autonomous software.

Today's computers handle low-level processing of large amounts of raw data and numeric computations extremely well. However, they perform poorly when trying to turn raw data into high-level actionable information because they lack the capabilities we call "reasoning," "interpretation," and "judgment." Without learning through experience or instruction, our systems will remain manpower-intensive and prone to repeat mistakes, and their performance will not improve. DoD needs computer systems that can behave like experienced executive assistants, while retain their ability to process data like today's computational machines.

The Personalized Assistant that Learns (PAL) program is developing integrated cognitive systems to act as personalized, executive-style assistants to military commanders and decision-makers. PAL is creating a new generation of machine-learning technology so information systems automatically adjust to new environments and users, help commanders maintain battle rhythm, and adapt to new enemy tactics, evolving situations and priorities. The program will help new personnel be effective more quickly in command operations, while making more effective use of resources.

PAL technologies are being used by the Army's Command Post of the Future (CPOF) to amplify the capabilities of overworked combat command and control staffs. Working with CPOF, PAL learns significant battlefield activities; organizes and locates them on maps, and helps users collect information, plan, and execute operations. Evaluations at the Army Battle Command Battle Lab (BCBL) were highly successful: In a head-to-head evaluation, a PAL-enhanced CPOF prototype strongly outperformed the existing manually controlled CPOF.

PAL technology has been integrated and deployed on the situational awareness network of a unified command to facilitate the sharing of intelligence, enabling analysts and decision-makers to stay abreast of events unfolding throughout the world in real time. PAL technology is also helping get the right information to the right people at three military websites – one for platoons, one for companies, and one for military families.

PAL technology is used at a major military hospital center to automate and streamline patient booking. Hospital receptionists, not programmers, will teach PAL tasks such as finding appointments, making referrals, booking appointments with doctors based on referrals, adding notes, and sending reminder notices by demonstrating how to perform each task. By combining

new information with prior knowledge and a concrete demonstration by the user, PAL will "learn" complex tasks in a single brief training session.

High Productivity Computing Systems

The High Productivity Computing Systems program is pursuing economically viable, high productivity supercomputing systems. The major goal is to produce extremely high performance computing systems that can be easily programmed and used by experts and nonexperts alike. These innovative systems will emphasize programmability, portability, scalability, and robustness as well as high performance goals of achieving multiple petaflops and thousands of global updates of memory per second.

The program continues to make progress. Key hardware components are fabricated and being tested, and software from the program is beginning to make its way into some of the latest, most high performance products. The program will culminate in prototype demonstrations that will begin at the end of 2010.

Language Processing

Real-time language translation technology will help U.S. forces better understand adversaries and the overall social and political contexts of the operational areas. This enhanced awareness will decrease costly mistakes due to misunderstandings and improve our chances of success.

Today, linguists translate important information, but it is a slow and arduous process. Massive amounts of raw data are collected, but there are not enough linguists to handle it. To deal with the volume of data, we must dramatically reduce the reliance on linguists at both the strategic and tactical levels by using revolutionary machine translation capabilities.

At the strategic level, the goal of the Global Autonomous Language Exploitation (GALE) program is to translate and distill foreign language material (e.g., television shows and newspapers) in near-real-time, highlight the salient information, and store the results in a searchable database. Through this process, GALE will produce high-quality answers to the questions that are normally provided by bilingual intelligence analysts. GALE is making progress toward achieving this very ambitious goal by 2011.

Currently, GALE performance for newswire is 90 percent of the documents exceed 87 percent accuracy, while for web logs and news groups, 85 percent of the documents exceed 84 percent accuracy. For broadcast news, 85 percent of the documents exceed 85.6 percent accuracy, and for broadcast talk shows 75 percent of the documents exceed 84 percent accuracy.

But the real proof of GALE's value is that it is being used today. A Special Forces unit is using GALE technology to translate Arabic television broadcasts and other sources in Iraq. Users watch Arabic television while GALE provides synchronous English translation. They then search through transcripts and translations of video from multiple channels. Synchronization among the video, Arabic text, and highlighted English translation allows for easier and more timely identification of relevant information.

