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DEPARTMENT OF DEFENSE LABORATORIES: INNOVATION THROUGH SCIENCE AND ENGINEERING IN SUPPORT OF MILITARY OPERATIONS

HEARING

BEFORE THE

SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

OF THE

COMMITTEE ON ARMED SERVICES
HOUSE OF REPRESENTATIVES

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HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES,
Washington, DC, Wednesday, September 28, 2016.

The subcommittee met, pursuant to call, at 2:00 p.m., in room 2212, Rayburn House Office Building, Hon. Joe Wilson (chairman of the subcommittee) presiding.

OPENING STATEMENT OF HON. JOE WILSON, A REPRESENTATIVE FROM SOUTH CAROLINA, CHAIRMAN, SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

Mr. WILSON. Ladies and gentlemen, welcome. I call this hearing of the Emerging Threats and Capabilities [ETC] Subcommittee of the House Armed Services Committee to order. I am pleased to welcome everyone here today for this hearing on the role of the Department of Defense [DOD] laboratories in supporting military operations.

While the Secretary of Defense has been highlighting the need for increased partnerships with commercial providers in Silicon Valley, Boston, and elsewhere, I think it is important to remember that the Defense Department also maintains its own in-house sustained source of innovation. The Defense Laboratory Enterprise is a robust network of 67 laboratories and engineering centers that are dedicated to providing responsive scientific and engineering advice to support military needs.

As we look to make the Department more flexible and adaptable to take on new innovations, it will be vitally important to ensure that the labs maintain the workforce and infrastructure needed to keep them relevant for the future warfighting environment. And looking at the challenge over the past 2 years, as chairman of this subcommittee, I am concerned that the Department is not doing enough to keep pace with the ever-evolving set of threats.

In order to get a better perspective of these issues, I would like to welcome our distinguished panel of witnesses, which includes Major General Robert D. McMurry, U.S. Air Force, Commander, Air Force Research Laboratory [AFRL]; Dr. Jeffery Holland, Director, Engineering Research and Development Center [ERDC], U.S. Army Corps of Engineers, Waterways Experiment Station; Dr. Edward Franchi, the Acting Director of Research at the Naval Research Laboratory [NRL]; and Dr. Philip Perconti, the Acting Director of the United States Army Research Laboratory, ARL.

I would like now to turn to my friend and ranking member, Mr. Jim Langevin from Rhode Island, for any comments he would like to make.

I would like to remind our witnesses that your written statements will be submitted for the record so that you would summarize your comments to 5 minutes or less.

[The prepared statement of Mr. Wilson can be found in the Appendix on page 25.]

STATEMENT OF HON. JAMES R. LANGEVIN, A REPRESENTATIVE FROM RHODE ISLAND, RANKING MEMBER, SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

Mr. LANGEVIN. Well, thank you, Mr. Chairman.

And thank you to our witnesses for being here today. I certainly look forward to hearing your testimony.

And this hearing represents a unique opportunity to engage the individuals who run the Department of Defense, the DOD in-house innovation centers, the major science and technology laboratory directors.

So, this year in particular, we have heard a lot about the need for innovation in defense technology, and we often associate it with the defense innovation centers, or DIUx, initiative. Although I support outreach to nontraditional defense contractors, today is an important reminder that there are existing tools in DOD's toolbox that have a long history of producing game-changing technologies for our warfighters.

This includes the Naval Undersea Warfare Center's [NUWC] Newport Division in my home State of Rhode Island. NUWC has produced technical advances throughout the lifecycle of many undersea platforms and systems, such as improved mine warfare sonar technology to ensure safe access and passage to vessels both on and below the waves.

Our labs, our DOD labs, are institutions that can and should be further leveraged and enabled by Congress and the Department to make technical advances necessary to maintain our edge. These lab directors are not only intimately familiar with warfighting needs and future requirements, they also have longstanding partnerships with academia and industry in their surrounding communities. If we give them support, facilities, and additional enabling authorities, I believe that they can do even more.

The ETC Subcommittee has long recognized the importance of our defense labs. Over the years, we have granted the Department many different authorities aimed at maintaining innovation in these institutions. These range from providing lab directors direct hiring authority, to special pay and incentives for workforce recruitment and retention, to using research, development, and technology money for military construction [MILCON] and facility repair.

Furthermore, this year, in the National Defense Authorization Act [NDAA] for Fiscal Year 2017, we are considering a pilot program that will enable our lab directors to waive, with approval, internal regulations that hinder technological advancement.

Yet there is more that we can do and more the Department can do to support our labs, including taking a serious look at how the

services' varying and stringent conference attendance policies over the last few years have impacted the ability of the technical workforce to network, to learn, and to showcase.

Today, I look forward to hearing each of your perspectives on innovation in our labs, specifically how past authorities granted have aided in keeping our labs innovative and what more can be done to keep our labs at the forefront of technological advancements.

With that, again, Mr. Chairman, I want to thank you for holding this hearing, and I look forward to the testimony of our witnesses. And I yield back the balance of my time.

Mr. WILSON. Thank you, Mr. Langevin.

It is very appropriate that we have Congressman Mike Turner here today. He is a champion for the Air Force Research Laboratory at Dayton, Ohio, of course. And I am very grateful. Ten thousand persons, military and civilian, work there, and he is a champion. And that is why he is here.

And I ask unanimous consent that non-subcommittee members be allowed to participate in today's hearing after all subcommittee members have had an opportunity to ask questions. Is there objection?

Hearing none, without objection, the non-subcommittee members will be recognized at the appropriate time for 5 minutes.

General McMurry.

STATEMENT OF MAJ GEN ROBERT D. McMURRY, USAF, COMMANDER, AIR FORCE RESEARCH LABORATORY

General MCMURRY. Chairman Wilson, Ranking Member Langevin, members of the subcommittee and staff, Congressman Turner, as we move into fiscal year 2017, I am pleased to have the opportunity to provide testimony on the Air Force Research Laboratory and our efforts to lead the discovery, development, and integration of affordable warfighting technologies in the face of a dynamic, complex, and unpredictable future.

I would like to take a moment to thank Congress and especially the members of this subcommittee for your service and your continued support of our laboratories, facilities, and, most importantly, our valuable scientists and engineers. As the laboratory's commander, I have seen how your commitment to science and technology [S&T] enables us to advance game-changing capabilities, continually develop the S&T workforce, and strengthen and support industrial and academic base while leveraging them for the long-term security of our Nation.

Today's AFRL has a proud legacy of 99 years of critical research efforts enabling the Air Force and Department of Defense to keep the fight unfair. Our technology breakthroughs have contributed to or supported every major operational Air Force platform. As we approach our 100-year anniversary, we now face a relentless pace of change that is increasing complexity and decreasing predictability in warfare.

To address this complex environment, we follow the direction of the Secretary of Defense, Secretary of the Air Force, and Chief of Staff of the Air Force to bring a new level of agility and innovation into our capability development processes, workforce, and infrastructure.

Just as the laboratory provided key innovations in support of both the first and second offset strategies, I am pleased to confirm that our game-changing technologies are already providing support and foundation for realizing a third offset strategy.

Our efforts, many of which are described in my written statement, are aligned to the Long-Range Research and Development Planning Program initiatives. And as part of the Air Force acquisition process, we also incorporate and support Mr. Kendall's Better Buying Power 3.0 initiatives. Both of these broader initiatives provide tools strengthening our ability to innovate, achieve technical intelligence, and transition dominant military capabilities to the warfighter.

The laboratory executes the bulk of Air Force S&T investment. The fiscal year 2017 President's budget request for S&T is approximately $2.5 billion, a 4.5 percent increase from fiscal year 2016.

The budget request provides funding for the small advanced capability missile, the low-cost delivery vehicle, a high-speed strike weapon demonstration, component weapons technology, and for position, navigation, and timing technologies in direct support of the third offset.

We are investing heavily in basic, applied, and advanced research while continuing to focus on game-changers like autonomous systems, unmanned systems, nanotechnology, hypersonics, and directed energy.

At the request of the Chief of Staff of the Air Force, Air Force Materiel Command recently stood up a Strategic Development Planning and Experimentation Office. This office will reinvigorate development planning at the Air Force enterprise level. The new effort will shift the Air Force from platform-centric to strategy-based multi-domain solutions spanning air, space, and cyberspace. The office will support enterprise capability collaboration teams while providing modeling and simulation, wargaming, and data to facilitate development planning for the Air Force's highest priority mission areas.

The laboratory brings data and requirements together with operators, technologists, and acquisition professionals to support Air Force experimentation efforts. We integrate into and support the Air Force's four pilot experimentation campaigns: Future Attack, Directed Energy, Data to Decisions, and Defeat Agile Intelligent Targets.

Finally, I am extremely proud of our world-class scientists and engineers. Every day, I get to work with some of the brightest people in the world. They love this Nation and give selflessly to ensure its protection.

We are working to exercise every authority available to us to compete with industry in attracting and hiring the best people. AFRL does have unique facilities and capabilities, and we use them to attract and inspire individuals to Air Force STEM [science, technology, engineering, and mathematics] careers through outreach and student research experiences.

We endeavor to use all our authorities, including section 219 and MILCON funding, to ensure our laboratory facilities continue to meet our Nation's defense goals.

Mr. Chairman, members of the subcommittee, and staff, thank you again for the opportunity to testify today. I look forward to your questions.

[The prepared statement of General McMurry can be found in the Appendix on page 27.]

Mr. WILSON. Thank you very much, General McMurry.

We now proceed to Dr. Holland.

STATEMENT OF DR. JEFFERY P. HOLLAND, DIRECTOR, ENGINEER RESEARCH AND DEVELOPMENT CENTER, U.S. ARMY CORPS OF ENGINEERS, WATERWAYS EXPERIMENT STATION

Dr. HOLLAND. Chairman Wilson, Ranking Member Langevin, distinguished members of the subcommittee, Congressman Turner, thank you for the opportunity to discuss the U.S. Army Engineer Research and Development Center's role as a major Department of Defense science and technology organization. I greatly appreciate the support this committee has shown to S&T and the opportunities that your support has provided ERDC to carry out its mission.

ERDC is the S&T arm of the U.S. Army Corps of Engineers. We conduct research and development in support of the warfighter, military installations, and the Corps' civil works mission. We also manage the Department of Defense's High Performance Computing Modernization Program, which provides supercomputing capabilities to DOD research, development, testing, and evaluation communities throughout the Department.

In fiscal year 2016, we are executing a $1 billion program, $500 million of which is associated with reimbursable projects from every military service, the Office of the Secretary of Defense, and most Federal agencies.

Today, I would like to address three elements that are critical to everything that we do within the ERDC: people, programs, and facilities.

Innovation requires a talented workforce, and I am proud to represent ERDC's 2,100 engineers, scientists, and support personnel. ERDC's human capital goal for this fiscal year and the next 5 years is to hire more than 800 new scientists and engineers to our organization.

We exceeded our annual recruiting goal this year, in large part due to the direct hiring authorities that have been made possible because ERDC is one of the 18 Science and Technology Reinvention Laboratories with laboratory demonstration projects authorized by the 1995 National Defense Authorization Act.

Differing NDAAs have provided numerous enhancements to our hiring authorities, and NDAA 2015 provided direct hiring authorities for students. However, that authority, as yet, has not been delegated to the laboratories.

I want to thank the Congress for its continued support to S&T laboratories by including language in the House and Senate versions of the 2017 NDAA that should greatly enhance our organizations.

Because we have great people, we execute impactful programs. DOD service laboratories play a key role in national security, and ERDC has a long history of providing innovative solutions to keep our warfighters and civilians safe.

Our force protection technologies are installed in theater to protect base camps from rocket and mortar attacks. As an example, though, of a counter-use, the State Department is using this technology to protect critical facilities and personnel worldwide. And many buildings in the National Capital Region, such as the one in which we sit, the Pentagon, and others, are safer because of ERDC protection technologies.

Our airborne counter-IED [improvised explosive device] systems are currently providing CENTCOM [Central Command] with unique capabilities. ERDC's tunnel detection technologies have been applied in Iraq, along the Egypt-Gaza border, and along the U.S.-Mexico border in support of DOD and the Department of Homeland Security.

We deliver environmentally sustainable solutions for energy, water, and waste in installations. And we are the Army's leader in energy R&D [research and development] in support of contingency basing. ERDC is also the world leader in water resources research and development, supporting the Corps' critical missions that provide economic security for our Nation.

Finally, I welcome the opportunity to discuss our facilities in the 219 program. ERDC needs to modernize and recapitalize our facilities in order to ensure that we continue to do the world-class research that we do in support of the warfighter and our Nation. Our 219 authority allows us to fund facilities' improvements, and we have had great success in the use of this authority.

This is particularly important given ERDC's difficulties in obtaining major MILCON funding. We benefit greatly from the committee's willingness to extend and enhance the 219 authorities.

We have not, as yet, been able to take advantage of the authority to provide the 2014 NDAA capabilities that have been written into law to accrue funds over multiple years for larger infrastructure activities. We are working on processes that would allow us to accrue these in an accountable, sustainable fashion.

In conclusion, I invite you to visit ERDC at any time to see firsthand why we come to work every day. We make a difference. We save lives. We safeguard our military and civilians at home and abroad. And we protect and enhance the environment around us.

Mr. Chairman, this concludes my statement. I look forward to the opportunity to answer questions from you and the other members. Thank you.

[The prepared statement of Dr. Holland can be found in the Appendix on page 65.]

Mr. WILSON. Dr. Holland, as a grateful dad of a member of the U.S. Army Corps of Engineers. Thank you for your service.

Dr. HOLLAND. Thank you, sir.

Mr. WILSON. Dr. Franchi.

STATEMENT OF DR. EDWARD R. FRANCHI, ACTING DIRECTOR OF RESEARCH, NAVAL RESEARCH LABORATORY

Dr. FRANCHI. Chairman Wilson, Ranking Member Langevin, and distinguished members of the subcommittee, I thank you for this opportunity to talk about the Naval Research Laboratory's work, how it performs its S&T mission, and some of the challenges it faces to the successful execution of that mission.

NRL was borne from an idea conceived in 1915 by Thomas Alva Edison. The idea became a reality on July 2, 1923. At its most elemental, Edison's idea was that NRL, working with industry and academia, and knowledgeable of naval needs, would help build American seapower through long-term mission-related research and development. For more than 90 years, NRL has fulfilled that inventor's idea and vision.

I would like to give you just a few examples over that time period. In the early years leading up and including World War II, NRL invented the first U.S. radar and we developed the first operational U.S. sonar. During the Cold War, NRL provided America's first intelligence satellite, launched 52 days after the downing of the U–2 aircraft over the Soviet Union. NRL also developed the original concept and two prototype satellites for what is now the Global Positioning System.

As we go forward into regional conflicts and the current uncertain future, we are focusing on key technologies that encompass the third offset strategy. As one example, the laboratory is making important contributions to laser weapons and railguns. NRL scientists were the first to prepare and simulate the use of incoherently combined, high-power fiber lasers as the architecture for the Navy's new Laser Weapon System. NRL's railgun program began in 2003 and has since become a critical element in the efforts to development hypervelocity electric weapons.

Rapid prototyping and experimentation is an important mechanism in transitioning science and technology to demonstrations of operational capabilities. One mechanism is the Navy's rapid prototyping process, where fleet needs are identified through the OPNAV [Office of the Chief of Naval Operations] and Secretariat organizations to energize the entire Naval Research and Development Enterprise to develop solutions for demonstration and evaluation.

The reasons for NRL's success in providing science at the cutting edge through patents and publications and delivering value to the fleet and Nation through technology development and transitions depends on two fundamental imperatives: a high-quality workforce and satisfactory facilities. These are our two main challenges today.

NRL's most serious challenge is the need to remodernize our aging infrastructure. NRL facilities and laboratories are experiencing excessive infrastructure failures. While this is to be expected given the average age of the buildings at NRL's main campus is 59 years, it is further compounded by inadequate investment in new facilities and major repairs of existing facilities.

NRL continues to work with Navy and the Department of Defense to address these issues, as it is critical that facilities be improved so we can attract and retain qualified personnel to work at NRL and deliver state-of-the-art research and technology solutions in facilities adequately suited not only for our current requirements but our future requirements.

The second challenge, which we have done, I think, very well with the help of this subcommittee, is in workforce. We have a world-class workforce of about 1,600 scientists and engineers, with

more than 870 of them having Ph.D. degrees. This high-quality workforce is the biggest reason for NRL's sustained success.

But we must constantly renew this workforce. We use three primary vehicles authorized by Congress: the Naval Innovative Science and Engineering Program, part of section 219; the Laboratory Demonstration Program; and direct hire authority.

Section 219 is primarily used in workforce development, where we have established the Karles Fellowship Program, which provides funding to new hires within a year of their graduation at any degree level with a grade-point average of 3.5. The fellowship provides for 2 years to conduct their own proposed research, and we typically fund 25 to 30 of these new fellows each year.

The Laboratory Demonstration Program began in 1999, and I will say it is working very well, and high satisfaction from the workforce. We are also working with DOD's Laboratory Quality Enhancement Program to achieve other authorities that have been granted.

And, finally, direct hire authority has, since its beginning, enabled NRL to hire almost 500 people in the science and engineering disciplines.

I invite each of you to visit the Naval Research Laboratory, located a short drive from the Capitol. Thank you for your time today, your interest in NRL's work, your concern for defense science and technology, and support of the DOD laboratories and their missions. I look forward to answering any questions you have.

Thank you.

[The prepared statement of Dr. Franchi can be found in the Appendix on page 83.]

Mr. WILSON. Thank you, Dr. Franchi.

We now proceed to Dr. Perconti.

STATEMENT OF DR. PHILIP PERCONTI, ACTING DIRECTOR, UNITED STATES ARMY RESEARCH LABORATORY

Dr. PERCONTI. Good afternoon, Chairman Wilson, Ranking Member Langevin, distinguished members of the subcommittee, and Congressman Turner. Thank you for inviting me to speak about Army science and technology in support of military operations. I am truly honored to be here and to represent my colleagues.

Army Chief of Staff General Mark Milley has made readiness the Army's top priority. As the world's preeminent ground combat force, the Army's definition of readiness must include meeting today's urgent operational needs while ensuring decisive overmatch for the future force.

As the Army's corporate research lab, ARL performs foundational research to discover, innovate, and transition technological developments geared toward acting on opportunities in power projection, information, lethality and protection, and soldier performance.

ARL is a part of the Research, Development, and Engineering Command [RDECOM], the Army's lead for technology integration and the Army's enabling command in the development and delivery of unprecedented capabilities for the warfighter.