At the tactical level, there are not enough translators for each patrol or checkpoint. Our warfighters need automatic, on-the-spot speech translation to take advantage of what they may be told by locals and to train or conduct missions with Iraqi units. DARPA's Spoken Language Communication and Translation System for Tactical Use (TRANSTAC) program is working on two-way speech translation to convert spoken foreign language input to English output and vice versa. TRANSTAC works on basic questions and answers about people, medical screening, civil affairs, and force protection.

DARPA's first Iraqi Arabic speech translation system was prototyped in 2006 and has undergone rapid enhancements. In March 2008, the Marines successfully trained with TRANSTAC prototypes during exercises with Iraqi Arabic speakers covering such scenarios as vehicle check points, census collections, home searches, and civil affairs meetings.

Bio-Revolution

DARPA's strategic thrust in the life sciences, called Bio-Revolution, is a comprehensive effort to harness the insights and advances of modern biology to make U.S. warfighters and their equipment safer and more effective.

The Bio-Revolution thrust has four broad elements.

Protecting Human Assets

Advances in biological warfare defense (BWD) should protect warfighters not only from traditional and modern biowarfare agents, but also from the infectious diseases they regularly encounter overseas.

Developing defenses against biological attack poses daunting problems. Strategies using today's technologies to counter future biological threats are seriously limited. From the moment a new pathogen is first identified, today's technology requires at least 15 years to discover, develop, and manufacture large quantities of an effective therapy. Since it is nearly impossible to predict what threats might emerge in 2 decades, particularly engineered threats, it would be exorbitantly costly to attempt to "cover the bases" with the research and development required to deal with a wide range of potential threats, and then stockpile, maintain, and indefinitely renew population-significant quantities of vaccines or other therapeutics just in case one or more of those threats might emerge. And if, in spite of all this, a previously unknown or unpredicted pathogen does appear, there may well be no effective therapeutics available.

DARPA has been seeking to change the stockpiling paradigm by creating technologies to shrink the time from when a pathogen first appears to the production of millions of doses of effective therapeutics from today's 15 years to *16 weeks or less.* This plan includes work to identify and characterize pathogens, boost the effectiveness of vaccines, and find and design new therapeutics that are effective against an extremely broad array of pathogens.

Central to this vision, DARPA's Accelerated Manufacturing of Pharmaceuticals (AMP) program is producing technology for large-scale, rapid manufacturing of therapeutics and vaccines. Instead of the years required to ramp up today's manufacturing practices, AMP technologies will combine high-speed, natural biological production systems, such as fungi, plants, and mushrooms, with powerful enabling technologies such as flexible bioreactor systems and automated growth processes and enable rapid and inexpensive manufacture of millions of doses of life-saving drugs or vaccines, at unprecedented scale, in a matter of weeks.

The AMP program advanced the fungal approach to demonstrate an emergency capability for production of monoclonal antibodies at less than $10 per dose, approximately 1/100 the cost of current production methods.

In the case of plants, DARPA demonstrated that a hydroponic growth rack, roughly 14 feet by 10 feet by 10 feet tall, can yield sufficient protein for at least 1 million vaccine doses – replacing 3 million chicken eggs as a growth medium. This technology is readily scalable to 3+million dose capacity: the seed stocks are easily stored and, within 6 weeks of seeding, the plant-generated vaccine materials can be harvested for purification. This approach has also demonstrated the capability to produce vaccines that cannot be produced using current egg-based methods, such as a vaccine against a strain of avian flu that cannot be produced by traditional means because, not surprisingly, it kills the eggs. Work has begun on a large-scale, automated Good Manufacturing Practice vaccine production facility based on this technology.

We also made great progress in demonstrating that a third approach based on the common button mushroom, like the ones you buy in the grocery store, could be used to produce viable proteins, such as human monoclonal antibodies and vaccines. This approach offers the prospect that today's automated commercial mushroom farming practices can be combined with current protein expression technologies to produce massive doses of protein therapies and vaccines at comparatively low cost.

"Protecting human assets" also means doing everything we can to greatly improve the chances of our wounded forces surviving battlefield injury. Hemorrhage continues to be the leading cause of death from combat injuries on the battlefield, accounting for about 50 percent of fatalities. To extend the time available for evacuation, triage, and supportive therapies, DARPA's Surviving Blood Loss (SBL) program is developing novel strategies to delay the onset of hemorrhagic shock due to blood loss by extending the "golden hour" after severe trauma, during which successful treatment is possible, to 6-10 hours, or more. SBL is working to understand how the body's energy production, metabolism, and oxygen use is controlled and to identify protective mechanisms to preserve cellular function despite low oxygen caused by blood loss.