The RDECOM's strategy for understanding emerging threats and the operational requirements that next-generation systems will face are shaped by the strategic guidance from the Office of the

Secretary of Defense [OSD]; the technical and programmatic oversight of the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology; the Army Materiel Command; and various members of the Army requirements and acquisition communities.

The uncertainty and complexity of future warfare necessitate innovation across a broad range of science and technology, which requires a research culture that is agile and effective, with an emphasis on collaboration that enables the continuous flow of people and ideas between government, academia, and the private sector.

ARL is piloting a new business model to create an S&T ecosystem emphasizing mutual reliance and interdependent, collaborative research as a critical element of national security. This new business model, which we call "Open Campus," focuses on three major initiatives: modern workforce management and policies, shared facilities with our partners, and fostering an entrepreneurial and innovative culture.

Through the Open Campus, ARL scientists and engineers work side by side with colleagues from academia, government, and industry at ARL and our partner facilities. Over the last year alone, the number of Open Campus agreements with academia and industry has more than doubled, from 60 to over 180, with 170 more in negotiation. These agreements have leveraged over $23 million from our Army partners.

Early in 2016, we opened ARL West in Playa Vista, California. As part of the Open Campus initiative, ARL is hiring scientists and engineers on the West Coast in order to gain access to subject-matter experts, technical centers, and universities not well represented east of the Mississippi. By the end of this year, ARL will have similar hubs established in Chicago and in Austin, Texas.

RDECOM enables readiness for today's Army and is now developing capabilities for the Army of the deep future. RDECOM scientists and engineers were intimately involved with developing concepts for the DOD's third offset strategy, as leading members of the two long-range research and development planning studies. The third offset strategy places major emphasis on technologies incorporating unprecedented levels of automation and integration, and ARL is concentrating on research areas that are essential to enabling this third offset.

ARL has greatly benefited from the authorities this committee has worked so intensely to provide. In particular, section 219 authority gives ARL the ability to quickly plan and execute leading-edge research in support of strategic land power dominance. 219 authority for facilities revitalization enables ARL to maintain world-class laboratories.

This authority, when combined with the direct hire authority, gives ARL the ability to attract, train, and then retain the best workforce our country has to offer, permitting us to provide competitive starting salaries and benefits on par with universities and most of the private sector. So, on behalf of my nearly 3,000 colleagues at the laboratory, thank you for these vital efforts.

Within fiscal constraints, the Army is investing in modernization while rebuilding readiness and producing a more capable, leaner, and globally responsive Army. We will continue working with our

partners to rely on our S&T to develop the technologies that support the Army's priorities. We will focus S&T investment priorities to provide the innovative technologies that close capability gaps, address emerging threats, reduce acquisition and sustainment costs, and change the nature of the fight.

There are many opportunities to take advantage of, and there is more hard work ahead, but I believe ARL is winning the innovation challenge placed before us. But we need your continued support as we continue to evolve as the Nation's premier lab for land forces.

Thank you. And, along with my colleagues, I would like to extend an invitation to you to visit ARL, which is just up the beltway. Thank you very much.

[The prepared statement of Dr. Perconti can be found in the Appendix on page 101.]

Mr. WILSON. Thank you, Dr. Perconti.

And thank each of you. This is remarkable; each of you were within the 5-minute rule. And now Kevin Gates is going to make sure that Members of Congress stay within the 5-minute rule, beginning with me. And so we will begin immediately.

And for each of you, could you name one problem or impediment that you see keeping the labs from being more effective at supporting the science and engineering mission of the Department?

Beginning with General McMurry.

General MCMURRY. I think that our biggest impediment, when we talk to our customers, has actually been our ability to put things on contract in a timely manner. That feedback came back resoundingly from internal customers and external.

We have taken steps to bring an external team in to look at our processes and figure out what we have to do to make that work. And we have begun that process of really trying to capture the end-to-end, kind of, if you will, engineering or industrial process of getting things on contract.

That said, things like Direct to Phase II for SBIR [Small Business Innovative Research] and those authorities that we have to allow us to bring small-business contracts in place quickly have been very useful, but the one biggest complaint from customers has been our ability to put things on contract and retaining contracting officers and keeping people.

It is more than a problem of just contracting officers. They are key, but we also have to find a kind of a survivalist level of training for acquisition. Because it doesn't matter that you are a lab; you are really focused on trying to make the same kind of quality decisions and preparations to put something on contract.

Our researchers need to be competent at that, but we really need them to be better at—you know, to be researchers. So we need to get them to a level of competence to support that process well in a low-overhead manner. And so we are working that through a multiple set of programs.

Mr. WILSON. And, General, if there is any legislative initiative that we need to follow up—because we have constituents come to us frequently with extraordinary innovation that would be helpful to small businesses, and however we can expedite them working with you, please let us know.

General MCMURRY. We will do that.

Mr. WILSON. Doctor.

Dr. HOLLAND. Mr. Chairman, I would say that you have heard an allusion to the issues of facilities, and modernizing our facilities, I would say, is a major issue for us. The ability to fund those, given the extraordinary priorities that we have for readiness elsewhere within the services and across the Department of Defense, the relative priority that science and technology would have against those, is a major, major issue for us.

The Department has extraordinary issues associated with readiness and modernization of its installations in and of itself. So we have not been able to, thus far, crack the nut, if you will, sir, on issues of military construction, for major military construction. We have been successful, in my organization, getting some unspecified minor MILCON activities thus far.

And that does put the importance of the opportunity to possibly aggregate 219 funding back in the game as a major source of possible funding for modernizing and recapitalizing facilities.

Mr. WILSON. And we want to back you up too.

Dr. Franchi.

Dr. FRANCHI. Yes. First, I would like to add to Dr. Holland's comments about facilities and ways to be able to do more both the minor and major construction at our facilities.

As another example, as NRL works under the Working Capital Fund, that means we are a coin-operated operation, 100 percent customer-funded. And while I think we do world-class science and technology and engineering and we have a very dedicated workforce to that, there is a lot of frustration in being able to do the business operations, not from the competency of the people, but it is very difficult to retain contracting officers, supply officers, accountants, budget people. And that really slows the process down.

And I think General McMurry alluded to that in one sense, but that is also part of our difficulties, as an example.

Thank you, sir.

Mr. WILSON. And we appreciate your acting leadership on that too.

Dr. Perconti.

Dr. PERCONTI. Yes, sir. So I think my colleagues have really hit on something that we all experience, and that is this frustration with speed and agility in the system.

When you think about hiring, we have lots of authorities from DHA, direct hire authority, but now we get to hire people into the system only to be caught by things like security, delays for security processing, delays for hiring through the human resources, things of that nature, which causes you to lose, you know, very, very high-quality candidates oftentimes.

So I think, across the board, what you are seeing is, if we could streamline processes along a number of different opportunities, that would be very, very helpful.

Mr. WILSON. We look forward to working with you on that. Thank you very much.

Mr. Langevin.

Mr. LANGEVIN. Thank you, Mr. Chairman.

Again, thank you to all of our witnesses for your testimony and for the work that you are doing.

I have several questions, but let me get right into it. For all of our witnesses, please describe how warfighting needs and future requirements have driven investments and priorities. And, in particular, how are our lab enterprises closely connected with the customer?

Dr. HOLLAND. Sir, I would say that the defense labs are remarkably connected to their customers. I will use my organization as an example. We meet routinely, perhaps monthly, quarterly, annually, with a variety of different customers of different echelons to understand what their requirements are, even going to the point of placing people directly in line with customers to understand their requirements very closely.

We attempt very strongly to balance the short-term requirements that they will bring to us with the long-term requirements of science and technology to be sure that we are ahead of the requirements gristmill, if you will, sir, so that we are not working on today's problems alone all the time. There is a strong connectivity inside the Army for long-range assessment planning within the Assistant Secretary of the Army for Acquisition, Logistics, and Technology, as well as the Long-Range Research and Development Planning process, LRRDP, that is ongoing at present at the OSD level.

So there are multiple levels of planning. We work our plans each year against each of those requirements, working to align ourselves with those annually.

Gentlemen.

Mr. LANGEVIN. General, you are next.

General MCMURRY. I think we are aligned very carefully through strategic planning documents all the way down. We have also maintain an outreach process with our major commands [MAJCOMs] where we are talking to them through acquisition sustainment reviews, also advanced technology councils.

And then we link almost all of our projects to the core functions support plans that those MAJCOMs put out and the gaps that are identified in those. Beyond that, it is joint needs and urgent needs that we are really heavily focused on in the near term.

Mr. LANGEVIN. Thank you.

Dr. Franchi.

Dr. FRANCHI. Yes, for our science and technology, our basic research, early technology development, we are well-aligned with the Naval Science and Technology Strategy, and that derives from higher level strategies. We have divisions that represent over 15 different disciplines, and that means that we are working on problems that are part of and will be important to the third offset strategy, just as we have done in the past.

What the challenge is for us is to see where are those areas where we have sufficient expertise, sufficient people power to do it, and emphasize those areas more, such as in cybersecurity expertise, synthetic biology, people who know about autonomy and cognition and autonomous and manned interactions and things of that nature.

So I think we are well-positioned to address that in the future.

Mr. LANGEVIN. Okay. Thank you.

Dr. PERCONTI. Yes, sir. So we work very, very closely with the Army's Training and Doctrine Command [TRADOC] to look at future requirements together, both near-term and far-term. And much of what we do for the command is to really understand what the Army future warfighting challenges are and how we can bring technology to bear to support those challenges.

We are also very much involved with TRADOC's new Big 6+1, as they call them, the new capabilities that have come out of the Army Operating Concept Framework. ARL and the Research and Development Engineering Command has been a very, very important player in developing the technologies that will go into those capabilities.

So it is a very, very tight relationship. We very much love to have TRADOC soldiers in our organizations to work with us side by side to really teach our scientists and engineers about what warfighting means and what capabilities mean.

Thank you.

Mr. LANGEVIN. Thank you.

And for all of you very quickly, I think collaboration is very important in understanding what other capabilities are out there, what is commercial, off-the-shelf technology that you can leverage.

What is your respective services' current conference attendance policy? And, more specifically, who is the final approval authority? How have the last few years of limitations on conference attendance impacted the workforce, the lab, and, ultimately, innovation?

Dr. FRANCHI. Yes, sir. Right now, conference travel still requires approval by the Secretary of the Navy's office.

We have worked to streamline the process in the sense of shortening the lead time involved. We have expanded the qualifications, if you will, for conference attendance from just being presenting a paper at a conference to presenting posters, being on committees, for technology managers being able to go and see what the state of the art is.

And all of that has been successful, and we have had a very high approval rate from the Secretary of the Navy's office.

What it requires is—still requires a fair amount of paperwork to be submitted, and that is probably the one frustration that our scientists and engineers have. But we are able to go to conferences. That number of people is growing again. And so just deleting some of the additional paperwork would be most helpful, from the Navy's point of view, or at least my personal opinion, sir.

Mr. LANGEVIN. My time has expired, but if each of you could respond to that in writing, I would appreciate it. I know the vote has been called.

[The information referred to can be found in the Appendix beginning on page 115.]

Mr. LANGEVIN. I yield back.

Mr. WILSON. Thank you, Mr. Langevin.

And we have had votes called. We will proceed for Congressman Lamborn of Colorado, and then we would recess, with the goal of coming back around 3:20.

Congressman Lamborn.

Mr. LAMBORN. Mr. Chairman, I am going to yield the balance of my time to Representative Turner, but I do have one quick question for Dr. Holland.

Which of your four locations does the tunnel research?

Dr. HOLLAND. Vicksburg, Mississippi, sir.

Mr. LAMBORN. Okay. I would like to come see that one of these days. Thank you.

Dr. HOLLAND. Very good.

Mr. TURNER. Thank you, Mr. Lamborn. This is a just-in-the-nick-of-time delegation of time. Thank you.

General McMurry, you and Dr. Holland have both given very impressive commercials, if you will, for the importance of the 219 provision that allows you to use up to 3 percent of your laboratory's budget toward revitalization and recapitalizing facilities infrastructure.

Dr. Holland, you even state that you have not had a project funded with MILCON in recent memory, which I think gives us the stress of the need for looking for investment in our laboratories.

General, you talked about the current opportunities of where you are trying to advance knowledge being in autonomy, UAS [unmanned aerial systems], hypersonics, directed energy, nanotechnology—all areas that it would seem would require both investment in labs and investment in technologies to advance that research.

So my question to the panel is: We have, really, two aspects of this—one, obviously, to continue and strengthen the authorities that you have in 219, which has given you some flexibility to direct funds to these types of investments. But, secondly, how can we increase the competitiveness or your success rate in the MILCON process?

And if you would, please, give us your thoughts on ways that the MILCON process perhaps has criteria or a process that does not give you an advantage, that disadvantages you, and ways in which we might be able to improve it, and your additional thoughts on 219.

If General McMurry and Dr. Holland could respond on that.

General MCMURRY. Congressman Turner, good seeing you again.

I would say that—let's start with the 219. The project limit increase would be significant capability. I believe that moves from $4 million to $6 million. That would change what we can do there. Otherwise, 219 is the—I mean, that is the crowd-pleaser within the lab. Everybody is very happy with the capabilities that that brings.

With respect to MILCON, we have had some success. We had a project at Kirtland on our space vehicles lab that has been underway from last year. And we are—well, we have a submission that should happen in 2017, all things being equal, down at Eglin for a munitions, advanced munitions, capability.

To improve our capability, it appears that the closer you are to the flight line and the more you are to hazard response, the better chance you have. What I have been trying to explain to people is that, for the labs, the facilities are our runways. You know, they are the things that allow us to do our mission. So I think we are trying to educate ourselves to better explain how the facilities impact mission.

And the reason I didn't highlight that as the number-one issue is because, currently, our rating of what our facilities are capable of doing is pretty—it is okay. We can get the mission done; we have support issues. But as we look down the way, that is when we start to see them tail off in capability and the need to upgrade them. 219 helps alleviate that a lot. MILCON will help more.

Dr. HOLLAND. Certainly, the opportunity to implement the process of aggregating and, if you will, rolling over 219 funding to be able to bring funding from certain years forward, to be able to fund larger projects, would help this process. It would provide for an additional funding source. The actual legislation does exist. Our implementation process has not yet come to fruition for us.

As for the actual MILCON process, I would say that the process as it exists today, for the sake of the Department, is not particularly flawed. There are enormous sets of issues in the Department that require aspects of military construction.

Rather, if we are going to be able to make inroads for, in the case of Army—and I would not propose to speak for the Navy, but in case of the Navy's issues, we would be in a situation where we would almost have to have a separate set of criteria or funding opportunity that would be specific to the laboratories to be able to cause that to happen.

The Air Force has actually been somewhat more successful than I have been able to be, thus far, for funding MILCON projects.

Mr. TURNER. Thank you both.

Mr. WILSON. Thank you very much.

And we are in recess.

[Recess.]

Mr. WILSON. Ladies and gentlemen, we will call the subcommittee back to order. And my other colleagues, I am confident, are racing across Capitol Hill as we speak.

And as we are awaiting others to proceed, a question for each of you that would be important: Could the labs play a bigger role in training future workforces for emerging technologies like cyber, autonomy, or quantum technologies?

General.

General MCMURRY. I think that we can contribute to a training environment; I don't know that we are the best training ground. I think that there is no doubt that we can contribute to doing that. I do think that, as we move into those new technologies, we will likely draw on lab expertise to figure out how to set up education and training and build that expertise. That is more across the force, but that is kind of where I come down on that, sir.

Mr. WILSON. And Doctor.

Dr. HOLLAND. Mr. Chairman, I believe that if we could set the right conditions, I believe the answer is very much "yes" to that.

Within the work that we are able to do within the science, technology, engineering, and mathematics communities, particularly for K through 12 activities and even within the college realm, if we were able to continue to get some funding for these activities to work with younger students to get them engaged in these efforts, to hold summertime activities with them to introduce them to the types of opportunities and facilities that we have, many of our people are remarkably passionate about having the chance to share

these types of opportunities. And so, at that level, I think we could be extremely successful.

Mr. WILSON. And you are probably already doing this, but I am really grateful the Savannah River National Laboratory is in the district I represent. And they have internships and programs with the local technical college to provide opportunities for shadowing—and I am sure you all probably already do that, but I—and then promoting STEM programs, as you mentioned, at every level.

So thank you very much.

And Dr. Franchi.

Dr. FRANCHI. Yes, at NRL, we have several programs. We have the Science and Engineering Apprenticeship Program for 10 weeks in the summer. A very diverse community comes to that. We have the Naval Research and Engineering Internship Program, which is sponsored by the Office of Naval Research—similar. We engage with high schools in the area very much to encourage regular students coming in.

I think two things. I think one is for management to encourage more of our workforce to be mentors, because it does take time. And, secondly, to perhaps have a source of funding for that mentorship, since we are working for customers on reimbursable orders, and I think a lot of our scientists and engineers give more than their—way more than their 40 hours as it is. And it is not that they don't want to do it, but they feel sometimes it is difficult to trade that off over what our customer is working for.

Mr. WILSON. Thank you.

And Dr. Perconti.

Dr. PERCONTI. Yes, sir. So it is absolutely vital for us to bring students in at the earliest age, K through 12 in particular. If you can hook them when they are young, then they want to move into S&T as a profession. So we work very hard to make sure that we have programs available for—STEM programs available for K through 12.

The Army has a wonderful program called eCYBERMISSION that allows students to compete in computer sciences and cyber-related kinds of activities. So, very, very fortunate for us to have programs like that to continue to train the workforce.

Mr. WILSON. And I am delighted to hear about the eCYBERMISSION. There is no question that the younger the person is introduced to these issues, the better and then the more proficient as they grow older. So I wish you well.

And then a final question from me, and you have all touched on it, and it is regarding the sustainment and repair of existing infrastructure. And I am concerned to hear the age of 59, as to the age of the buildings. What more can we do to help each of you address this?

And this time, we will reverse this way, with Dr. Perconti going first.

Dr. PERCONTI. Well, sir, SRM [sustainment, restoration, modernization] is a big problem for us because of the reductions in the Army SRM budgets in general. I think that one thing that people need to do is recognize the difference between services or, say, laboratory operations versus the difference in services that are provided for generalized offices and the things like that. It is a very

complicated space that needs lots of planning and lots of maintenance and requires sustained investment to keep those facilities operating in a manner that is proficient for all of us.

So I think that is a recognition that those services need to be increased, or perhaps we can then use other financial resources to perhaps use—if it is a mission-related problem, perhaps to use some of our RDT&E [research, development, test and evaluation] mission funds to actually take care of some of those problems.

Mr. WILSON. And Dr. Franchi.