SBL identified two very promising therapeutics -- hydrogen sulfide and estrogen -- that, in large animal tests, extended survival from potentially lethal hemorrhage to more than 3 hours without requiring resuscitative fluids. Human safety trials for the hydrogen sulfide treatment are proceeding: one clinical study on the toxicology has been completed, and a second clinical study on dosing is underway. Our commercial partners in the estrogen-based countermeasures are preparing designs for clinical trials.

DARPA's PREventing Violent Explosive Neurological Trauma (PREVENT) program seeks to analyze and build understanding of blast-induced traumatic brain injury (TBI) so as to be able to better treat and prevent TBI. PREVENT's systematic study evaluated the nature of physiological injury on animal surrogates exposed to increasing blast levels both in the open and in confined spaces that mimic conditions in an armored vehicle. Early evidence shows that low level of blast in animals does not lead to TBI. At the other end, very high blast levels can directly cause severe TBI including gross tissue damage, vasospasm and death.

At moderate blast levels, however, the results appear more important. At those levels, there is little evidence of direct blast-induced destruction of brain neurons. But in the acute phase, there is significant inflammation of intercellular tissue around the neurons, which persists for days to weeks. When untreated, this inflammation is found to eventually lead to degeneration of brain fiber tracts. The mechanism for this degeneration appears to be disruption of the extracellular matrix and not the brain cells themselves. This discovery, if confirmed, suggests the possibility that by treating people for inflammation after moderate blasts, perhaps even with over-the-counter medicines, we may be able to prevent long-term TBI in some cases. At this point in our investigations this is just a possibility, not a known solution, but our discovery of the potential role of inflammation in TBI could be very important if confirmed.

PREVENT has also sponsored studies of Marine breachers in training. It was found through brain imaging scans (MRI) and neurobehavior testing that, even though these Marines are exposed to up to 70 explosive blasts over a two week training period, there was no evidence of brain injury. However, one surprising finding was elevated levels of lead in their blood, although still within OSHA approved levels. While the levels alone were not high enough to cause neurological damage, other tests suggest that when an electromagnetic burst, such as can be caused by some IEDs, occurs in the presence elevated levels of lead, neurons can function abnormally and degenerate. It should be noted that in training, the breachers do not use explosives that emit electromagnetic bursts. These investigations suggest there could be multiple and synergistic factors in the creation of TBI.

In Phase 2 of PREVENT, treatment and mitigation strategies will be developed based on these new insights.

Biology to Enhance Military Systems

DARPA is creating new systems by developing materials, processes, and devices inspired by living systems. The idea is to let nature be a guide toward better engineering.

For example, our brain is among the finest processors of visual imagery of which we are aware. No inanimate machine yet devised comes close to the brain at visual pattern recognition. DARPA's Neurotechnology for Intelligence Analysts (NIA) program seeks ways to harness this unique capability of the brain to vastly improve the productivity of our imagery analysts so they can spend more time on actual analysis.

In the current phase of NIA, researchers are testing increasingly complex imagery in a variety of modalities. Additional tests with imagery analysts confirmed findings from the initial observations, and pilot experiments investigating differences associated with target complexity and alternative chip presentations are underway to further improve this technology.

On the ground, today's U.S. infantry squads must carry large loads, in many cases more than 100 pounds per soldier, into remote areas inaccessible to traditional wheeled or tracked vehicles. DARPA's Big Dog program developed a walking robotic "mule" to travel with dismounted infantry carrying supplies. Big Dog proved the basics of quadruped control and terrain negotiation, culminating in two 250-pound prototypes. In joint DARPA-Marine Corps experiments, Big Dog repeatedly negotiated a difficult 200-meter section of a Marine infantry training course carrying an 80-pound mortar system. The robot demonstrated its endurance by autonomously following Marines on a trail for 7.8 miles in 3 hours and autonomously navigating along waypoints provided by a mission planning unit.