Dr. FRANCHI. Yes. First of all, regarding SRM, we collect SRM in our overhead, I think, sufficient to do a lot of our maintenance and some modernization. It would very much help if we could do that with minor construction authority levels raised. I understand that is under consideration. As Dr. Holland said, being able to accumulate funding for facilities over years and then use it, that would be very helpful.

And we are working very seriously in the Department of the Navy to look at ways to put more attention and perhaps funding into the military construction process. NRL in the last 15 years has been, I guess, fortunate, because that 59 years has been decreased by two very significant military construction projects—one, an Institute for Nanoscience, which has really put us on the leading edge of nanoscience and quantum. That was about 15 years ago. And 4 years ago, we opened the Laboratory for Autonomous Systems Research, which gives us facilities that simulate, emulate all of the environments that our warfighters—Navy, Marine Corps, compatriots in the Army and the Air Force—could take advantage of.

So it is really continuing down that road as we move into these emerging areas where we have to put more emphasis would really be helpful.

Mr. WILSON. Thank you.

And Dr. Holland.

Dr. HOLLAND. Sir, just to reiterate, the opportunity to have a greater understanding of the total cost of laboratory space and what it actually costs to maintain that versus a standard barracks or a standard office space would be a very helpful piece of information to understand.

Secondly, anything that is done that increases our opportunity to modernize will very much decrease the cost of maintaining these extremely old facilities that we have. So, for example, even though I have not given a number, inside ERDC, our average building is over 41 years old. And that includes the construction of three new facilities in the last 5 years that we have been able to build not off MILCON but off of other resources available through the Corps of Engineers.

Mr. WILSON. Thank you.

And we conclude with General McMurry.

General MCMURRY. First, Mr. Chairman, I would say that on the previous question regarding the training, I think the STEM aspects I wholeheartedly support, and I probably misinterpreted your question slightly.

As we go forward on this, I really think the ability to do projects outside of MILCON is huge. I think anything that would raise the

level of—allow us to use 219, R&D, anything. The deferred maintenance budget within the Air Force is a big deal. I mean, we have really squeezed facilities in order to deal with the ongoing fight and modernization. So I think anything that gives us a little flexibility is fine.

We are not the only ones feeling the squeeze on facilities and maintenance. And we know that the resources to do just routine maintenance are very stretched.

So I will leave it at that. I think the others have talked very eloquently about it.

Mr. WILSON. Well, thank each of you for your response.

And we now will be concluding with Congressman Langevin.

Mr. LANGEVIN. Thank you, Mr. Chairman.

If I could go back to when I was asking about transition of technologies to the warfighter, can you describe examples of successes in rapidly delivering game-changing technologies or capabilities? For example, a capability to protect against improvised explosive devices. What enabled you to ultimately deliver these game-changing technologies? Was it things like funding, for example, or authorities? What precludes transitioning such technology into systems or platforms on a more routine and rapid basis?

General MCMURRY. Well, sir, I would say that the thing that enables us to solve that is actually putting the focus on it. That is generally the first thing. We resource it, we put it into—for us, we use the Center for Rapid Innovation, and they tear that problem apart and look at it as what is the real problem, not what is your preferred solution. I think that is a key step in how we deal with it. It is really back to that strategy-based look, but what are we really trying to solve.

Examples that we have is providing ISR [intelligence, surveillance, and reconnaissance] assets—that is of Silver Fang—or the LEAP [Long Endurance Air Platform] aircraft that is flying over there now are pretty good examples of things that we have been able to put out. And we end up providing capabilities that meet the need as opposed to capabilities that meet the expected solution. And when we do that, we tend to do it at a lower cost and a shorter rate.

The thing that prevents transition, it is hard to say, but I think it is really just getting the agreement that we are going to transition and how we are going to bring that into the operational fold and which service will pick that bill up and when. Because, usually, the bills aren't that big, but everybody is so tight on money, just trying to figure out how to plan for that and a timeline is a challenge. And part of what I am trying to do is get that agreement up front.

Mr. LANGEVIN. Anybody else want to comment on that?

Dr. HOLLAND. Yes, sir. The funding aspect of it I think could perhaps be best shown by the extreme emphasis that we put on counter-IED issues through the Joint IED Defeat Organization during its existence. Because we had a very dedicated pot of money associated with that and an extraordinary need in theater, we were able to, across the Department, come together to bring a variety of technologies together very quickly compared to what we might

refer to as normal means, many times bringing very basic research into application in as little as 24 months.

Admittedly, in doing that, we were also identifying levels of risk that we were taking that were levels of risk that are not normal for a normal program of record. But the requirement, that joint urgent need that we had, mandated that we take those risks at that time. And we were able to field a number of capabilities that we brought to theater that met a requirement for the short term that we had in theater, particularly in Afghanistan.

Now, transitioning those over the long term then falls back to the process of working within our program of record to ensure that we are able to do that. And that goes back to the process, the tried-and-true process, of working that through the system to achieve that transition within those programs. But we are fully capable of developing that integrated capability when the opportunity arises.

Mr. LANGEVIN. And how do you coordinate to reduce our redundant investments amongst the enterprise, as well as to leverage lessons learned and investments made?

Do either of the other two witnesses want to comment?

Dr. FRANCHI. Yes, sir. I can add a few things here.

I think it is at the bench level, principally, when we have our scientists and engineers across the DOD Laboratory Enterprise engaging with industry, engaging with academics at conferences, meetings, other venues. That is where we learn what the capabilities are.

And then it is incumbent on them and their managers to say, okay, are we doing the same type of work? And, if so, if it is complementary or even duplicative in the sense of taking a different approach, that is good, because that is how we learn. And so I think that is one way to reduce the concern about redundancy.

I would also like to comment on your first question, if I may, Congressman.

Mr. LANGEVIN. Sure.

Dr. FRANCHI. You asked what enables, sort of, rapid responses to capabilities. I think it is the sustained investment over many years of science and technology at your defense laboratories. Because we often have the technology on the shelf, but not until there is an urgent need for it does it come forward. And it is either a technology we have or a technology that we can adapt in a reasonable amount of time to meet a need.

And so, in that sense, it is transitioning to today's warfighting needs, the urgent needs. But I think processes that would allow us to look further into the future and transition warfighting capabilities from our science and technology that may not be as urgent today but might be in 5 or 10 years.

Dr. PERCONTI. Sir, if I may add, I think that the Department has the communities of interest, which is run by ASD(R&E) [Assistant Secretary of Defense for Research and Engineering], where the three services come together to really look at our programs across a number of disciplines to ensure that we are aligned, to ensure that redundancies in those programs are reduced or eliminated, and to ensure that we are leveraging the resources to the best of abilities across our program.

This has been very, very effective in bringing the three services together to make sure—everyone has slightly different requirements, but many times, particularly at the component level, those technologies are leveraged.

Mr. LANGEVIN. Very good.

Well, thank you very much. With that, I will yield back the balance of my time. I appreciate you all being here and the work that you are doing.

Mr. WILSON. Thank you, Mr. Langevin.

I would like to thank Kevin Gates again for his leadership on the committee. We have a terrific professional staff that are available to you. And, each of you, thank you for your service on behalf of our country.

We are now adjourned.

[Whereupon, at 4:00 p.m., the subcommittee was adjourned.]

A P P E N D I X

SEPTEMBER 28, 2016

PREPARED STATEMENTS SUBMITTED FOR THE RECORD

SEPTEMBER 28, 2016

Chairman Wilson Opening Statement
Hearing:
"Department of Defense Laboratories: Innovation through Science and Engineering in Support of Military Operations"

September 28th 2016, 2:00pm, 2212

I call this hearing of the Emerging Threats and Capabilities subcommittee of the House Armed Services Committee to order.

I am pleased to welcome everyone here today for this hearing on the role of the Department of Defense laboratories in supporting military operations. While the Secretary of Defense has been highlighting the need for increased partnerships with commercial providers in Silicon Valley, Boston, and elsewhere, I think it is important to remember that the Defense Department also maintains its own in-house sustained source of innovation.

The Defense Laboratory Enterprise is a robust network of 67 laboratories and engineering centers that are dedicated to providing responsive scientific and engineering advice to support military needs. As we look to make the Department more flexible and adaptable to take on new innovations, it will be vitally important to ensure that the labs maintain the workforce and infrastructure needed to keep them relevant for the future warfighting environment. In looking at that challenge over the past two years as the chairman for this subcommittee, I am not convinced that the Department is doing enough to keep pace with an ever-evolving set of threats.

In order to get a better perspective on all of these issues, I would like to welcome our distinguished panel of witnesses, which includes:

Major General Robert D. McMurry, USAF
Commander
Air Force Research Laboratory

Dr. Jeffery Holland
Director, Engineer Research and Development Center, U.S. Army Corps of Engineers
Waterways Experiment Station

Dr. Edward Franchi
Acting Director of Research
Naval Research Laboratory

Dr. Philip Perconti
Acting Director
United States Army Research Laboratory (ARL)

I'd like to turn now to my friend and Ranking Member, Mr. Jim Langevin from Rhode Island, for any comments he'd like to make.

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HOUSE ARMED SERVICES COMMITTEE
SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES
U.S. HOUSE OF REPRESENTATIVES

DEPARTMENT OF THE AIR FORCE

PRESENTATION TO THE HOUSE ARMED SERVICES COMMITTEE
SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

U.S. HOUSE OF REPRESENTATIVES

28 September 2016

SUBJECT: Fiscal Year 2017 Air Force Research Laboratory

STATEMENT OF: Maj Gen Robert D. McMurry, USAF
Commander, Air Force Research Laboratory

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HOUSE ARMED SERVICES COMMITTEE
SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES
U.S. HOUSE OF REPRESENTATIVES

INTRODUCTION

Mr. Chairman, Members of the Subcommittee and Staff, I am pleased to have the opportunity to provide testimony on the Air Force Research Laboratory, our Service's premiere research organization and our efforts to lead the discovery, development, and integration of affordable warfighting technologies in the face of a dynamic, complex and unpredictable future.

Headquartered at Wright-Patterson Air Force Base (AFB), Ohio, the Air Force Research Laboratory (AFRL) leads a worldwide government, industry, and academia partnership in the discovery, development, and integration of affordable warfighting technologies for the Air Force. AFRL is the single Air Force laboratory and the largest single defense laboratory world-wide. It is responsible for planning and executing the Air Force Science and Technology (S&T) program with world-class facilities across the nation. The laboratory provides leading-edge warfighting capabilities and revolutionary technologies that keep our air, space, and cyberspace forces the world's best.

The Air Force, through AFRL, manages Air Force S&T as an integrated program by using AFRL's special resources to invest in future capabilities and provide the warfighter with near-term technical support. AFRL carefully balances the investment portfolio in basic research, applied research, and advanced technology development, allocated between in-house and contracted activities, to produce both evolutionary and revolutionary technologies focused on 12 Air Force Service Core Functions and capabilities. This statement describes how AFRL executes the Air Force S&T Strategy.

As stated in the *Air Force Posture Statement 2016*, "today's national security challenges come from a combination of strong states that are challenging world order, weak states that cannot preserve order, and poorly governed spaces that provide sanctuary to extremists who seek to destabilize the globe." This shift in the geopolitical landscape, along with the rapid globalization of technology, is allowing adversaries to boldly challenge America's superiority in air, space, and cyberspace. AFRL is uniquely positioned, as one of the few organizations responsible for research and development supporting all three domains, to ensure that we have the capabilities we need to dominate the current fight, prepare for the future fight, and perhaps deter that future fight from happening.

In line with the *2016 Air Force Materiel Command Strategic Plan* and the *Air Force Future Operating Concept*, AFRL is pursuing additional agility and innovation into our capability development processes, workforce and infrastructure. AFRL's investments in strategic agility support the building blocks of the Department's Third Offset Strategy, the Fiscal Year 2017 Air Force S&T Program and the Long Range Research and Development Planning Program initiatives.

From an acquisition perspective, AFRL investments also address and support the Better Buying Power (BBP) 3.0 initiatives under the leadership of Mr. Frank Kendall, Under Secretary of Defense for Acquisition, Technology and Logistics (AT&L). The BBP 3.0 initiatives are endeavoring to strengthen our ability to innovate, achieve technical excellence, and field dominant military capabilities.

The following testimony provides an overview of the Air Force Research Laboratory as an organization. It addresses our pursuit of strategic agility, the impact of our warfighter-focused S&T programs (game-changing, enabling, relevant, and rapid technologies), the stand-up of a strategic development planning and experimentation office, the importance of prototyping in our mission, and leveraging the critical contributions of our world-class workforce and infrastructure.

AIR FORCE RESEARCH LABORATORY STRUCTURE

AFRL is a single full-spectrum research organization that executes the Air Force's investment portfolio in basic research, applied research and advanced technology development. AFRL is unique among the Services because the laboratory directs *all* Air Force efforts to discover, develop and integrate affordable aerospace warfighting technologies. Two decades ago, the Air Force laboratory system spread research across 14 different organizations nationwide. In 1990, these locations were merged into four "superlabs." Finally, in 1997, those were merged into a single, unified structure to create AFRL and bring Air Force S&T to a new level of efficiency, collaboration and innovation.

AFRL Commander

Aside from serving as the AFRL Commander, I am also the Air Force Technology Executive Officer (TEO). In this capacity, I meet with the Secretary of the Air Force and Chief of Staff of the Air Force every six months in order to maintain alignment with Air Force needs and priorities, and to review progress. These meetings occur at S&T Forums where the health of AFRL and the Air Force S&T Enterprise is discussed. We engage with each Air Force customer (Major Commands, Program Executive Officers and Program Managers) at least twice a year during formal Applied Technology Councils as well as with a TEO Review every 18 months.

Directorates

AFRL Headquarters staff provides the workforce and infrastructure necessary to ensure that AFRL can accomplish its mission and assist me in formulating and disseminating policies, plans, and directives affecting the lab. Aside from AFRL Headquarter functions, there are nine Technology Directorates (TD)- Air Force Office of Scientific Research, Aerospace Systems, Directed Energy, Information, Airman Systems, Munitions, Sensors, Space Vehicles and Materials and Manufacturing. The 711th Human Performance Wing is a large operational unit within AFRL and includes Human Systems and Integration, Air Force School of Aerospace Medicine and the Airman Systems TD. Each of our TD directors also serves as a Capability Lead responsible for meeting the needs of Air Force Service Core Functions.

Research Sites

AFRL maintains 12 operating locations across the globe. AFRL Headquarters, the 711th Human Performance Wing and four TDs (Aerospace Systems, Sensors, Airman Systems and Materials and Manufacturing) are located at Wright-Patterson AFB, Ohio. The Air Force Office of Scientific Research is located in Arlington, Virginia. Our Munitions Directorate is at Eglin AFB, Florida. Our Information Directorate is in Rome, New York and the Directed Energy and Space Vehicles directorates are located at the Phillips Research Site, Kirtland AFB, New Mexico. Additionally, we maintain facilities in Maui,

Hawaii; Edwards AFB, California; Fort Sam Houston, Texas; Arnold AFB, Tennessee; Santiago, Chile; London, United Kingdom; and Tokyo, Japan.

AIR FORCE RESEARCH LABORATORY FISCAL YEAR 2017 S&T PROGRAM AND ASSOCIATED EFFORTS

We are excited that Air Force senior leaders and Congress are committed to S&T and are embracing efforts in capability development. The Air Force Fiscal Year 2017 President's Budget request for S&T is approximately $2.5 billion. This is an increase of $108 million or a 4.5% increase from the Fiscal Year 2016 President's Budget request. We have emphasized research in hypersonic and low cost cruise missile technologies, advanced air combat missiles, and position, navigation and timing (PNT) technologies to highlight capabilities focused on operations in anti-access and area-denial (A2AD) environments. These technologies, discussed later, directly increase support of the Defense Department's Long Range Research and Development Planning Program and Third Offset Strategy.

The Air Force Fiscal Year 2017 President's Budget request also includes funding in Budget Activity 4 (Advanced Component Development and Prototypes) and in Budget Activity 6 (RDT&E Management Support) part of which supports AFRL prototyping, experimentation, and modeling and simulation efforts. More information on these efforts is provided later in this statement.

AGILITY IN CAPABILITY DEVELOPMENT

To capitalize on the increasingly dynamic environment, AFRL is aggressively pursuing a path toward *strategic agility* by providing technologies to keep the fight unfair (revolutionary), focused on near and midterm needs (relevant) and delivering the warfighter's needs "right now" (responsive). Additionally, AFRL is focused on achieving greater agility in how we organize, train, equip, and employ our laboratory to provide a *strategic* advantage over potential adversaries.

This is not an entirely new endeavor. In addition to the *S&T Guiding Principles*, the Secretary of the Air Force laid out seven specific S&T goals focusing available resources on issues of critical importance to the Air Force. These goals are to leverage and create technology trade space to support near-, mid-, and far-term acquisition programs, innovate technical solutions to rapidly respond to urgent warfighter needs, develop concepts and create new S&T options addressing threats and maintain/increase capability, invent concepts and S&T supporting *Global Vigilance, Global Reach, Global Power*, employ business practices increasing inventiveness, productivity and responsiveness, acquire, develop and retain a high-performing workforce, and invest in core S&T infrastructure to ensure future health.

AFRL responds in real time to Air Force current and future demand signals through the use of Capability Collaboration Teams (CCTs). CCTs interact directly with Air Force Major Commands (MAJCOMS), Centers, and Program Element Officers (PEOs) to align Air Force S&T with Air Force priorities and improve the return on investment provided by AFRL.

AFRL is integral to the reinvigoration of development planning at the Air Force enterprise level to formulate truly innovative strategic choices and leverage the attributes of agility in our capability development. Development planning enables us to understand and synthesize future warfighting needs and reconcile those with available and potential capabilities. It serves as a key process to support Air Force strategic decisions. To provide this capability AFRL will engage in: systems engineering to formulate and evaluate viable concepts; operational trade space analysis and definition; technology shortfall identification; S&T needs and gap analysis; and requirements refinement.

In conjunction with development planning, AFRL is conducting experimentation and prototyping activities exploring the full range of multi-domain innovative materiel and non-materiel solution options. These activities provide an environment where our Airmen can take smart risks while testing innovative ideas.

Through the newly formed Strategic Development Planning and Experimentation Office, AFRL is supporting the Enterprise Capability Collaboration Team (ECCT) approach to facilitate development planning for our highest-priority mission areas. ECCTs have the freedom to explore concepts with a direct path to senior leadership for quicker decisions on courses of action to increase agility across the enterprise.

CONTRIBUTION OF AIR FORCE S&T IN AGILE CAPABILITY DEVELOPMENT

Our S&T program lays the technological foundation for the current and future Air Force to assure America's security through *Global Vigilance, Global Reach, and Global Power*. The Air Force emphasized the role of S&T by dedicating an annex in the *Strategic Master Plan*. We adhere closely to the strategic approach to S&T outlined in the annex and provide the supporting elements necessary to bring forth the next generation of capabilities.