Maintaining Human Combat Performance

We train our warfighters to be in peak condition when deployed, despite extreme battlefield environmental stresses such as heat and altitude acclimatization, prolonged physical exertion, and sleep deprivation. DARPA is working to maintain the warfighter's physical and cognitive performance once they are deployed.

The Peak Soldier Performance program is developing technologies to maintain optimal warfighter performance, despite the stressors of combat. This program's past achievements

include the simple, novel "cooling glove" technology that can both cool troops who have become overheated and warm those who have become chilled.

In 2008, Peak Soldier Performance researchers identified that calcium leaking into muscle cells was a major cause of muscle fatigue, contributing to muscle damage and inflammation – negative effects that can last for weeks. This research also demonstrated that a novel drug, S107, which prevents calcium leakage, limits muscle fatigue in mice. S107 may enable the warfighter to perform at peak levels without the fatigue related muscle damage normally associated with extended missions.

Restoring Combat Capabilities after Severe Injury

Beyond the obligation to care for our troops when they are injured, a longer-term obligation is to do the best we can to rehabilitate them. DARPA's goal is to return wounded warriors, as best we can, to who they were before they were injured.

Improvements in body armor and medical care increase the chances of survival, but also lead to more limb amputations. While current prosthetic leg technology is good and is advancing, prosthetic arm technology, involving so many more joints and complex movements, as well as the combined abilities to touch, sense, and manipulate fine objects, is much more challenging.

The ultimate vision of our flagship program, Revolutionizing Prosthetics, is to utterly transform upper extremity prosthetics, specifically arms and hands. Our goal is to develop a prosthetic arm that can be controlled directly by the brain and provide the manual dexterity and sensation feedback approaching that of a natural hand or arm.

We are making rapid progress. Clinical and home trials will soon begin at two Veterans Affairs clinics with an intermediate-stage prototype arm. While not neurally controlled and having less capability than the ultimate goal, this prototype is already the best in the world and, because of its modular design and flexible control, is meeting the needs for a variety of amputees. After only a few hours of training, patients display a range of function far beyond that of even the best conventional prosthetics, including field stripping, reassembly, and firing an M16; opening doors; eating soup; and even reaching above their head, grabbing a bottle, and opening it with a bottle opener. This prototype weighs only 8 pounds, has 10 powered degrees of freedom, and

nearly 11 hours of battery life. The device can provide afferent feedback so the amputee can sense pressure applied to an object.

For patients who do not need or want a neurally controlled prosthetic, this prototype could provide a significant improvement in function over currently available commercial devices. The prototype has been evaluated in six patients with more than 500 hours of use and is entering advanced clinical trials with anticipation of full manufacture, marketing, and delivery to combat amputees.

The next phase of the program will demonstrate the use of an implanted wireless chip to enable full brain or peripheral control of the prosthetic. By comparison, these chips are smaller and use less power than the implanted heart pacemakers in use by millions of people around the world. Early investigations with wired devices and ongoing experiments with wireless devices demonstrate the feasibility of using wireless signals from the brain and peripheral nerve to control a prosthetic arm. If the goals of the program are fully achieved, the prosthetic arm will mimic the response of the original natural arm. DARPA expects submission for FDA approval of this prosthetic in early 2010.

Core Technologies

While our strategic thrusts are strongly driven by national security threats and opportunities, a major portion of our research is largely independent of current circumstances. These investments in fundamentally new core technologies historically have been the technological feedstocks for new systems.

Quantum Science and Technology

Until recently, quantum effects in electronic devices have not had overriding significance. As devices shrink to near atomic dimensions, quantum effects not only have to be taken into account, but can dominate device performance. DARPA is sponsoring research aimed at technology that actually exploits these quantum effects to achieve revolutionary new capabilities.

The Quantum Entanglement Science and Technology (QuEST) program is (1) creating new quantum information science technologies, focusing on overcoming the loss of information due to quantum decoherence and limited communication distance due to signal attenuation, and (2)

developing protocols and techniques for exploiting larger numbers of quantum bits (qubits) and their entanglement.

Bio-Info-Micro

For the past several years, DARPA has exploited and developed the synergies among biology, information technology, and micro- and nanotechnology. Advances in one area often benefit the others, and bringing together the science and technology from these three areas produces new insights and new capabilities.