Game-Changing (Revolutionary) Technologies

As outlined in *America's Air Force: A Call to the Future*, AFRL is focused on several game-changing technologies to amplify and augment the enduring attributes of airpower—speed, range, flexibility and precision. These five game-changing technologies are autonomous systems, unmanned systems, hypersonics, directed energy and nanotechnology. Our efforts in autonomous systems and unmanned systems in particular provide key support to the realization of the five enablers of the Department's Third Offset Strategy.

Autonomous Systems

Autonomy has the potential to enhance Air Force readiness for increasingly complex, future operating environments. We are seeking to enable the *right balance* of human and machine capability to meet Air Force challenges in the future. Our focus is on growing autonomous system capability, integrated with the human capacity to perform in a high-tempo, complex decision environment and to optimize airmen working together with machines both effectively and efficiently.

AFRL's goal for autonomous systems is to increase efficiency; empowering airmen to engage in a more rigorous analysis that leverages available data across multiple domains and mission areas. This vision aligns with the Third Offset Strategy underscoring optimization of human decision making with technology.

Current autonomy efforts are focused on enabling improved safety, efficiency of operations, multi-system collaboration, and command and control. We are building from the previous ground collision avoidance systems to demonstrate air collision avoidance. We will then move on to autonomous formation flight. We are also transitioning technologies to aid the Intelligence, Surveillance and Reconnaissance (ISR) analyst in efficiently producing intelligence information. In Unmanned Aerial Vehicle (UAV) ISR, technologies are in development to demonstrate the benefit of multi-system collaboration. This will ensure target identification and tracking without the need for airman control. For command and control, autonomy technologies are being demonstrated to support decision-making through course of action generation and execution monitoring.

AFRL completed demonstrations of early autonomy capabilities as well as initial multi- UAV autonomy. We are currently demonstrating user interface technologies that are naturalistic and enhance human trust and teaming across the Department to mature autonomy technologies. Efforts with both the Army and Navy are demonstrating multiple platform collaboration technologies across the ground, marine and air environments.

Our work is postured to advance autonomy technologies for future applications. We are on point to demonstrate an intelligent analytic system that will exploit existing data and integrate it with incoming sensor data to provide more complete intelligence for the airman. Additionally, AFRL will demonstrate the technologies needed for a UAV to autonomously balance the use of resources with unplanned events through a dynamic, contested environment. We will enable autonomous systems to receive mission objectives and be able to coordinate mission execution with other unmanned systems to optimize operations and extend the capabilities of the manned flight lead.

Unmanned Systems

AFRL is pressing forward on the full integration and exploitation of unmanned air systems (UAS) for an agile combat force. The advent of UAS introduced a class of air platforms that not only may be smaller and cheaper, but also provide new freedom to distribute operational risk-taking. AFRL is creating the technology base to pair manned and unmanned platforms together and also to build systems with a large number of unmanned platforms. With UAS, we are forging a path for rapid development and frequent technology refresh to fuel future warfighting agility.

AFRL is working closely with Air Force Special Operations Command to integrate tube-launched UAS; providing additional sensing in weather and at stand-off. AFRL has also developed a technology base allowing for the teaming of UAS with our future fighter fleet, augmenting the front-edge fight with additional weapon and sensing resources.

We see additional opportunity in fielding teams of smaller UAS that are individually limited but collectively effective. AFRL has laid a foundation for autonomous and cooperative flight, from fundamental theory, to computer models and multiple flight demonstrations. We are also developing operationally relevant sensor options in very small form factors. The technology breadth of AFRL also allows us to converge expertise in both aircraft and munition technology to develop this new class of high performing small UAS.

One aspect of our mission is reworking the Air Force design and manufacturing processes. The Laboratory is actively developing an approach to designing attritable aircraft with a limited service life that can be produced at a fraction of the cost of other platforms. This capability relies on AFRL's additive and flexible manufacturing efforts, combining AFRL's world class in-house resources with a network of national manufacturing partners.

The rapid onset of attritable and expendable UAS aircraft is enabling AFRL to revolutionize ISR with new, highly agile, distributed capability platforms. We are developing low cost UAS platforms to obtain

persistent situational awareness within contested environments. Our experts enabled persistent situational awareness by decoupling high-performance hardware from long-lifetime platforms in new sensor designs. We are also working on autonomy in UAS flight control, allocation of sensor assets and fusion of sensor data to provide much faster access to critical ISR information with greatly reduced UAS flight crew requirements.

We are leveraging aspects of UAS, such as open system architectures, to reduce lifecycle costs as ISR and UAS technologies evolve at different paces. This will greatly increase a commander's options to rapidly deploy ISR flight packages tailored to specific missions. These key shifts in sensor research and development, now under way within AFRL, will provide persistent situational awareness on the battlefield within increasingly challenging operational environments.

Hypersonics

Hypersonics are one of the game-changers providing high-speed options for engaging time sensitive targets, while improving the survivability of Air Force systems. This is a discipline where several technologies must integrate together to deliver capability options for the warfighter. AFRL facilitates hypersonic technology development coordination and collaboration by utilizing its lead position in the Air Platforms Community of Interest (CoI), High Speed/Hypersonics Sub-area. This CoI draws representatives from DoD agencies (Air Force, Navy, Army, DARPA) and NASA to mature required technologies.

We also conduct our own technology development across the full S&T spectrum from basic to applied research and through advanced technology development; an effort that involves the majority of our technical directorates.

Examples of the diverse set of hypersonic technology development programs within AFRL include:

High Speed Strike Weapon (HSSW) Technology Maturation (Tech Mat): This program develops technologies for a high speed strike weapon enabling responsive and long-range strike capabilities. It focuses on longer term enabling/enhancing technologies.

Medium Scale Critical Components (MSCC): This is the exploration of performance and reusability of larger scramjet engines with a mass capture of approximately ten times (10X) that of the X-51A engine.

MSCC is a great example of collaborative effort with Arnold Engineering Development Complex's Aerodynamic and Propulsion Test Unit (APTU) facility.

Hypersonic International Flight Research (HIFiRE): This program investigates fundamental hypersonic phenomena, advances component technologies and instrumentation, and conducts flight experiments in relevant environments in collaboration with Australia. HIFiRE has produced vast quantities of hypersonic data, validated numerous component technologies and demonstrated an affordable flight test approach.

Underpinning all of the AFRL investments in hypersonic systems is sustained, robust basic and applied research. We are currently exploring Hot Structure Behavior Prediction, Fluid Structure Interaction, Non-equilibrium Flows, Sensors for Engine Control, Ignition and Flame Propagation and Boundary Layer Transition.

Directed Energy

The Directed Energy (DE) technologies AFRL is developing have the potential to provide unprecedented self-defense, air superiority, and precision strike capabilities with speed of light engagement, minimal collateral damage and a deep magazine. In the next five to ten years, it may be possible to use matured DE technologies to enhance the survivability of legacy and future aircraft and defend forward bases against aircraft and missiles.

The Secretary of the Air Force chartered a multi-organizational, inter-disciplinary, Integrated Product Team (IPT) to develop an Air Force DE Weapon Flight Plan. The Flight Plan will guide comprehensive activities across the Air Force to support operational DE and enable delivery of key effects to the battlefield.

Through the Strategic Development Planning and Experimentation Office, AFRL is leading completion of the Flight Plan and will identify and mature all primary and support system/sub-system technologies that are required to employ game-changing DE weapons. To support this, we have already developed collaborative multi-service/agency technology development roadmaps to inform the DE Weapon Flight Plan.

AFRL is currently engaging in military utility analysis and experimentation to realize the highest payoff DE weapons for near-term transition and long-term continued investment. With recent world-wide proliferation of UAV and regional missile threats to our bases, our analysis suggests that ground based DE systems for force protection could be transitioned in the near-term. AFRL is also addressing potential

operational deficiencies of DE systems through field experiments like the Demonstrator Laser Weapon System (DLWS) at White Sands Missile Range.

Since the 1980's, airborne High Energy Laser (HEL) systems have demonstrated the ability to precisely engage difficult targets from the air. These were primarily gas or chemical lasers that were large, heavy, and logistically difficult to support. In the last 15 years, DoD, the Air Force, and commercial investment has driven significant advances in electric (solid state) laser and high power radio frequency (HPRF) technologies and systems.

AFRL is continuing to capitalize on HPRF technology advances by pursuing a joint airborne counter electronics demonstration called High Power Joint Electromagnetic Non-Kinetic Strike (HiJENKS) in partnership with the Navy.

We are also currently engaged in the Self-Protect High-Energy Laser Demonstrator (SHiELD). This program includes two incremental phases. In the first phase, we will track agile targets at range to show that we can mitigate complex aerodynamic disturbances. The second phase will incorporate a moderate powered laser to assess performance in an operationally relevant environment.

Nanotechnology

Nanoscale structures create unique properties by leveraging both unique surface physics and the exploitation of quantum effects. AFRL is currently infusing international and commercial investment at the component level to enable improvements in a variety of Air Force capabilities including ISR, weapons, airframes, and propulsion. We believe the continued development of nanotechnology will produce Air Force game-changing capabilities. Nanotechnology will, in part, underpin technology innovations that will revolutionize future air, space, and cyberspace capabilities by delivering materials, coatings, devices and sensors with new and novel performance.

The past decade of nanotechnology work has been categorized by the investigation of nanomaterials and concepts and through examining the state of the possible. We are leveraging the Manufacturing Institutes across the country and will continue to utilize these and core efforts to drive research and development programs.

Currently, we are developing ultra-small, customized munitions enabled by the precise control of components at the nanoscale. New designs of energetic material, casing and solid propellant are projected to enable higher energy and smaller weapons reducing size and weight while delivering the same or greater effect. We are also learning how to "place" atoms in specific planes at the atomic scale which greatly increases signal to noise and thus efficiency of a sensor. This enables tremendous improvements

with regard to the size, weight, and power consumptions and eliminates the need for large external cooling components.

Multifunctional and adaptive structural materials harden electronics from electromagnetic threats and maintain structural performance during hypersonic conditions. We are developing smart coatings that will provide protections from adverse environments while self-reporting integrity to facilitate sustainability in military systems. Lightweight and pliable electronic systems, such as antennas, energy harvesting, batteries and power conditioning systems are being developed to extend mission duration and capability.

Enabling Technologies

In addition to these game-changing technologies, the Air Force S&T Program also invests in several enabling technologies to facilitate major advances and ensure maximum effectiveness in the near-, mid-, and far term.

Basic Research

AFRL's basic research efforts include working with world class universities, innovative small businesses and government research laboratories to invest in foundational science to generate the new knowledge necessary for the Air Force of tomorrow.

We execute the strategy outlined in *America's Air Force: A Call to the Future* by investing to create and support an innovation network. AFRL is focused on empowering the Air Force to rapidly adjust to both the evolving threat environment and the opportunities afforded by new science and technology. Our basic research program tracks and invests in the best S&T in the world by working with our partners in the Army, Navy, DARPA, and the Defense Threat Reduction Agency. We also monitor and leverage the investments and breakthroughs of the National Science Foundation, NASA, the Department of Energy, the National Institute of Standards and Technology, and intelligence community agencies such as Intelligence Advanced Research Projects Agency (IARPA). We also leverage the basic research investments of our international partners, such as Europe's billion Euro investment in quantum computing research.

The National Science Foundation noted that between 2001 and 2011, the U.S. saw its market share of global research and development attrite from 37 percent to 30 percent. By investing in the best open,

publishable research in the world, we are developing the relationships and collaborations to mitigate—and even turn around—the impact of this trend.

Our basic research program also plays a role in the development of future scientists and engineers. We are combining fundamental research efforts at universities and National Labs with state-of-the-art Air Force facilities and capabilities. The best and brightest students are working directly within the Air Force laboratory infrastructure right from the beginning of their careers.

Live, Virtual, and Constructive (LVC)

The Secure Live, Virtual, and Constructive Advanced Training Environment (SLATE) is an Advanced Technology Demonstration formally commissioned in February 2015 as a result of the 2014 Air Combat Command Acquisition and Sustainment Review to enhance Live Operational Training for the Combat Air Force, specifically the F-35.

The AFRL role is comprised of two main efforts: hardware/software integration and waveform maturation. Under the first effort, a team of industry partners will provide core LVC-enabling technologies for 4th and 5th generation tactical aircraft. The second effort updates the Range Instrumentation Waveform specification to meet the requirements of a 5th generation LVC training environment.

Position, Navigation, and Timing

Positioning, Navigation and Timing (PNT) is a critical enabling technology that supports nearly every Air Force warfighter and weapon system. The Global Positioning System (GPS) is the "go-to" PNT capability; however, we know we need to find alternatives. These alternative PNT technologies must be tailored to the mission, environment and platform in order to be effective. AFRL's PNT vision is to lead the discovery and development of robust, resilient PNT services that are available anywhere, anytime. Our challenge is to achieve this vision affordably.

The success of the GPS, the world's first global utility and the gold standard for satellite navigation, cannot be understated. Neither the depth of our GPS dependence, nor the scope of threats, could be envisioned when satellite navigation was first conceived.

AFRL's Space Vehicles Directorate is planning a revolutionary technology development program to "reinvent" satellite navigation. The Navigation Satellite Technology 3 (NTS-3) is the first program of its kind since the introduction of atomic clocks to spaceflight in the 1970's. NTS-3's associated Advanced GPS Technologies (AGT) program plans to launch a truly revolutionary navigation satellite by 2022 that

will be the basis of a yearlong space flight experiment investigating advanced signals, new waveform generation capabilities, improved spacecraft components and an innovative ground control system. NTS-3 and AGT are exploiting agile technologies, such as an on-orbit digitally reprogrammable waveform generator, to ensure our space based capabilities stay a step ahead of our adversaries.

AFRL's Sensors Directorate is working on the business end of the NTS-3 program; namely, how do we build flexible, adaptable, upgradable receivers that can be integrated into Air Force weapons systems? Specifically, we are conducting research into the development of secure, software defined radio-based (SDR) satellite navigation receivers. In FY16, AFRL sponsored the development of the first avionics form factor GPS and Multi-Global Navigation Satellite System (GNSS) compatible SDR. In FY17, we plan to investigate how to appropriately protect military GPS technology in an SDR.

On another front, the Munitions Directorate is collaborating with industry on a relevant Application Specific Integrated Circuit (ASIC) design that combines state-of-the-art anti-jamming capability with a fully modernized military GPS receiver. We will be developing multiple configuration options to suit nearly any munition or aircraft application.

AFRL has partnered with DARPA in the development of the All-Source Positioning and Navigation (ASPN) effort. This effort seeks new algorithms and architectures to rapidly reconfigure a navigation system with new and non-traditional navigation sensors. We have worked with multiple teams from industry and academia to develop reconfigurable, agile navigation system and tested these on the ground, in the air, and at sea.

Our Information Directorate has developed an open, extensible hardware and software architecture that allows AFRL engineers to insert new PNT technology into aircraft with little to no aircraft Operational Flight Program (OFP) modifications. This technology can be used to constrain the navigation solution of an aircraft when GPS is denied. Initial in-flight experiments with vision aided navigation using a targeting pod is planned for FY17.

Finally, AFRL has partnered with the Air Force Life Cycle Management Center, PEO Agile Combat Support and the Joint Systems Sustainment Management Office to develop and encourage the adoption of open architectures for our navigation and timing systems. Our goals are to rapidly and iteratively prototype open system processes, and open standard PNT technology and deliver robust evidence that this "open" approach can improve PNT capability-per-cost and decrease cost-per-PNT-capability across the Air Force enterprise.

Manufacturing Technologies

The Air Force's Manufacturing Technology program is focused on leading paradigm shifts in tomorrow's manufacturing domain. The long-term goal is to change the current, slow platform-specific assembly infrastructure to an agile manufacturing capability.

AFRL is working on innovative approaches to overcome defense-unique production challenges. We supported the F-35 production by enabling reduced production cost, the use of lighter weight components and increases in the durability of components. This, in turn, has improved production yields and performance of turbine blades, automated drilling, and other manufacturing aspects.

We are also developing and implementing advanced manufacturing techniques for open architecture multi-sensor ISR pods and exploring "on-demand" system manufacturing approaches for a low cost attritable aircraft. In additive manufacturing, we are in the midst of establishing the proper set of control experiments and processing methodologies to enable rapid and reliable verification and validation methodologies for parts and components.

The Air Force's ManTech Program continues to provide leadership and subject matter expertise for several of the Administration's National Network for Manufacturing Innovation (NNMI) Institutes. The Air Force is a key leader in the development and implementation of many of these institutes, focused on additive manufacturing, robotics in manufacturing, digital and design innovations, flexible electronics, photonics, and others.

Material Technologies (Sustainment)

AFRL's efforts in sustaining the force remain a priority. We are leading Department efforts to become more innovative and less risk averse in discovering and demonstrating additional methods to sustain our existing assets.

Our commitment in this area provides Non-Destructive Inspection (NDI) techniques and improves maintenance and repair diagnostics, technology for Digital NDI lifecycle data capture and methods for non-destructive quantifying of damaged systems, and characterizes micro-scale material features and analysis tools for life prediction and extension. We are delivering advanced NDI methods and tools, robotic tools for remote access, surgical tools for high velocity maintenance inspections, advanced inspection methods for turbine engines, multi-layered structure evaluation without disassembly and foundational technology for the Air Force's Condition Based Management concept.

To date, we estimate we have provided approximately $2 billion in life cycle cost savings with new low observable inspection technologies and $5 million in annual savings on the inspection of turbine blades. In addition, our efforts have extended structural inspection intervals by utilizing conformal eddy-current probes that improve sensitivity with no negative safety impacts.

Relevant Technologies

Cyber

AFRL cyberspace operations magnify military effects by increasing the efficiency and effectiveness of air and space operations across all domains. At the same time, cyberspace is becoming increasingly contested and denied with risks from malicious insiders, insecure supply chains, and increasingly sophisticated adversaries. AFRL's cyber efforts include:

Cyber-Based Mission Assurance on Trust-enhanced Hardware (CMATH). This is an ATD program for Air Combat Command to address mission assurance and provide cost reduction. CMATH develops secure server virtualization for a weapons system with built-in security features to limit the effectiveness of cyber-attacks and maintain operations in a contested cyber environment.

Autonomous Defensive Cyber Operations (ADCO). AFRL is researching technologies to create force multipliers for defensive cyber operations through machine learning and artificial intelligence. This effort seeks to identify and understand the level of confidence operators have in the employment of autonomous defensive systems.

Metasponse. This is an incident response framework for executing actions on multiple remote hosts from a central workstation. It provides an easy-to-use job building interface that guides the user through the incident response process in a fire-and-forget manner. The framework provides users with an agile, modular, and flexible capability to counter targeted nation-state level threats and intrusions. This system is currently deployed and in use by U.S. forces.

Distributed Assured & Dynamic Configuration (DADC). This automated tool for generation, verification, and deployment of secure system/network configurations automatically manages consistent information among configuration tools to reduce errors. Configuration errors currently cause 50 to 80 percent of network vulnerabilities and downtime. DADC has already been installed on several systems within the Air Force.

Ruby Slipper. This effort consists of the development of mission components to support operations in a single common framework where multiple tools work together. A pathfinder prototype developed by AFRL has been delivered to two Air Force organizations to enable risk reduction for future procurement efforts.

Aircraft Avionics Cybersecurity. AFRL is researching methods and technologies to protect aircraft from cyberattack. We have created realistic testbeds, discovered and exploited avionics weaknesses and developed ways to defend against them. The resulting knowledge is documented in a manual that has been shared with more than 75 DoD units, federal agencies and U.S. aircraft manufacturers.

Strategic World-wide Integration Capability/Advanced Capability for Understanding and Managing Effects Networks (SWIC/ACUMEN). This effort improves the Cyber Tasking Order (CTO) process by decreasing the CTO production time by 50 percent and increasing the number of cyber missions generated from 60-75 per week to 100 per day. It also enables near real-time effects-based plan monitoring, forecasting and impact analysis, and plan improvement recommendations.

Assured Communications

AFRL's assured communications S&T portfolio is focused on the innovation, development, and maturation of secure communications, networking, and information management technologies to build a timely, secure, and mission-responsive network of networks. Our work will provide the translation of sensory data into actionable information and assure tailored situational awareness and Command & Control (C2) communications globally. Example efforts include:

Secure Beyond Line of Sight (BLOS) *Communications at Extreme Latitudes via Mobile User Objective System* (MUOS). We have developed and demonstrated secure and reliable communications to assure global reach missions spanning mobility to combat. AFRL and Navy SPAWAR have demonstrated global C2 connectivity in airborne MUOS tests over the Pacific Ocean and southern hemisphere. Further, AFRL successfully conducted the first-ever Antarctic MUOS ground transmissions from McMurdo Station, Antarctica. Voice transmissions, as well as chat and file transfer applications were successfully demonstrated, while real-time Precise Position Location Information (PPLI) was simultaneously streamed over MUOS using existing tactical military radios.

Wideband Communications Links. AFRL is developing a suite of capabilities providing new spectrum availability and maneuverability, enabling the Air Force to cope with a congested and contested spectrum. Multiple communications pathways are being developed for advanced wideband airborne

communications. These technologies will provide an increase of several Gbps throughput for hundreds of ISR platforms that are critical for operations in contested environments.

Netted, Distributed Multi-platform Connectivity. This capability was developed by AFRL in partnership with Navy SPAWAR and it addresses both joint and Air Force needs outlined in several Core Function Support Plans. AFRL continues to advance this capability by developing conformal apertures suitable for airborne platforms as well as network protocols to enable robust, rapid multi-platform connectivity for Command and Control ISR exchange.

Secure Remote Radio Communications & Control for Ground Theater Air Controller System (GTACS). AFRL in-house researchers are developing communication interfaces and remote control software to enable secure remote radio operations. The remote radio system allows VHF and UHF radios used by battle managers to be remotely deployed and operated over existing satellite long-haul communications equipment. Each of the remote radio circuits operates in secure or clear-voice modes and also supports anti-jam functions of the remote radios. AFRL enhancements support Advanced Narrowband Digital Voice Terminal (ANDVT) encryption for UHF SATCOM and high frequency over-the-horizon communications. Our current S&T development will support future software defined radio systems over IP-enabled long-haul communications systems for heterogeneous network functionality.

Wideband HF Robust Communications. AFRL is developing a long-haul (approximately 5,000 mile) system to augment the aging High Frequency Ground Communications System by communicating over a Wideband High Frequency (WBHF) communications system, providing 16 times (16x) the bandwidth of the legacy system with inherent resiliency. The WBHF system will provide C2 messaging to forces in the Pacific Area of Operations, enabling robust, assured connectivity when satellite, underwater cables, and other wired connectivity is lost. A multi-point relay proof-of-concept demonstration with advanced signal processing/communications techniques is planned for 2017.

Spectrum-Agile Communications. AFRL is developing fundamental capabilities to adapt complex waveform parameters in response to rapidly changing operational environments. These parameters include power, bandwidth, modulation, coding, and routing to achieve low probability of intercept, anti-jam, and low latency assured communications. AFRL has lab-demonstrated survivable multi-node networking among cooperative assets reconfiguring network topology and spectrum utilization to overcome congestion and mitigate adversary actions. This fundamental AFRL research has garnered international citation and innovation awards. Ongoing work extends these capabilities to rapidly moving platforms.

Electronic Warfare

The traditional approach to updating U.S. electronic warfare (EW) systems has been based on a Cold War industrial model that is neither responsive nor effective. In order to stay ahead of the refresh rate of adversary systems, a new paradigm is needed that moves beyond the parametric-based classification, identification and the pre-programmed countermeasure response that has been used in the past. With this goal in mind, AFRL has been focused on incorporating machine learning into EW systems in an effort called Cognitive EW.

Cognitive EW uses machine-learning research and threat behavior to help classify and identify adaptive threats that have the capacity to change their radar signal attributes such as frequency, pulse repetitive interval and pulse-to-pulse signal modulation in near-real time. AFRL is involved with several industry partners to collaboratively pursue this approach.

In June 2015, AFRL and Northrop-Grumman performed a flight test of the Cognitive Mission Computer (CMC) at the NORTHERN EDGE exercise. The CMC is a project to develop a system that can better classify unknown signals based on both parametric data and behavior using advanced machine-learning algorithms. During the flight, the CMC demonstrated an initial capability to classify signals of interest using a real-time live feed from another sensor.

AFRL continues to develop cognitive EW capabilities with industry with the goal of transitioning technology that will be able to detect novel threat signals and adaptively create EW countermeasure waveforms in near-real time.

Long Distance Sensing

AFRL continues to push forward the Air Force's state-of-the art in long distance sensing capabilities. With a great depth of knowledge in radio frequency (RF) and electro-optical (EO) sensing, AFRL has demonstrated the ability to both enhance existing sensors and capabilities, as well as bring new ones to life in a timely and affordable way. We are expanding and developing both active and passive technologies in RF and EO disciplines with the capability to sense activity in multiple domains. This push is driven by the need to address current global long-range sensing challenges.

We are driving the capability to persistently sense the dynamics of the RF spectrum via ground, air and space and construct a situation awareness picture capable of responding to an adaptive anti-access/area-denial (A2/AD) environment. This multi-dimensional RF sensing space creates the challenge of correlating all ISR and EW electromagnetic activity with more transparency and low-latency.

Our research and development in signal processing, atmospheric physics, antennas and radar is producing significant improvements in Air Force capabilities to observe targets at long distances. Over-the-horizon-radar (OTHR) is a fairly mature technology benefiting from renewed research and development in these areas. Continued development of ground-based radar systems is offering greatly improved situational awareness of our space-borne assets.

A critical component to U.S. ISR capabilities continues to be passive electro-optical imaging. Using alternate wavelength bands and advanced image processing and enhancement techniques, AFRL has demonstrated, in a rigorous and methodical way, an approach to extend the useful range of airborne imaging ISR significantly well beyond the current state-of-the-art. Current research efforts will expand on this success and extend that capability even further.

The ability to identify critical targets with high confidence is also being extended through AFRL efforts in laser radar (LADAR). LADAR images in three spatial dimensions allow the warfighter to understand the true shape of a target. It greatly reduces confusion caused by partial obscuration common in the modern battlespace and is a key enabler in target recognition needed for autonomous operations. AFRL is working across its directorate boundaries to bring this capability to our 4th and 5th Generation aircraft without loss of current capabilities and with minimal integration.

LADAR also offers the potential to employ techniques commonly used in the RF domain with optical imaging. Such a system will produce 3D imagery with resolution beyond a more conventional system. Through the use of synthetic aperture LADAR, AFRL is pursuing an unparalleled 3D imaging capability for the Air Force.

Hydrocarbon Boost

In support of our nation's engine development efforts, the AFRL Hydrocarbon Boost effort is maturing critical Oxygen Rich Staged Combustion (ORSC) technologies with a technology demonstrator using liquid oxygen/kerosene. Technologies developed in the AFRL Hydrocarbon Boost effort are applicable to the existing range of booster engine thrust classes. As the primary organization responsible for research and development of liquid rocket engines for the DoD, AFRL is advancing state-of-the-art in model-driven rocket design with a "crawl-walk-run" testing approach.

In test campaigns, the Hydrocarbon Boost effort will first conduct systematic testing of individual engine components, followed by testing of the integrated engine system. All testing will be highly instrumented to attain unprecedented understanding of rocket engine operation and enable targeted risk reduction.

The Hydrocarbon Boost effort is planned to complete component level testing by 2019 and integrated engine testing is planned for 2021. However, there have been and will continue to be, transitions to support domestic industry engine development efforts throughout the coming years. Our effort has already provided significant impact to the U.S. rocket industry with direct transitions to multiple companies developing ORSC booster engines.

Munitions

AFRL is investigating new munitions technologies to support advanced capabilities for future platforms including alternate weapons PNT for A2/AD, advanced seekers and automatic target recognition, hypersonic technologies, additive manufacturing of munitions, advanced nano and structural energetics, and counter hard and deeply buried targets. We are also pursuing significant integrated systems demonstrations to support technology transition to emerging acquisitions. These include:

Long-Range Strike Demonstrations assist the Joint Force Commander by providing responsive and persistent capabilities enabling the application of force against a variety of targets, to include time-critical, high-value and heavily defended targets. The High Speed Strike Weapon (HSSW) effort is the centerpiece of this concept. Working in partnership with DARPA, we are developing guidance and ordnance technologies for a family of hypersonic air-launched missiles.

Collaborative Strike Demonstrations use distributed, collaborative and cooperative weapons to provide improved mission effectiveness in an A2/AD environment. By employing validated semi-autonomous capabilities in alignment with human-defined Rules of Engagement, these weapons could collaborate to be more effective than weapons employed independently. Smaller weapons can use cooperation to produce scalable effects that increase the capacity and capability of 5th Generation aircraft. The value of these concepts will be assessed through a variety of simulations, hardware-in-the-loop testing, sub-scale testing and integrated weapon flight demonstrations.

Air-to-Air Munitions Demonstrations for Offense and Defense addresses an over-arching emphasis for advanced air superiority weapons is significant size and weight reduction to increase internal carriage capacity. Integration of advanced propulsion and guidance and control system technologies will expand missile operational envelops both within and beyond visual range. These combined technologies provide the warfighter with the capability to rapidly destroy or neutralize air targets and ground-based air defenses at greater distances from the launch aircraft enhancing survival and mission effectiveness.

Selectable Effects/Low Collateral Damage Demonstrations support several Air Force mission areas by developing, maturing, demonstrating, and transitioning armament technologies. AFRL is providing the

user with operational flexibility across the range of military operations. Some of the key attributes are: effective C2, flexibility in operations, tailored lethality effects, dependability, and interoperability. Technologies from this area are needed to support current, ongoing military operations.

Space Situational Awareness (SSA)

The SSA S&T investments needed to maintain our core Space Superiority and C2 missions are substantial and include research in Assured Recognition and Persistent Tracking of Space Objects, Characterization of Space Objects and Events, Timely and Actionable Threat Warning and Assessment, and Effective Decision Support through Data Integration and Exploitation. AFRL along with Air Force Space Command (AFSPC), work across these areas in cooperation with the DoD, intelligence community, and industry.

We provide technologies to support AFSPC and meet the growing demand to ensure space superiority in the face of new threats. Using both ground-based and space-based collectors and exploring multiple phenomenologies, AFRL innovates, matures and transitions technology to support the Joint Space Operations Center (JSpOC) and Joint Interagency Combined Space Operations Center.

The Air Force's S&T investment is designed to leverage our in-house expertise while engaging with academia, industry and international allies. Examples include the deep space uncorrelated target association problem to improve custody of space objects and reduce the burden on the space surveillance network, better conjunction assessment and re-entry estimation algorithms to reduce collision probabilities and unnecessary maneuvers and infrared star catalog improvement to ease observation calibrations.

Recently, the Automated Navigation and Guidance Experiment for Local Space (ANGELS) effort examined techniques for providing a clearer picture of the environment around our vital space assets through safe, automated spacecraft operations above Geosynchronous Earth Orbit (GEO). Equipped with significant detection, tracking and characterization technology, ANGELS launched in 2014 and transitioned to AFSPC in 2015. It maneuvered around its booster's upper stage and explored increased levels of automation in mission planning and execution, enabling more timely and complex operations with reduced footprint. The Air Force is building on the success of ANGELS by partnering with NASA to enhance the coverage of PNT signals in space at and above GEO altitudes by updating the Global Positioning System (GPS) Space Service Volume (SSV) to support even greater autonomy for newly emerging spacecraft operations.

AFRL's ground assets include two unique approximately 3.5 meter telescopes that it uses to conduct research in characterizing space objects in low earth orbits up to GEO orbits and to support various customers in providing near real-time data on such satellites.

The Starfire Optical Range (SOR) on Kirtland Air Force Base, New Mexico, develops optical sensing, imaging, and atmospheric propagation technologies. As one of the world's premier adaptive-optics telescopes, the SOR is capable of tracking low-earth orbiting satellites. Day and night adaptive optics for Low-Earth Orbit (LEO) objects and closely-spaced-object are two example efforts developing capabilities enabled or enhanced by utilizing the unique SOR infrastructure.

The Maui Space Surveillance System (MSSS) takes advantage of Hawaii's complementary technical, geographical, and atmosphere benefits. The MSSS provides critical data to our space warfighters on the health and status of many satellites. A recent breakthrough is providing outstanding images during daylight hours which allow us to support AFSPC with requested information on short timeframes. The co-location of the AFSPC Space Surveillance Network (SSN) optical telescope on the top of Haleakalā and the contributing sensor status of the MSSS telescopes enables rapid and efficient transition.

AFRL is developing key enabling S&T capabilities for data integration, multi-sensor fusion, space object and event characterization, and threat indications and warning for enhanced SSA. The Air Force's Multi-INT Activity Pattern Learning and Exploitation (MAPLE) suite of tools, already in operational use in the intelligence community, are currently being enhanced to provide advanced multi-intelligence fusion, satellite characterization, and space system behavioral analysis capabilities for "left of the event" recognition of anomalous activities.

Rapid prototype fusion, characterization, assessment, and decision support capabilities have already been successfully demonstrated using passive radio frequency and electro-optical SSA data and are being further developed for planned transition to JSpOC Mission System (JMS) and/or operational BMC2 systems called for by USSTRATCOM.

AFRL is testing next-generation space environmental impact and prediction technologies as part of exquisite global space situational awareness for operations in contested space and A2/AD environments. By building on the extensive space weather expertise, AFRL is opening new opportunities to ensure our ability to operate through space weather events while characterizing the effects of the dynamic space environment.

Space Resilience

The AFSPC *Space Enterprise Vision* (SEV) addresses how the Air Force stays competitive in today's environment by working with commercial and other government partners. Under the SEV, AFRL is directly supporting Air Force Space and Missile Center (SMC) with executing the "rapid prototyping" needed to demonstrate resilient and advance technologies.

AFRL continues to work assured satellite communications that are critical to the warfighter in all aspects of the Air Force core missions. We are also helping the Air Force lead the way in the use of small satellites. Small spacecraft are adaptable, tactically responsive, potential mission gap fillers, and provide reconfigurable constellations at an affordable price point.

Leaning ahead, AFRL has implemented efforts to address, and where possible demonstrate emerging technologies, including:

The *Resilient Bus Evaluation Laboratory* (REBEL) has been stood up to understand how integrated technology solutions and innovative satellite operations can enhance the resilience of U.S. space capabilities. Featuring a high fidelity emulation of a satellite and associated ground system, REBEL enables the integration of new sensors, algorithms, processing, and protection technologies. It enables the simultaneous and synergistic development of technologies and the "operational arts" to ensure critical space mission capabilities.

AFRL, in partnership with NASA and commercial partners, has developed the *Roll-Out Solar Array* (ROSA), which uses passively deployed, composite structural booms and a flexible solar cell blanket. ROSA's innovative architecture beats the current state-of-practice rigid solar arrays in all areas of performance. Space Systems Loral will use ROSA to replace its existing arrays for 37 GEO/LEO communications satellites in production.

The *Navigation Technology Satellite-3* (NTS-3) flight experiment is AFRL's next major flight experiment and will explore innovative technologies such as On-Orbit Digital Waveform Generators (ORDWGs), high efficiency amplifiers, and advanced antenna systems. NTS-3 is planned for launch in the early 2020s.

The *Demonstration and Science Experiments* (DSX) space flight experiment, scheduled for launch in late 2017, is centered on demonstrating and maturing technologies to gain better understanding of the MEO space environment and its effect upon satellites.

Additionally, AFRL is testing space craft thermal technologies. We will demonstrate a heat spreader capable of increasing communication bandwidth by supporting higher electronics power loads. Reduced

processor and amplifier temperatures provide for increased functionality/power and improved anti-jamming performance. AFRL has also developed a variety of resilient thermal bus technologies to enable the Air Force to perform agile maneuvering and operate-thru and adjust to unexpected thermal loading events in real-time. Technologies focus on managing the thermal bottlenecks at the component, panel, inter-panel interfaces, and insulation/radiator levels.

Spacecraft Propulsion

Since the 1980's, AFRL has transitioned spacecraft propulsion technologies to most of the nation's National Security Space systems. The latest system to be flying Air Force spacecraft propulsion technology (Hall Effect Thrusters) is the Advance Extremely High Frequency (AEHF) satellite. This technology was recently highlighted when the on-orbit Hall Effect Thrusters had to be used to put the satellite into its proper orbit after the primary orbit raising thruster failed on an AEHF satellite.

More recently, AFRL, the Rapid Capabilities Office, SMC, and industry partners teamed to quickly modify and characterize the XR-5 thruster on the AEHF satellite and test it on orbit using the X-37B reusable space vehicle. The modified XR-5A thruster incorporates modifications to improve performance and operating range.

The Air Force has matured Hall Effect Thrusters and is now researching Field Reverse Configuration thrusters. These multimode thrusters are characterized by highly efficient, low thrust operations. This provides a large dynamic range that extends from station keeping to the high thrust needed for quick maneuvers, all using a single propellant.