The Fundamental Laws of Biology (FunBio) program is working to discover the fundamental laws that govern biological behavior on multiple, interconnected scales – from molecule to cell to organism to population – and to show that such laws can be used to make accurate predictions about biological processes, just as physical theory enables predictions about processes in the inanimate world.

The program has delivered results of enormous potential benefit. New models of viral and bacterial evolution are providing insight into how those organisms leverage genetic variation to escape the body's immune system and will guide the development of new treatments for disease. Other models explain how cyclic growth patterns in plants and animals link gene expression with structural development and provide a deeper understanding of tissue generation. Novel analytical techniques provide insight into new ways of diagnosing congestive heart failure. Underlying all these discoveries is an emerging picture: Environmental pressure, under the right set of biological conditions, forces a spontaneous and quantifiable change in biological organization. The mathematical expression of this principle will be a key insight toward unlocking a unified, predictive, theoretical foundation for biology.

Materials

DARPA continues to maintain a robust materials research program. Its approach is to push new materials opportunities and discoveries that might change how the military operates. DARPA's current programs in material science are focused on the following areas:

- Structural Materials and Components: low-cost and ultra-lightweight materials designed for structures or to accomplish multiple performance objectives in a single system;

- Functional Materials: advanced materials for nonstructural applications such as electronics, photonics, magnetics, and sensors; and
- Smart Materials and Structures: materials that can sense and respond to their environment.

The Prognosis program is developing the science and technology to revolutionize the maintenance of turbine engines and aircraft. The idea is to perform preventive maintenance when physics predicts it is actually required, rather than according to a schedule. The program recently completed tests on a retired outer wing panel from an EA-6B naval aircraft. Predictions made by Prognosis technology correctly identified the actual crack sizes found during post-test teardown. The test validated Prognosis as a management tool for both legacy and new aircraft. Prognosis technology shows that, using the same risk criteria, the aircraft's flight capability was more than 60 percent longer than prescribed by the Navy's original Fatigue Life Expended retirement strategy.

Power and Energy

Developing portable, efficient, and compact power supplies has important ramifications for increasing our military's reach, decreasing our logistics burden, and improving the overall efficiency of our warfighting forces – especially for distributed and net-centric operations.

Our BioFuels program is developing an affordable surrogate for military jet fuel (JP-8) derived from oil-rich crops, such as canola, to reduce the military's reliance on petroleum-based fuels to power aircraft, ground vehicles, and ships. A modified version of the process has been successfully scaled up and produced more than 6,000 gallons of fuel for engine certification for aircraft. Eventually much larger capacity facilities will be needed.

The Bio-Fuels program also is investigating using short chain oils, say from biomass waste, that must be "stitched up" to create JP-8. Having an efficient process for doing so is a key technical challenge. We have made progress here as well, producing small quantities of fuel that meet some of the most important JP-8 requirements like energy content, flash point, and freeze point.

The newest development in the program is a concerted look at algae-based ("algal") fuels. Nonedible feedstocks like algae promise to reduce biofuel's price pressure on food by using

nonagricultural land. The great advantage of algal fuels for JP-8 is the extremely large potential yield per acre. This work is in its early stages.

As electronic devices continue to shrink in size, their application in small autonomous networks and miniature robotics become limited by the size of the power source. Conventional batteries lose energy density as they lose volume due to the current packaging schemes. The Micro Power Sources program is working to overcome this constraint to produce cubic-millimeter-sized batteries by exploiting advances in battery chemistries and new architectures to maintain and increase energy densities. DARPA researchers demonstrated a 0.77-cubic millimeter microbattery with an integrated silicon photovoltaic having an energy density greater than 300 watt-hours per liter, compared to conventional batteries with approximately 350 watt-hours per liter packaged in cells many orders of magnitude larger, and a power density greater than 200 watts per liter. Our goal is to produce a battery more than 1,000 times smaller than today's lithium-ion cells – less than one cubic millimeter – with comparable energy density.

Microsystems

DARPA is shrinking ever-more-complex systems into chip-scale packages, integrating microelectronics, photonics, and microelectromechanical systems (MEMS) into "systems-on-a-chip" that have new capabilities. It is at the intersection of these three core information age hardware technologies where some of the greatest opportunities for DoD applications arise. By integrating elements from these core technologies with advanced architectures and algorithms, bulky existing systems can be reduced to sugar-cube size, and completely new capabilities can be developed.