Rapid Innovation (Responsive) Technologies

AFRL's Center for Rapid Innovation (CRI) exploits state-of-the-art technology in novel ways to provide affordable and suitable solutions for urgent operational needs. Under AFRL's proven Rapid Innovation process, critical operational needs from warfighters, system program offices, or senior military leadership are referred to the Center for Rapid Innovation, with the approval myself as the AFRL Commander.

CRI draws on user, industry, academia, and laboratory subject matter experts to form a multi-disciplinary team tailored to the nature of each problem. The team analyzes the problem in the context of operational procedures, standards, and limitations; and shapes innovative technology options that can be transitioned into the field, typically in 12 to 18 months. This innovation process leverages the breadth and depth of knowledge within the laboratory and its "innovation network" to form a team to work in a rapid prototyping, collaborative, spiral development environment that generates real solutions.

This development process relies heavily on close interactions with the user and frequent design and development spirals, testing, and experimentation to converge on a "just-right" prototype. The process has been successful over its eight year history in providing near term capabilities for critical warfighter gaps, via field testable and deployable prototypes. Often, the user will work with their acquisition agents to pursue programs of record based on these prototypes.

One recent example of the Rapid Innovation process is our Long Endurance Aerial Platform effort, or LEAP. LEAP provides a revolutionary, low-cost, low acoustic signature, persistent aerial ISR capability to address Combatant Command and U.S. Special Forces ISR gaps by converting a proven, fuel-efficient Light Sport Aircraft into an UAS.

LEAP significantly bends today's ISR cost-performance curve and enables needed counter-insurgency capability and ISR capacity at a fraction of the cost of comparably performing systems. Based on the success of these tests, USSOCOM requested, and the Office of the Undersecretary of Defense for Intelligence (OUSD(I)) funded, an operational evaluation of the system in theater. AFRL procured the hardware for a complete system consisting of four air vehicles and payloads, and deployed the system in early 2016. This system is being operated in conjunction with the USSOCOM user in ongoing overseas operations. The results to date have exceeded expectations. AFRL is discussing transition options with OUSD(I) and USSOCOM, based on these preliminary evaluations.

AFRL also developed Rapid Innovation solutions for AFSPC to enhance SSA for geostationary orbits, leveraging advanced algorithms to develop orbital tracks and solutions for the population of smaller GEO objects and providing timely detection of changes in those populations. AFRL developed the Search and Determine Integrated Environment (SADIE) tool, fast orbit propagators based on Picard integration methods, and two multi-hypothesis trackers and correlation engines. These tools were installed in a test environment at the Space Situational Awareness Laboratory (SSAL) to evaluate performance against real-time Space Surveillance Network (SSN) data. This innovative approach has shown significant improvements in accuracy and a reduction in man-power to correlate tracks and develop candidate orbits in collaboration with the Alternate JSpOC at Dahlgren. The outputs of the resulting capability has already been used to find 226 new candidate orbits to add to the space catalog, and its remarkable success has led to an ongoing effort to transition the capability to the Dahlgren Mission Processing System in 2016 for continued operational support.

In addition, AFRL has developed a Rapid Innovation solution for the para-rescue community. These heroic individuals need the ability to lift armored vehicles from uneven sloping shale type terrain to aid in

extrication of casualties in a rescue/recovery situation. AFRL developed a solution that reduces the size and weight of the current equipment, while providing an enhanced lift capability, using advanced fiber reinforced airbags and battery powered compressors. Testing of the first prototypes showed that they met all requirements, and a few minor enhancements and improvements were identified. AFRL completed a second design spiral delivered 10 units for extended user field testing, which has gone very well so far.

EXPERIMENTATION

AFRL's experimentation efforts enables the unfettered exploration of alternatives in future environments and involves operators, technologists, requirements, acquisition professionals, and others collaborating from beginning to end in a truly integrated fashion. Our goal in experimentation campaigns is to enact a series of progressive and iterative activities designed to build knowledge and provide a method to rapidly evaluate capability concepts.

In May of this year, the Air Force established the Strategic Development Planning and Experimentation Office. This office supports the Secretary of the Air Force through the Air Force Materiel Command (AFMC) in providing ECCT support, war-gaming, modeling and simulation, and virtual and hardware prototyping to assess concepts and advanced technologies. The focus of this multi-disciplinary team is to build-in agility and formulate truly innovative strategic choices.

As has been noted by AFMC Commander General Ellen Pawlikowski, development planning is not a new competency for the Air Force, but it is an area that has been allowed to wane in recent years. Programming solutions for capability gaps have become platform-centric, rather than strategy focused. Assessments under the new effort will involve multi-domain, air-space-cyber approaches to solutions.

We support the Air Force in all four of the current pilot experimentation campaigns: Future Attack Capabilities (FAC); Directed Energy (DE); Data to Decisions (D2D); and Defeat Agile Intelligent Targets (DAIT). The D2D and DAIT campaigns are supporting the Air Superiority 2030 ECCT, which leveraged AFRL subject matter experts to assess the current climate and provide recommendations. AFRL is a cornerstone in these experimentation campaigns by providing timely empirical data to enable strategic investment decisions and to reinvigorate the culture of experimentation within the Air Force.

AFRL supports the FAC Experimentation Campaign in characterizing the Air Force's ability to conduct future attack (FA) and explore concepts through experimentation. Our goal is to enhance the joint capability to perform FA in a variety of operational environments and across a range of timeframes. Initial experimentation results demonstrated remotely accessible internet protocol (IP) networks can be used to enhance Tactical Data (Link 16) with National Technical Data and improve FA targeting

identification. Our LVC demos have also helped to improve joint training through FA experimentation. LVC experimentation has connected live A-10, F-16, and AH-60 platforms with virtual MQ-1s in the constructive Modern Air Combat Environment to validate JTAC training benchmarks in a Distributed Mission Operations Network. We are also involved in planning FA munitions experimentation for testing on the range and in a LVC environment. Our efforts are helping to ensure near-, mid-, and far-term weapons development is consistent with future FA mission requirements.

AFRL is also involved in the DE Experimentation Campaign. We are beginning to take the concepts and capabilities out of our laboratories and put them into the hands of the warfighter. We are using constructive and operator-in-the-loop simulations to understand the interplay of technologies, concept of operations (CONOPS), and doctrine in close collaboration with operators and technology developers. A related effort involves experimentation with employment of an air-to-ground HEL weapon system on an AC-130 gunship. This work is in close collaboration with the Air Force Special Operations Command to assess and deepen our understanding of system performance characteristics, airborne platform integration considerations, and CONOPS. The body of knowledge gained through these efforts will identify key risk areas and technology needs to better focus our research and accelerate the realization of HEL capabilities across a range of systems and platforms.

AFRL continues to engage with the operational Air Force in the two additional experimentation campaigns being planned in response to Air Superiority 2030 ECCT direction. The D2D experimentation campaign will explore various concepts to provide the right data to decision-makers in the time and manner required and the DAIT experimentation campaign will explore new technology-enabled concepts to defeat challenging targets.

AFRL Strategic Development Planning and Experimentation will understand and synthesize future warfighting needs and reconcile those with available and potential capabilities, concepts, and emerging technologies. Core development planning functions include formulating and evaluating viable future concepts, defining operational trade space, identifying technology shortfalls and S&T needs, and assisting the operational community in refining requirements.

PROTOTYPING

AFRL engages in prototyping as a valuable tool for development planning and experimentation as it enables evaluation of design, performance and production. Prototyping activities are useful at various levels of technology maturity. Specifically, we use concept prototypes to assess feasibility, development

prototypes to test advanced concepts and integrated capabilities and operational/fieldable prototypes that look toward the production and deployment stage. AFRL engages operational users intimately in need analysis, solution conceptualization, and prototype development to ensure delivery of a suitable prototype that satisfies the user need. We often employ a rapid spiral development process that incorporates experimentation and prototyping to quickly evolve design and incorporate lessons learned during operations.

Our recent efforts in improving Convoy C3 and Situational Awareness have been successful. In response to a request from 20th Air Force and Air Force Global Strike Command, we participated in the first spiral of a convoy communications and situational awareness solution. This system provides a self-configuring, self-healing mobile network that allows the members of a nuclear convoy to share voice and text chat messages, imagery from on-vehicle cameras (including overhead imagery from supporting UH-1N helicopters), moving map displays, and reach-back to a command and control center. In parallel with the system deployment to all three 20th AF missile wings, AFRL implemented product improvements in the system based on lessons learned from a previous Operational Demonstration and Evaluation. The second spiral of the system design has been selected for full-scale development with support from Air Force Global Strike Command and the 20th Air Force.

AFRL also supports the Air Force's Adaptive Engine Transition Program (AETP) through rigorous adaptive engine technology maturation to reduce risk prior to Engineering and Manufacturing Development (EMD). This follows from our effort in the highly successful Adaptive Versatile Engine Technology (ADVENT) and Adaptive Engine Technology Demonstration (AETD) efforts. We will continue to participate in AETP's jet engine demonstration and validation program that will advance designs through extensive ground testing for future integration and flight test.

All of our efforts follow AT&L's BBP 3.0 lead to reinvigorate the use of experimentation and prototyping for the purposes of rapid fielding of technologically advanced weapons systems, providing warfighters with the opportunity to explore novel operational concepts, supporting key elements of the industrial base, and hedging against threat developments or surprises by advancing technology and reducing the lead time to develop and field new capabilities.

WORLD CLASS WORKFORCE

Our most important and most valuable resource continues to be the people who comprise AFRL. The technical talent and innovative spirit of our workforce is singly responsible for the technological

superiority of the Air Force. In order to maintain an agile science, technology, engineering and mathematics (STEM) workforce, AFRL is focused on STEM outreach, using all of our human capital advantages in attracting and inspiring individuals to Air Force STEM careers, leveraging our intellectual capital, and maintaining the STEM workforce via our Laboratory Demonstration (Lab Demo) authority.

STEM Outreach

In May 2014, the Assistant Secretary of the Air Force for Acquisition (SAF/AQ) designated AFRL as the Air Force Executive Agent for K-12 STEM Outreach. In this capacity, AFRL is building a K-12 STEM outreach program that institutionalizes and coordinates STEM outreach throughout the Air Force, leverages industry and other government agencies, promotes diversity, and measures results.

As the Air Force STEM Executive Agent and the lead for Air Force K-12 STEM Outreach Strategy, AFRL is directly supporting Air Force K-12 STEM outreach programs at 26 Air Force installations that have K-12 STEM efforts in their respective communities. In FY15, more than 245,000 students were reached across the 26 sites, with more than 180 activities targeted to underrepresented groups across all Air Force locations.

Air Force K-12 STEM outreach also contributed to the success of the national STEM initiatives like the White House's "National Week at the Labs", CyberPatriot National Finals, StellarXplorers National Finals, USA Science & Engineering Festival, Junior Science & Humanities Symposium and the Tragedy Assistance Program for Survivors (TAPS).

AFRL Community K-12 STEM outreach programs are reaching farther back into the educational system to influence younger STEM students with the intent of establishing a long-term pipeline of diverse research talent headed for AFRL. To build this STEM workforce base we utilize hands-on activities and demonstrations, teacher development, competitions, mentoring and tutoring, science fair support, and programs and events such as the DoD STARBASE Programs, *For Inspiration and Recognition of Science and Technology (FIRST)* LEGO Leagues, *FIRST* Junior LEGO Leagues and *FIRST* Robotics Competitions.

Human Capital Advantages

Development, Retention, Recruiting

A primary goal for AFRL is the recruitment, development, and retention of a diverse workforce that is committed to leading in the discovery, development, and integration of affordable technologies for the nation's air, space, and cyber space forces. These tenets are critical to AFRL mission support and to building and maintaining the workforce human capital. Programs focused on workforce acculturation,

pre-supervisory development, supervisory development, and continuous leadership development are designed to develop and grow the AFRL workforce. AFRL personnel also participate in formal Air Force career development programs.

AFRL is committed to achieving this goal and maintaining its presence as a world-class technical enterprise for the best and brightest scientific and technical leaders in the world. As part of our recruiting activities, AFRL has created a website (www.TeamAFRL.com) where prospective candidates can learn about AFRL technologies, research areas, and civilian job opportunities. In addition, AFRL has established a University Relations position focused specifically on schools identified as "best-in-class" for particular AFRL core technical competencies. Some other activities the laboratory accomplished in this area include new summer internship programs, the AFRL minority recruiting program and the new AFRL Postdoc Fellowship Program.

The Air Force recently developed a coordinated strategy for engagement with Historically Black Colleges and Universities and other Minority-Serving Institutions (HBCU/MIs) including Tribally Controlled Colleges and Universities, Hispanic-Serving Institutions, Asian-American and Native American and Pacific Islander-Serving Institutions, and Predominantly Black Institutions to support the development of science, technology, engineering, and mathematics (STEM) capabilities in support of Air Force needs and to alleviate competency gaps between HBCU/MIs and traditional research universities. As the research arm of the Air Force, AFRL is responsible for executing this strategy which incorporates several goals and metrics to include increasing the new hires from HBCUs/MIs by three percent over the next three years.

In an effort to retain a skilled workforce, AFRL proactively utilizes a variety of programs and initiatives such as student loan repayments, tuition assistance, the Developmental Opportunities Program (DOP), and retention incentives. Furthermore, this past year AFRL reinstituted exit interviews to gain greater insight to why some individuals may choose to seek opportunities outside of the Laboratory.

AFRL Scholars Program

As a means to identify, recruit and hire top S&T talent in the U.S., AFRL operates the Scholars Program. This program is dedicated to preparing students for leadership positions in STEM fields, through the integration of education and experience in our research and development.

From its inception in 2001 to date, the AFRL Scholars Program has provided internship opportunities for over 1,300 high school, undergraduate and graduate students. Students from across the U.S. benefit from and contribute to the Laboratory through research experiences at AFRL locations including Kirtland AFB,

New Mexico, at the Air Force Maui Optical and Supercomputing (AMOS) site in Maui, Hawaii, Eglin AFB, Florida, and at Wright Patterson AFB, Ohio.

Until 2012, the AFRL Scholars Program was administered by on-site government civilians within the AFRL. In 2013, Universities Space Research Association (USRA) was awarded a multi-year cooperative agreement to execute future scholar programs on behalf of AFRL. USRA's expertise, in partnership with AFRL, provides the Scholars Program with successful processing of security clearances, stipends, management of in-and-out processing, and general facilitation of an outstanding scholar experience.

As part of the Scholars Program, AFRL holds a Career Forum. AFRL partners with both local and national industry-specific employers to give Scholars an opportunity to meet with employers in a small group setting to facilitate informal question and answer sessions, as well as participate in short interviews with employers. Post-internship communication indicates that several Scholars have secured employment in defense-related industries as a result of their participation in the Career Forum.

We plan to expand the Scholars Program to offer year-round internships at Kirtland AFB. We are also considering the possible integration of "hybrid" internships between AFRL and industry partners to continue to collaborate and build AFRL's relationships with the STEM industry.

From survey results 97 percent of AFRL Scholars responded that they would like full time careers at AFRL in the future, 90 percent responded that the program has affected their career decisions and 86 percent responded that they would recommend the internship opportunity to others. Numerous Scholars have been employed by AFRL, government/DoD, and local and national STEM industry employers.

Intellectual Capital

AFRL is home to 3,573 of our nation's best researchers and engineers working across disciplines and geographical locations to address Air Force technology challenges. Our expertise spans across 37 core technical competencies (CTCs) and 109 sub CTCs by leveraging the expertise of 1,096 doctoral and 1,694 master's degrees.

AFRL is committed to being the laboratory of choice for the world's best talent and has established a Human Capital Strategy defining the infrastructure, processes and tools to realize our human capital mission and values. This strategy lays out an approach for developing our people, actively managing the development of targeted talent, capturing and leveraging our organizational knowledge and telling the story of our strategy, priorities and key initiatives.

As part of this strategy, we have stood up an Enterprise Learning Council, with Learning Officers assigned to every technology directorate. Learning Officers serve to assess and develop individuals, teams and the organization and promote the preservation of knowledge through coaching, mentoring and other organizational learning programs.

Each year AFRL sends members of our workforce to Long-term Full-time (LTFT) training to earn advanced degrees in under-resourced disciplines or newly emerging knowledge areas. Over the past five years AFRL has invested over $9 million in developing our intellectual capital through LTFT programs.

For scientists and engineers, professional society conferences are the standard mechanism for staying current and connected to the global disciplinary community. While participation in professional conferences was restricted for several years due to funding, we appreciate your help in restoring this capability. Today, scientists and engineers across AFRL are able to identify and fully participate in the professional societies that bring most value to their particular competency.

AFRL serves as a "treasure trove" of intellectual capital and technology that can be leveraged to bring the necessary advantage to our warfighters, or to meet other major technology needs faced by our federal government or society. A portion of the AFRL intellectual capital is captured as invention disclosures and patents. New, aggressive programs are being developed to commercialize this intellectual property to get it to the warfighter faster, quicker and cheaper.

Beyond intellectual property, our intellectual capital is tapped to meet a variety of needs, both military and civil. Emerging and urgent needs often result in a call for help from our rich pool of intellectual resources. A few recent examples include:

Aircraft Crew Breathing System. A team of AFRL experts developed a standard for aircraft crew breathing systems using On-board Oxygen Generating Systems (OBOGS), in response to hypoxia-like incidents experienced by airmen. The Air Force, in conjunction with the Navy and aerospace industry, developed MIL-STD-3050, which covers the design, integration, certification and sustainment requirements for aircraft crew breathing systems using an OBOGS. The standard now prevents inconsistent application of life-support-system-critical items that include an OBOGS.

Aerospace Mishap Support. AFRL engineers provided critical root cause information and corrective actions on 17 aerospace mishaps (including eight class A mishaps), preserving fleet safety and saving Air Force resources in 2016. AFRL engineers also support the FAA in generating and revising material data bases used in aerospace design and providing additive manufacturing guidance for aerospace components.

Dyess Air Force Base HVAC Duct Collapse. The AFRL Systems Support Division provided the root cause for the collapse and recommendations to update the civil industry specification for duct supports. This specification is now used in building codes nationwide.

Laboratory Demonstration (Lab Demo) Authority

The Lab Demo authorities authorized to the Science and Technology Reinvention Laboratories (STRLs) continue to provide AFRL a more responsive and flexible personnel system through direct hire authorities, broad banding, the contribution-based pay system, simplified job classification, developmental opportunities and voluntary emeritus corps among other unique workforce shaping tools. These authorities have enabled AFRL to successfully attract and retain high quality scientists and engineers.

Delegated position classification and broad banding provide management greater control of the workforce by transferring decision-making authority from an inflexible personnel hierarchy to first line supervisors who know what is needed to accomplish the mission. The Direct Hire authority has enabled AFRL managers to hire scientists and engineers in less than half the time of traditional hiring methods.

The Contribution-based Compensation System provides management the ability to manage employee expectations, focus employee contributions toward mission accomplishment and compensate employees appropriately based on contribution to the AFRL mission. The DOP provides opportunities for AFRL personnel to acquire knowledge, experience, and expertise that cannot be acquired in the standard working environment. These developmental activities not only enhance employees' contributions, but also advance the AFRL mission.

We appreciate the work of Congress to provide continued improvements in personnel authorities. These authorities allow AFRL to be as competitive as possible with industry in attracting top scientists and engineers.

LABORATORY INFRASTRUCTURE

Infrastructure focused on S&T is necessary to support innovation and force modernization. From FY07 to FY16, the AFRL received Congressional support for four Military Construction (MILCON) projects executed across three AFRL sites.

Thanks to the approval of the Congress in FY16, we will soon have a new Space Vehicles Component Development Laboratory. The Component Development Lab will support development of space power generation, solar arrays and photovoltaic cells, space power storage, space vehicle mechanisms (launch

separators and maneuvering components), mechanism controls, space protection including radiation-hardened electronics, and environmental sensors and cryocoolers. This new facility consolidates 11 separate S&T infrastructures and provides four light laboratories, two medium laboratories, and class 1,000 clean rooms required for space vehicle research, development, and experiments.

The FY17 President's Budget includes the proposed construction of an Advanced Munitions Technology Complex on Eglin AFB, Florida. This laboratory facility will provide the capability to support research and development of sub-scale high speed munitions requiring advanced energetics containing nano and conventional materials. This laboratory would be capable of handling and using nano-explosive powders, a much needed DoD capability that does not currently exist in the U.S. today.

As the Laboratory Commander, I am especially appreciative of the authorities which allow me to conduct minor infrastructure projects, known as the "Section 219" authority. This authority has enabled rapid improvements to S&T infrastructure. One important Section 219 project is under construction at our Munitions Directorate. The Site C-86 range implements a variable height tower enabling extended slant range measurements, full access to test range geography, optical turbulence distortion reduction, ground clutter elimination, and high value assets protection from over exposure to the elements in support of research, development, and testing of next-generation weapon seekers. This tower supports the delivery of active and passive seeker concepts to defeat adversaries in A2/AD environments as well as urban target environments and long-range targets. In addition, warfighters from Air Combat Command and Air Force Special Operations Command benefit from the use of this tower in their drive to mature technologies for killing moving targets, testing of hard and deeply buried targets, seeker development, wire-strike avoidance LADAR technique, helicopter burnout solutions, and sniper identification efforts.

We also leveraged our Section 219 authority for the Maui Innovative Space Awareness Laboratory (ISAL). The ISAL is a world-class research facility at the Remote Maui Experiment (RME) supporting the mission of the Air Force Maui Optical and Super Computing Site (AMOS). The facility provides laboratory space to complete experiment preparations, mission equipment testing and staging, and observatory remote operations within one mile of AMOS's primary office complex. This facility greatly reduces the need to complete the nearly 100 mile, 4 hour, round trip commute to the Maui Space Surveillance Site (MSSS) located on top of Mount Haleakala. Furthermore, the facility establishes Maui's first quantum computing lab and testing in support of AMO's supercomputing mission.

CONCLUSION

Chairman, Members of the Subcommittee and Staff, thank you again for the opportunity to testify today on the Air Force Research Laboratory's move toward strategic agility in capability development, the impact of our world-class S&T program (game-changing, enabling, relevant, and rapid technologies), the stand-up of a strategic development planning and experimentation capability, prototyping and leveraging the contributions of our entire world class workforce and infrastructure.

Major General Robert D. McMurry Jr.

Maj. Gen. Robert D. McMurry Jr. is the Commander, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio. He is responsible for managing a $2.1 billion Air Force science and technology program and an additional $2.3 billion in externally funded research and development. He is also responsible for leading a government workforce of approximately 6,000 people in the laboratory's nine component technology directorates and 711th Human Performance Wing.

General McMurry entered the Air Force in 1984 through the University of Texas ROTC program. He has served in a variety of engineering, program management, staff and command positions within Air Combat Command, Office of the Assistant Secretary of the Air Force for Acquisition, Air Force Materiel Command, Air Force Space Command and the Missile Defense Agency. He commanded the 508th Aircraft Sustainment Group, Ogden Air Logistics Center, Hill Air Force Base, Utah, and the Airborne Laser Systems Program Office, Aeronautical Systems Center, Kirtland AFB, New Mexico. He was the Director, Iraq Security Assistance Mission in Baghdad, Iraq. He also served as Space Programs Director for the Office of the Assistant Secretary of the Air Force for Acquisition, Washington D.C. His most recent assignment was Deputy Program Executive Officer for Space and Vice Commander, Space and Missile Systems Center, Los Angeles AFB, California.

EDUCATION

1984 Bachelor of Science degree in electrical engineering, University of Texas, Austin
1990 Squadron Officer School, Maxwell AFB, Ala.
1993 Master of Science degree in control and systems engineering, University of West Florida, Pensacola
1997 Advanced Program Managers Course, Defense Systems Management College, Fort Belvoir, Va.
1998 Master of Arts degree in national security and strategic studies, College of Naval Command and Staff, Naval War College, Newport, R.I.
2002 Master of Science degree in strategic studies, Air War College, Maxwell AFB, Ala.
2005 Joint Forces Staff College, Norfolk, Va.
2005 Program Manager's Course, Defense Acquisition University, Fort Belvoir, Va.
2008 Air Force Enterprise Leadership Seminar, Kenan-Flagler Business School, University of North Carolina at Chapel Hill
2013 Air Force Smart Ops For The 21st Century, The University of Tennessee, Knoxville

ASSIGNMENTS

1. February 1985 - July 1986, instructor, Mission Control Center Operations, 3423rd Technical Training Squadron, Peterson AFB, Colo.
2. July 1986 - January 1989, undergraduate space training courseware developer, 3301st Space Training Squadron, Peterson AFB, Colo.
3. January 1989 - January 1992, F-15/16 electronic warfare systems engineer, U.S. Air Force Air Warfare Center, Eglin AFB, Fla.
4. January 1992 - June 1993, electronic warfare systems test engineer, U.S. Air Force Air Warfare Center, Eglin AFB, Fla.
5. June 1993 - April 1995, Electronic Combat Program Element Monitor, Directorate of Global Power Programs, Office of the Assistant Secretary of the Air Force for Acquisition, Washington, D.C.
6. April 1995 - July 1997, staff officer, Office of the Assistant Secretary of the Air Force for Acquisition, Washington, D.C.
7. July 1997 - June 1998, student, College of Naval Command and Staff, Naval War College, Newport, R.I.

8. June 1998 - June 1999, Chief, Space Based Infrared Systems High Mission Payload, SBIRS High Program Office, Los Angeles AFB, Calif.
9. June 1999 - June 2000, Chief, Space Based Infrared Systems High Business Operations and System Engineering, SBIRS High Program Office, Los Angeles AFB, Calif.
10. June 2000 - July 2001, Program Manager, Space Based Infrared Systems High Ground Segment, SBIRS High Program Office, Los Angeles AFB, Calif.
11. July 2001 - June 2002, student, Air War College, Maxwell AFB, Ala.
12. July 2002 - February 2003, Chief, Management Operations Division, Airborne Laser Systems Program Office, Aeronautical Systems Center, Kirtland AFB, N.M.
13. February 2003 - April 2004, Director, Airborne Laser Block 2008 Development, Airborne Laser System Program Office, ASC, Kirtland AFB, N.M.
14. April 2004 - April 2005, Director, Airborne Laser Test and Integration, Airborne Laser System Program Office, ASC, Kirtland AFB, N.M.
15. May 2005 - July 2007, Commander, 508th Aircraft Sustainment Group, Ogden Air Logistics Center, Hill AFB, Utah
16. July 2007 - April 2008, Vice Commander, Space Based Infrared Systems Wing, Space and Missile Systems Center, Los Angeles AFB, Calif.
17. May 2008 - March 2011, Commander, Airborne Laser Systems Program Office, Aeronautical Systems Center, Kirtland AFB, N.M.
18. March 2011 – April 2012, Director, Iraq Security Assistance Mission, U.S. Forces-Iraq, U.S. Central Command, Baghdad, Iraq
19. April 2012 – May 2014, Director, Space Programs, Assistant Secretary of the Air Force (Acquisition), Washington, D.C.
20. May 2014 – May 2016, Vice Commander, Space and Missile Systems Center, Los Angeles AFB, Calif.
21. May 2016 - present, Commander, Air Force Research Laboratory, Wright-Patterson AFB, Ohio

SUMMARY OF JOINT ASSIGNMENTS
March 2011 – April 2012, Director, Iraq Security Assistance Mission, U.S. Forces-Iraq, U.S. Central Command, Baghdad, Iraq, as a brigadier general

MAJOR AWARDS AND DECORATIONS
Defense Superior Service Medal
Bronze Star
Defense Meritorious Service Medal
Meritorious Service Medal with four oak leaf clusters
Air Force Commendation Medal
Air Force Achievement Medal

EFFECTIVE DATES OF PROMOTION
Second Lieutenant Jan. 18, 1985
First Lieutenant Jan. 18, 1987
Captain Jan. 18, 1989
Major Sept. 1, 1996
Lieutenant Colonel May 1, 2000
Colonel May 16, 2005
Brigadier General Sept. 2, 2010
Major General Jan. 31, 2014

(Current as of May 2016)

RECORD VERSION

STATEMENT BY

DR. JEFFERY P. HOLLAND
DIRECTOR, U.S. ARMY ENGINEER
RESEARCH AND DEVELOPMENT CENTER

BEFORE THE

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SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

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STATEMENT BY

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Chairman Wilson, Representative Langevin, and distinguished members of the Subcommittee, thank you for the opportunity to discuss the U.S. Army Engineer Research and Development Center's (ERDC) role and mission as a major Department of Defense (DOD) Science and Technology (S&T) laboratory. I greatly appreciate the support this committee has shown to S&T, and the opportunities this support has provided ERDC over the years to enhance our ability to carry out our mission.

ERDC is the science and technology arm of the U.S. Army Corps of Engineers (USACE), conducting research and development (R&D) in the areas of Military Engineering, Geospatial Research and Engineering, Environmental Quality and Installations, and Civil Works. The Army's S&T investments develop technology options to ensure that the Army is ready today and remains robust for tomorrow. ERDC, and other Army laboratories, create new understandings that translate research into militarily useful technologies through innovative solutions to satisfy capability gaps across the entire force.

ERDC's seven laboratories are located in four states: the Construction Engineering Research Laboratory in Champaign, Illinois; the Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire; the Geospatial Research Laboratory in Alexandria, Virginia; and the Coastal and Hydraulics, Geotechnical and Structures, Environmental, and Information Technology Laboratories in Vicksburg, Mississippi. In addition to our laboratories, we have field sites conducting specialized research: our 1800-foot coastal research pier in Duck, North Carolina; our Aquatic Ecosystem Research Facility in Lewisville, Texas; our Permafrost Research Tunnel in Fairbanks, Alaska; and our International Research Office in London, which exists to promote cooperation with the international research community as a means to advance science and engineering knowledge and technical capabilities in areas relevant to the U.S. Army, DOD and our international military partners. ERDC has a workforce of more than 2,100 engineers, scientists and support personnel within its seven laboratories and field sites.

In Fiscal Year (FY) 2016, ERDC executed $425 million in research, development, test, and evaluation (RDT&E), highlighted by work in support of the nine Army S&T Objectives (STO) programs, the Army's top S&T efforts warranting Army senior leadership oversight. ERDC also executed just over $70 million in Civil Works direct

funding on R&D to address navigation, flood control and risk management, and ecosystem management and restoration. This body of R&D promotes safe and resilient communities and infrastructure; helps facilitate commercial navigation in an environmentally sustainable fashion; restores degraded aquatic ecosystems and prevents future environmental losses; and implements effective, reliable and adaptive life-cycle performance management of infrastructure. In addition to these major programs, ERDC executes more than $500 million in reimbursable programs for every Service within DOD and other federal agencies, such as the State Department, the Defense Threat Reduction Agency, the Department of Interior, the U.S. Bureau of Reclamation, the Department of Homeland Security, the National Geospatial-Intelligence Agency, and the National Science Foundation.

ERDC builds its program ($1 billion in FY16) by its customer base (i.e., Military Engineering, Geospatial Research and Engineering, Environmental Quality/Installations, and Civil Works). This approach forces ERDC to view problems from customer perspectives, rather than from our technical interest perspective, and necessitates that we solve problems that span technical areas by employing multi-disciplinary teams. As part of our annual program development process, we meet with a wide variety of customers to better understand their problems. At any given time, we have as many as 50 employees embedded in customer organizations to ensure complete understanding of customer requirements and to effectively transfer technology to these customers.

To meet our customers' objectives, we create tailored scopes of work and develop solutions to fit their business processes and decision making. We transition our technology to the Warfighter, to Civil Works, to the acquisition community, and to other government agencies, academia, and industry. We also provide the Warfighter and deployed civilian personnel around the globe with 24/7 access to subject matter experts through our USACE Reachback Operations Center. ERDC responds to more than 6,000 reachback requests each year from around the world. In addition, ERDC provides subject matter experts through deployment to both Contingency and Humanitarian Assistance/Disaster Relief (HA/DR) operations. Since 2003, ERDC has deployed 335 team members, some with multiple deployments, to support Contingency Operations; and more than 435 team members to support HA/DR operations both CONUS and OCONUS.

Today, I would like to discuss three components resident in everything we do as we carry out ERDC's diverse mission – People, Programs and Facilities.

Cutting-edge solutions to challenges of national importance, a satisfied customer base that returns time and again for the services we provide, and world-class facilities in

which to conduct that research -- none of these can be successful without our people. They are our most critical resource and the resource I am most passionate about.

Innovation requires a talented workforce, and I am proud to represent the more than 2,100 engineers, scientists and support personnel of the ERDC. These men and women are committed to solving national security challenges and developing technology solutions to ensure the readiness of our Warfighters and the installations that support them, as well as their responsibility to enhance and protect our nation's water resources and the economic security they provide. Our team members are agile, customer-focused, passionate about their work, leaders in their technical fields, and committed to the delivery of exceptional products and services.

ERDC partners with academia, industry and the other Services to provide solutions to military and national security challenges, but it is our in-house capability to assemble multi-disciplinary teams across our seven laboratories, in concert with key external partners, of which we are most proud. We bring the best minds to the challenge, and provide our customers and stakeholders with the technology, products and services they need to fit their requirements and meet mission goals.

If we are to continue providing reliable and sustainable S&T solutions to our Nation and Allies, it is vital that we hire and retain the best and brightest engineers and scientists our country has to offer.

ERDC has embarked on a human capital initiative to hire 800 engineers and scientists during FY16-20 in order to maintain and enhance our in-house capacity to meet our mission. In our first year, we exceeded our annual goal by hiring more than 160 new researchers. We were able to meet this important goal in large part because of our Direct Hiring Authorities, which save us time, effort and costs, and allow us to more effectively hire the best and brightest minds available.

These authorities are possible only because ERDC is one of 18 Science and Technology Reinvention Laboratories (STRLs) with Laboratory Personnel Management Demonstration (Lab Demo) Projects authorized by the National Defense Authorization Act (NDAA) for FY1995, PL 103-337, Section 342. Thank you for your support of Lab Demo.

ERDC's Lab Demo Program was implemented in 1998. Our program includes Performance Management (Pay for Performance); Position Classification (Pay Banding); Hiring flexibilities (Distinguished Scholastic Appointments); Employee

Development flexibilities (Degree Training, Sabbaticals), and Reduction in Force flexibilities to assure the best employees are retained.

Over the years, Congress has recognized and addressed unique human resources needs of the STRLs by including additional authorities and provisions in several NDAAs. These include:

- Exclusion of the STRLs from the National Security Personnel System;
- Direct Hire for Advanced and Bachelor's Degrees, STEM Technicians, and Senior Science and Technical Managers (SSTM) (and expansion of these authorities);
- Direct Hire for Students (authorized in December 1994, but not yet delegated);
- Ability to adopt a flexibility available in another STRL;
- Non-competitive conversion of students to permanent employees;
- Utilization of Retired Annuitants; and
- Retirement incentives payment.

The foregoing provisions address the uniqueness of STRLs like ERDC, first and foremost, by placing the responsibility for Human Resources and the accompanying authorities at the Laboratory Director level.

Our list of success stories is endless, but a few stand out. In an age where we are competing with the salaries and benefits offered by private industry, the Lab Demo Program has increased our ability to compete for the best and brightest students. Pay for Performance allows us to achieve a higher retention rate for high performers, with an increase in turnover for low performers. We have achieved increases in minority and female engineers and scientists, as well as an increase in PhDs. We have successfully utilized Voluntary Emeritus positions, whose experience and technical skills enhance ERDC's reputation and knowledge of our programs at universities and organizations around the country.

Implementation and increased authorization for SSTM positions within ERDC (23 positions in FY16) allow us to recognize positions responsible for directing many of our highly visible and technical programs. These SSTM positions are especially valuable to recognize the performance of higher-level duties when Senior Executive Service (SES) and Senior Scientists (ST) spaces are less appropriate.

While these authorities have greatly enhanced our ability to hire and retain world-class scientists and engineers, we still face challenges. When Congress includes new hiring authorities granted to Laboratory Directors in the annual NDAAs, we currently are required to implement them by publication of a Federal Register Notice. For example, in NDAA 2015, Congress delegated Laboratory Directors direct hire authorities for students. The NDAA was signed in December 2014. These authorities have not been

delegated, nor has a Federal Register Notice been published authorizing their use. As a result, the STRLs are continuing the untimely process of advertising student positions through USA Jobs and losing valuable students to the private sector. Additionally, NDAA 2016 authorized the noncompetitive conversion of students to permanent appointments, increased authorizations for direct-hire appoints and authorities regarding the utilization of reemployed annuitants and the payment of retirement incentives. These authorities have not yet been delegated.

I want to thank Congress for its continued support to the STRLs by including language in both the House and Senate versions of the 2017 NDAA that should greatly benefit the STRLs.

Our challenges in recruiting and maintaining a high-quality workforce also include competition for these individuals, a limited supply of top-quality STEM students and careerists, and the ability to make job offers in a timely manner. Our ability to offer competitive salaries and benefits, coupled with other provisions in our Direct Hiring Authorities, allows us to compete in this hiring pool. Additionally, we use every student program available to us to increase our pool of future recruits. During this past year alone, ERDC has employed more than 230 student interns from 65 colleges and universities. With authority to directly hire students, that number would increase.