DARPA is also exploiting advances in nanoscience and nanotechnology, where matter is manipulated at the atomic scale to enable still-more-complex capabilities in ever smaller and lower-power packages. The vision includes adaptable microsystems for enhanced radio frequency and optical sensing; more versatile signal processors for extracting minute signals in the presence of overwhelming noise and intense enemy jamming; high-performance communication links with assured bandwidth; and intelligent chips that allow a user to convert data into actionable information in near-real-time.

Together, these capabilities will create information superiority for our forces by improving their ability to collect, process, manage, and act on information – with the ultimate goal of enabling U.S. forces to think and react more quickly than the enemy in a rapidly changing battlespace.

Microelectronics

DARPA is tackling one of the most important roadblocks to increasing chip performance: heat dissipation. As transistor size decreases, their number and chip-clock frequency increases, causing waste heat generation to rise sharply. Today, some chips dissipate as much heat per square inch as a hotplate, with the result that chip-clock speeds cannot increase further. The long-term consequences threaten to break Moore's Law of continued performance improvement through transistor scaling and increasing clock speed.

DARPA is pursuing ways to push through the heat dissipation roadblock. An entirely new type of transistor, called a "tunneling transistor," is being investigated. This approach would operate devices at lower voltages – ¼ volt instead of today's 1 volt – and thereby greatly reduce heat generation, which is proportional to the square of the voltage. Efforts are underway to further reduce the heat dissipated in standby mode – when a transistor is nominally "off" – by using nanoelectromechanical switches to physically disconnect, or unplug a transistor when it is turned off, preventing leakage current that generates waste heat. Researchers also are working to reduce the heat generated in the wires connecting active devices within a chip by replacing longer metal wires with optical interconnects, which generate far less heat and greatly improve data transfer speed.

In addition to our work to reduce the amount of heat produced, we are working on new ways to better manage the heat that is produced. To that end, we have programs to better extract the heat, starting at the scale of individual devices, extending to transporting heat out of the chip with improved substrates, and even improving air cooling of systems.

In the longer term, nonsilicon electronics will play an increasing role in the advance of microelectronics. Alternatives to traditional silicon chips can provide key advantages to military systems, including greatly enhanced operating speeds, the ability to handle enormous power loads, or dramatically reducing power consumption.

DARPA's wide bandgap semiconductor research demonstrated transistors that offer speed and power performance far exceeding silicon devices. Gallium nitride devices promise much greater performance for radars. However, up to now, difficulty in producing high quality material has caused major reliability problems. Three years ago, gallium nitride-based microwave power transistors had lifetimes measured in minutes. Today, thanks to advances in our Wide Band Gap Semiconductors for Radio Frequency Applications program, transistor lifetimes have been extended to more than 100,000 hours. The program's dramatic success in meeting its reliability goals in a manufacturable process paved the way to rapidly transition the technology to multiple military systems, including electronic warfare/electronic attack transmitters, missile defense sensors, and Navy radars.

Photonics

Increasingly, light is used to move vast amounts of information between computers. DARPA has pioneered development of photonic components, such as optical wavelength converters, optical switches, optical waveform generators, and optical buffers, under the Data in the Optical Domain Network (DOD-N) program. DOD-N has, for the first time, shown a path to an optical network that eliminates electrical-to-optical-to-electrical data conversion at each data router, increasing the projected network data throughput by over a factor of 10.

DOD-N has had many successes, including the world's first optical random access memory that enables random access storage of optical data packets; highly scalable, multiple wavelength lasers with fast tuning speeds and small footprints; mode-locked lasers that enable retiming, reshaping, and reamplification of optical signals; and the world's highest functional component count photonic integrated circuit (PIC) – a monolithically integrated CMOS/photonic chip that realizes a compact, low-power, tunable optical router with 640 gigabits per second throughput. Combined with new network management strategies that dramatically reduce the amount of buffer memory required at each network node, DOD-N will enable new optical networks that can meet the growing DoD need for bandwidth, while minimizing latency.

Analog to digital (A/D) conversion technology has been around for a long time, but is bandwidth-limited and consumes large amounts of power. Defense applications demanding higher A/D bandwidth include signals intelligence, the need to capture and study large

bandwidths of communications and radar signals, and the growing bottleneck in high bit-rate communications networks at the interface between radio frequency (RF) broadcasts and Internet optical digital signals. Our Photonic Bandwidth Compression for Instantaneous Wideband A/D Conversion (PHOBIAC) program uses a novel, efficient mode-locked laser with ultra-low jitter to advance A/D conversion technology with high capture quality and large bandwidth. PHOBIAC promises to meet the power consumption requirements of many users, while providing 40 times greater bandwidth than today's A/D converters.

Advanced photonic technology is also having a dramatic impact on meeting the low-noise and high dynamic range demands of RF signal processing. Our Linear Photonic RF Front-End Technology (PHOR-FRONT) program is developing the critical, high-fidelity components for a universal photonic RF front end module: a highly stable, high power, low noise, and narrow linewidth laser used to convert the RF signal to a phase-modulated optical signal; and a highly linear, optical phase demodulator that converts the optical signal back to RF. PHOR-FRONT pursued two independent laser designs, resulting in dramatic progress in the laser module development. Both designs show great promise for a wide range of Defense applications that have stringent laser requirements, such as RF photonic links, coherent ladar, acoustic sensors, and advanced optical communications.

Microelectromechanical Systems (MEMS)

Miniaturizing mechanical, thermal, and chemical devices can yield dramatic increases in performance versus their conventional, bulky counterparts. Microscale chemical and biological sensors are being developed that yield higher performance at lower power, as seen in faster response times, lower false alarm rates, and higher probability of detection. The Micro Gas Analyzer program is shrinking a lab bench of equipment for analysis of toxic chemicals down to a few cubic centimeters, allowing for person- or UAV-carried systems that will revolutionize our awareness of the chemical and biological battlespaces.

Combined Systems-on-a-Chip

The Navigation-Grade MEMS Inertial Measurement Unit program is developing tiny, low-power, navigation sensors capable of achieving performance comparable to Global Positioning Satellite (GPS) in settings where GPS is unavailable (e.g., caves and underwater) or denied by an

enemy. This capability will enable precision navigation of small platforms, including individual troops, unmanned air vehicles, unmanned underwater vehicles, and even tiny robots. The program will revolutionize our ability to navigate in places we never could before and in places where adversaries would deny GPS, bringing the equivalent of hundreds of pounds of precision equipment down to systems that fit in a wristwatch.

Information Technology

DARPA's work in information technology is closely intertwined with its strategic thrust in Increasing the Tooth-to-Tail Ratio. It is a core technology that supports advanced military capabilities in the post-2010 timeframe with processing performance in excess of 1 quintillion (10^{18}) operations per second. A challenge we face is creating the tools needed to write applications (software) more quickly and effectively for these extremely high performance machines.

DARPA's Computer Science Study Group (CSSG) program selects a group of extremely talented early-career academic computer scientists for a program that combines support for their current innovative research with educating them on DoD's needs. CSSG challenges them to use the knowledge gained to compete for grants of up to $500,000 to conduct basic research of interest to DoD. Each group is typically about a dozen academics who obtain Secret security clearances and learn about DoD and its challenges.

CSSG performers interact with several military organizations in such diverse areas as analyzing and modeling speech and audio signals for military communications; efficient construction of networks of military sensors and detection devices; dynamic updating of mission-critical software; designing advanced prosthetic limbs with sensory feedback; cost control via improved software dependability; and ensuring secure information flow.

Mathematics

Current program themes include topological and geometric methods, inverse methods, multiresolution analysis, representations, and computation that are applied to design and control complex systems, extract knowledge from data, forecast and assess risk, develop algorithms, and perform efficient computations. These techniques underlay key Defense applications such as

signal and image processing; understanding biology, materials, and sensor data, design, and deployment; and design of complex systems. Inspired by the famous 23 problems posed in 1900 by mathematician David Hilbert, DARPA issued its own 23 mathematical challenges. Hilbert's challenges drove much of mathematics over the next 100 years, and we hope to have at least a fraction of that impact.

Specifically, our Topological Data Analysis (TDA) program is developing mathematical concepts and techniques to determine the fundamental structure of massive data sets with the tools to exploit that knowledge. The result will be easy-to-use algorithms that find and display hidden properties of massive data sets and allow greater and faster understanding of the phenomena they represent. Recent program results include key insights in such diverse fields as images, material science, cancer biology, virus evolution, and medical diagnostics.

Distinguishing high-dimensional patterns in the statistics of natural images is leading toward a novel, nonlinear compression scheme that will revolutionize the way images are analyzed. For example, TDA researchers developed the Mapper tool, which automatically reduces a data set containing millions of points into a mathematical space with far fewer points, based on how a data set fits around a particular geometric shape or topology. These tools successfully demonstrated these principles on a variety of data sets – including natural images and compression, epidemiology, cardiology, and breast cancer – by unraveling distinct features and unique patterns in the data not obtainable using standard statistical tools.

Manufacturing Science and Technology

DoD requires a continuous supply of critical, defense-specific materiel and systems. To ensure reliable, robust, and cost-effective access to these items, manufacturing technologies that can meet those needs must be available in the DoD industrial base.

DARPA's Disruptive Manufacturing Technologies (DMT) program is developing manufacturing technologies and processes that can provide significant and pervasive cost savings for multiple platforms or systems, and/or decreases in manufacturing cycle time for components for existing and future military procurements. A new process pioneered under DMT offers the potential of quickly fabricating armor parts in any shape. Boron carbide nanopowder was plasma-synthesized with trace amounts of titanium, magnesium, tungsten, and aluminum, resulting in a

powder sample that sintered without pressure to greater than 93 percent of theoretical density, and sintered to full density with hot pressing. DMT is currently manufacturing low-cost boron carbide (B4C) armor, with the ultimate goal of demonstrating densification sufficient for hardness and ballistic performance equivalent to conventional hot-pressed B4C used in today's body armor – but at one-third the cost.

Lasers

Lasers have multiple military uses, from sensing to communication to electronic warfare to target designation. DARPA has been involved in lasers since the early 1960's, and continues its work today.

The High Energy Liquid Laser Area Defense System (HELLADS) program is developing a practical, compact, high-energy laser weapon system (~150 kilowatt) with an order-of-magnitude reduction in weight compared to existing laser systems. With a weight goal of less than 5 kilograms per kilowatt, HELLADS would transform operations and provide a tremendous advantage to U.S. forces, such as use on tactical aircraft systems for effective self-defense against even the most advanced surface-to-air missiles.

The program has completed tests of a laser module that demonstrated high laser power output and outstanding optical wavefront quality in a compact package. Two competing contractor teams are developing full-scale laser modules that would be replicated and assembled to produce a continuously operating 150-kilowatt laser with near diffraction limited beam quality that weighs 5 kilograms per kilowatt – the program goal – in a volume of 3 cubic meters.

DARPA's Adaptive Photonic Phased Locked Elements (APPLE) program extends our vision for high energy laser programs. Imagine a laser system with multiple beams that can be independently electronically steered, eliminating electromechanical complexity. Moreover, imagine such beams coming from an aperture that conform to the shape of the aircraft, eliminating a pod that might stick into the airstream and create drag. Finally, imagine that these multiple beams could be used for low-power applications like communications, sensing and tracking—and could be brought together coherently as a high power weapon. That is what we are trying to do with APPLE.

APPLE is ultimately projected to deliver up to 300 kilowatts to a small spot on a distant target. APPLE succeeded, for the first time, in coherently combining a seven-element optical phased array, while utilizing an adaptive optic in each array element to correct for phase distortions introduced by turbulence in the atmosphere.

As I noted above, these systems rest on new core technologies. DARPA is working to develop higher performance components for electric laser systems in the relentless pursuit of ultra-compact, high power laser systems that fit on small platforms such as aircraft pods and UAVs. Over the past several years, the Super High Efficiency Diode Sources (SHEDS) program succeeded in improving the efficiency of diode lasers systems by nearly a factor of 1.5, from 50 percent to 72 percent. SHEDS laser diode bars now produce 120 watts. These advances in laser diode efficiency and power are not only reducing the size and weight of the laser electrical power supply, but also the size and weight of the laser thermal management system.

As many of you know, last year DARPA celebrated its 50th Anniversary. I hope what I have told you today shows that even though are now over 50, we remain bold in our pursuit of our mission.

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