Because we have great people, we are able to execute meaningful and impactful programs. DOD Service Labs play a key role in National Security, and ERDC has a long history of providing innovative solutions to keep our Warfighters and Civilians safe at home and abroad. On September 11, 2001, the plane that was flown into the Pentagon struck a section that had just been retrofitted with ERDC-developed blast protection technology. This protection kept the section from collapsing long enough to get personnel to safety, significantly reducing the death toll at the Pentagon.

ERDC has since developed and deployed several pioneering force- and terrorist-threat protection technologies. More than $1 billion in protection technology has been installed in theater to protect base camp structures from rocket and mortar attacks. Research into weapons' effects on structures and affordable mitigation techniques informed the composite and construction industry without revealing theater vulnerabilities. ERDC, working with industry partners, identified solutions that were technically feasible and readily available for immediate fielding. Our Overhead Cover Protection system development was fast-tracked, in part, by $250 million in supplemental funding from Congress. This multi-layer protection system was designed and constructed over existing critical facilities at U.S. base camps in Iraq – living quarters, dining halls and other high-occupancy facilities – to protect the force from insurgent rocket and mortar attacks by preventing them from penetrating overhead cover barriers and hitting facilities. This technology reduced a high casualty rate pre-

emplacement down to zero. The State Department later invested in this technology to protect its critical facilities and personnel around the world. The very building we are sitting in today is safer because of ERDC protection technologies in collaboration with the Architect of the Capitol.

Another technology breakthrough is our Deployable Force Protection (DFP) program. Products include the advanced, lightweight Modular Protection System (MPS), based on an innovative, patented material of high-strength, flexible concrete with ballistic performance – comparable to ceramic armor – at a fraction of the cost and weight. Four trained Soldiers can assemble an 8-by 12-foot MPS module in 15 minutes without equipment or special tools. The Army's Rapid Equipping Force (REF) quickly introduced the MPS into Iraq and Afghanistan, and in 2010, a modified version was developed for the Navy. DFP now includes MPS Mortar Pits, Guard Towers and other quickly-deployable protection systems that are easily constructed and reusable, keeping our Warfighters safe. Prototype protective structures developed in the DFP program were recently needed to protect critical assets in numerous deployed locations. The lab's inventory of prototype structures was rapidly made available to satisfy urgent theater needs, while the Army REF procured additional quantities from vendors holding licenses for the government-patented technology. Anticipating future orders, researchers are working with the Defense Logistics Agency Warstopper Program and Rock Island Arsenal's Joint Manufacturing and Technology Center to prepare both government and industry manufacturing groups to meet future surge requirements.

ERDC-developed technologies to deny, deter and defeat IEDs are being used in Afghanistan, where insurgents employ IEDs powerful enough to throw 14-ton MRAP vehicles into the air. In a five-month period at the beginning of this emerging threat, more than 100 Soldiers had suffered crushed or damaged spinal columns from being thrown around in MRAPs. One ERDC advance, called HARD IMPACT, defends U.S. and Coalition forces against IEDs placed in thousands of road culverts throughout the country by retrofitting exiting culverts with protection designs and incorporating those designs into new roadway systems. ERDC was approached by the U.S. Intelligence community to develop forensics capabilities after blast events. Two programs, CALDERA and FERRET, developed procedures, tools and training to effectively collect, measure and document post-blast forensic signatures of underbelly IED attacks. These technologies and products have been transitioned to Intel analysts and Warfighters.

In the interval between 2006 and 2014, in support of numerous U.S. Central Command (CENTCOM) Joint Urgent Operation Needs Statements, ERDC engineers and research teams led whole-of-government and industry teams in development of more than six major quick reaction capability (QRC) programs that were formerly recognized by the

Joint Improvised Explosive Device Defeat Organization (JIEDDO) and CENTCOM as effective counter-IED (C-IED) systems. The total ERDC QRC resource execution in this period exceeded $2 billion. Airborne systems included Saturn Arch, Desert Owl, Copperhead and Radiant Falcon, all of which were transitioned to Army Aviation by the close of 2014. At present, Saturn Arch and Copperhead continue to provide CENTCOM with unique C-IED operational capabilities. On the ground, ERDC led the successful development and deployment of the Sand Dog C-IED system, which was deployed on Talon robots for both Explosive Ordnance Disposal and Engineer Route Clearance teams.

Tunnel Detection technologies developed by ERDC have been applied along the Mexican border, in Iraq, and along the Egypt/Gaza border. ERDC is the technology lead for the U.S. Government's Interagency Tunnel Deterrence Committee – 11 law enforcement and intelligence agencies – which has been involved in hundreds of tunnel detection efforts along the border of Mexico since 9/11. ERDC developed and has remotely operated detection systems in Iraqi prisons; at the request of the State Department and DOD, ERDC installed a tunnel detection system along the Egypt/Gaza border and trained Egyptian military engineers to operate the system. We have worked with additional Allies to provide tunnel detection technologies and training to help ensure regional stability.

ERDC is collaborating with the U.S. Air Force, Army, Marine Corps and others to identify significant challenges for planners, analysts and operators that impede the ability to accomplish operations in an Anti-Access/Area Denial (A2/AD) environment and the capabilities needed to address the challenges. ERDC's role in force projection in A2/AD environments is focused on developing and demonstrating technologies for planning and conducting entry operations with non-existent, damaged or destroyed infrastructure. ERDC technologies include rapid airfield repair kits for early-entry airborne engineer units; terrain surfacing kits for Unmanned Aircraft Systems (UAS) landing strips, helicopter landing zones, and logistics over-the-shore operations; remote monitoring of critical infrastructure using infrasound; battlefield sensors for operational engineer reconnaissance, assessment and planning; and decision support tools to capture Subject Matter Expert (SME) processes for remote infrastructure assessment. Coastal modeling technology developed in ERDC's Civil Works mission area is also being applied to the A2/AD environment, a great example of dual-use technology that crosses mission area lines. Also, as part of the Long Range Research and Development Planning Program-Ground Combat (LRRDPP-GC), ERDC and our fellow S&T laboratories are currently working to help shape policy for the Third Offset Strategy. This strategy's goal is to identify high-payoff, enabling technology

investments to provide U.S. forces with a decisive advantage in land-associated operations in the 2030 timeframe.

ERDC's Map Based Planning Services (MBPS) program provides DOD with a unique, web-based capability for military planners to collaboratively develop strategic plans. MBPS employs the concept of a digital plan with automated tools to reduce the burden of manual work, the risk of human errors, and the resources expended on updates and corrections. With military planners deployed across the U.S. and all over the world, substantial time and cost savings also result from reduced travel to various planning team meetings. By increasing efficiency in the planning process, MBPS allows planners to provide senior decision makers with more options within months rather than years, and thereby meet the challenges of a rapidly evolving world.

National- and theater-level assets provide a synoptic view of the operational environment; there is a growing need and a growing number of requests for ERDC's Tactical Mapping (T-UAS) program on-demand, high-resolution tactical mapping capabilities at the lowest levels to support mission planning and enhanced situational awareness. The T-UAS program uses a variety of UAS full-motion video and electro-optical image data to rapidly produce 2D and 3D geospatial products and provide enhanced local situational awareness to users at the lower echelons of the Armed Forces. This technology builds on previous ERDC R&D to fill in gaps for mast-mounted Light Detection and Ranging (LIDAR) efforts and has gone from concept and capabilities demonstration in late 2015 to funding by REF to field mapping platforms and FMV kits for Warfighters in Iraq in June 2016 with the first map products created in July.

Future readiness includes not only providing our Soldiers with the equipment and technology advances they need to win the fight, but also delivering environmentally sustainable solutions for energy, water, and waste (EW2) on installations at home and abroad. ERDC R&D also supports installation training needs of while protecting the environment.

ERDC has developed a holistic approach for EW2 environmental sustainability at military installations around the world and in contingency environments. The ERDC-developed Net Zero Planner (NZP) is a web-based tool for installation-wide EW2 planning. The tool is designed to perform complex engineering calculations with relative simplicity and provide an engineering-based solution for planning EW2 investments at installations. NZP has been demonstrated at multiple DOD installations and is currently being used by the USACE Fort Worth District to develop sustainability component plans as part of the master planning process. ERDC is working closely with Headquarters, USACE to develop a transition plan for NZP and incorporate it into the planning process across the Corps.

ERDC is the Army leader in Operational Energy R&D and is developing scalable solutions for small, semi-permanent contingency bases (300 to 1,999 personnel). Operational energy R&D focuses on the primary areas of planning and analysis; resilient distribution; metering and monitory; demand reduction; and supply efficiency. These focus areas are inter-related and are designed to address all stages of the base camp lifecycle. Planning tools such as the Virtual Forward Operating Base assist in base camp planning and operation to reduce supply and logistics burdens on camp operators. Our Deployable Metering and Monitoring System gives operators knowledge of where their resources are being used.

ERDC, together with the National Aeronautics and Space Administration (NASA) Marshal Space Flight Center and Kennedy Space Center, and Caterpillar, Inc., are developing an additive 3D printing technology capable of printing custom-designed expeditionary structures on-demand, in the field, using concrete sourced from locally available materials. The three-year Automated Construction of Expeditionary Structures (ACES) program brings together expertise from within ERDC, NASA, Caterpillar, and Contour Crafting Corporation to conduct highly-focused research designed to prototype an automated construction system that can fabricate a 500 ft^2 structure in less than 24 hours. Recently, when the Secretary of the Army asked for examples of Army innovation, the Honorable Katherine Hammack, Assistant Secretary of the Army for Installations, Energy and Environment, briefed him on the ACES program. Presented with more than 35 examples of Army innovation, the Secretary chose ACES as one of three he will present to the Secretary of Defense to show the most promising innovation activities going on in the Army.

ERDC R&D is also providing integrated maneuver land sustainment technologies to support installation training land management through the use of vehicle-based impact models; application of training exercise impact assessment and monitoring technologies; range design guidance; impact mitigation and resolution technologies; and installation encroachment assessment software. One success story is ERDC's work to assess training lands at Fort Hood, Texas, home of the largest active duty armored post in the U.S. Every acre counts, to both the Army and to two endangered species of birds that call the installation home. In 1993, 36 percent of Fort Hood training land was under seasonal training restrictions for habitat protection. ERDC worked with Fort Hood biologists for years to assess habitats, sources of negative impacts, and potential stress from military training on both species. This collaboration has proven that military impacts on the species are nominal and that current management strategies have positive impacts on both endangered birds. By 2000, the percentage of restricted training lands had dropped to 24 percent; by 2010, it was 4.6 percent; and by 2015, it was 0 percent. The U.S. Fish and Wildlife Service rendered a Biological

Opinion in 2015 that allows the Army to manage all training lands at Fort Hood without seasonal restriction but within agreed-upon impacts to the bird species.

In the area of information technology, ERDC manages and executes the DOD High Performance Computing Modernization Program (HPCMP), a comprehensive, highly integrated high performance computing *ecosystem* that includes supercomputers and related expertise, a nationwide DOD research network, and system and application software to the Services and Defense agencies. The HPCMP is characterized by three core elements: DOD Supercomputing Resource Centers, information-assured networking (the Defense Research and Engineering Network and associated cybersecurity posture), and software applications expertise that addresses the unique computational requirements of the DOD. These three elements form a complete *ecosystem* that supports the DOD research, development, test, and evaluation (RDT&E) and acquisition engineering communities.

The HPCMP supports approximately 2,000 active users from Army, Navy, Air Force, Marine Corps, and other DOD agencies within the Science and Technology (S&T), acquisition engineering, and Test and Evaluation (T&E) communities. HPCMP users address challenges such as the discovery of new materials to address unique DOD requirements, numerical modeling of hypersonic flight, modeling and prediction of weather to support DOD, analysis of space systems, and evaluation of options for future DOD systems, including the design of next generation aircraft carriers, submarines, air vehicles and ground vehicles.

DoD Supercomputing Resource Centers (DSRCs) provide advanced computational resources and specialized expertise to enable DOD to take advantage of supercomputing. DSRCs are located in:

- AFRL DSRC at Wright Patterson Air Force Base in Dayton, Ohio;
- Air Force Maui High Performance Computing Center (MHPCC) DSRC at the Air Force Optical & Supercomputing Observatory site in Kihei, Hawaii;
- Army Research Laboratory (ARL) DSRC in Aberdeen, Maryland;
- Army ERDC DSRC in Vicksburg, Mississippi; and
- Navy DSRC at the Naval Meteorology & Oceanography Command, Stennis Space Center, Mississippi.

The Defense Research and Engineering Network (DREN) provides a robust cybersecurity posture for the HPCMP. DREN provides a very high bandwidth, low latency, low jitter network specially designed to serve the needs of the science/engineering and test/evaluation communities. The DREN supports Unclassified, Secret, and above Secret communications, and delivers service to 53 of the DOD's 62 laboratories and 20 of the DOD's 22 major range and test centers. In the

S&T environment, the DREN is a critical enabling technology for the collaborative science and engineering workflow; in the T&E environment, the DREN is a unique resource enabling a diverse range of critical activities that cannot be provided by traditional networks. For example, the DREN supported 26 T&E events in FY16, including:

- F-35 Joint Strike Fighter (JSF) Record and Playback Event 3
- Small Diameter Bombs (SDB) II Live Fly Testing (On Going)
- TRITON Flight Testing (On Going)
- Aegis Integrated Air and Missile Defense (IAMD) Base Line (B/L) 9C1D BLD 18.1.2
- Joint Distributed Infrared Countermeasures (IRCM) Ground-test System (JDIGS)

The HPCMP is also charged with the creation, improvement and optimization of software applications that use the network and supercomputers efficiently to develop effective solutions to the DOD's challenges. This includes training for engineers and scientists on effective use of HPCMP resources; R&D to pull emerging technologies from industry and academic centers into routine use by HPC users; and efforts to increase effectiveness of existing applications to new DOD challenges or develop new DOD-unique applications.

The largest strategic software investment for DOD resides in the Computational Research and Engineering Acquisition Tools and Environments (CREATE) initiative, which provides government-owned high fidelity, multi-physics software for ships, air vehicles, radio frequency, and ground vehicles essential to supporting the acquisition engineering community. While HPCMP-developed software applications are service/mission specific, they are designed to provide cross-service/OSD agency capabilities. As such, these investments provide the Department with significant synergies in terms of software sustainability and applicability within the services. One example of leveraging HPC resources to address high-impact DOD challenges is the ERDC-led Engineered Resilient Systems (ERS) program. DOD is leveraging years of S&T investment to transform acquisition processes through ERS. By enabling more detailed engineering analyses, ERS significantly increases the number of materiel alternatives examined early in the acquisition process in equal or less time than traditional methods. The program and its associated DOD Community of Interest are developing concepts, techniques and tools that significantly sharpen requirements prior to major acquisition milestones and support prototyping and experimentation.

In addition to our world-class research to support the Warfighter, ERDC is also the world leader in Water Resources Infrastructure and Management, Navigation, Operations and Maintenance, and Environmental Resources R&D in support of the

USACE Civil Works mission. This R&D is critical to national security by enabling a vital lifeblood link to our nation's commerce and economy, and supports the movement of supplies and materiel vital to our national defense. The Civil Works capability we develop and provide not only supports national security interests within our borders, but also enables this Nation to support water resources maintenance, repair and rehabilitation operations in war zones, like Mosul Dam in Iraq, and Kajaki and Dahla Dams in Afghanistan. Our Civil Works expertise, combined with our military technology and environmental security R&D, is truly unique. ERDC's ability to leverage these otherwise disparate capabilities within the bounds of one organization creates powerful dual-use opportunities. Our Critical Infrastructure Protection Program is a perfect example of how we leverage our military expertise to protect Civil Works infrastructure. Technologies developed to protect personnel and facilities in contingency environments have been transitioned to protect critical infrastructure in the U.S., from buildings in our capitol and major cities to locks and dams and other navigation infrastructure; and from bridges like the Golden Gate to other transportation infrastructure such as subway and railway systems.

Finally, I welcome the opportunity to discuss our facilities, infrastructure and 219 Program.

The ERDC employs a world-class team and conducts world-class research, but we have a need to modernize and recapitalize our experimental facilities to ensure we can continue to support the Warfighter and the Nation in a world-class manner. While we have some new and state-of-the-art facilities, the average age of ERDC facilities is 41 years, and our recapitalization rate extends into the next century. Technology advances are moving at a rapid pace and our adversaries are taking full advantage of these advancements. Research facilities must be built to be adaptable and resilient or they will become outdated and obsolete. Just as importantly, we must ensure our research facilities have sufficient sustainment dollars in order to minimize the amount of research dollars we must divert to support operations and maintenance. Finally, our research facilities must be of a quality to aid in recruitment and retention of the best and brightest research staff in the world.

In FY14 and FY15, we were successful in obtaining funding for two Unspecified Minor Military Construction (UMMC) projects using the Laboratory Revitalization Program authority provided by this Committee. With that funding, ERDC constructed a new $2.5 million Fragmentation Research Facility and will soon begin construction on a $3.8 million facility to construct large concrete targets to support blast, penetration and fragmentation research. In FY17, we had submitted our list of requirements for consideration in the UMMC program, our number one priority being a Transformer Yard at our Cold Regions Research and Engineering Laboratory in New Hampshire that will

improve efficiency, safety and operations. We have also included a project to expand our capacity to improve Projectile Penetration Research at our Vicksburg, Mississippi, campus to meet current and future requirements. The expanded authority for labs provided in the Laboratory Revitalization Program, particularly the $4 million UMMC threshold, has been extremely valuable to the ERDC. I was pleased to see that the House version of the FY17 NDAA makes this authority permanent and increases the threshold to $6 million. We are optimistic that your negotiations with the Senate will be fruitful and this will become law.

While ERDC has had some success with minor construction, we have yet to break into the Major Military Construction future years' defense plan. ERDC has not had a project funded with MILCON in recent memory, nor do we have one in the current POM. In light of significant reduction in funds available for military construction and the requirement for Army leadership to support Soldier readiness initiatives, ERDC has deferred asking for support in MILCON for the past few years. I have directed my staff to begin identifying requirements where MILCON would be an appropriate funding source and to try again in the next cycle. With limited funds available and considering Army needs, I understand there will be many more projects deferred than will be programmed for funding. This reality is likely to remain the situation for years to come, making the Laboratory Revitalization and 219 authorities even more critical to ensuring laboratory directors can respond quickly and adapt to emerging threats.

Our 219 Authority gives us a mechanism to provide funds for innovative research, technology transfer, workforce development, and to improve our facilities and infrastructure. We have had great success in using this authority over the years and greatly appreciate the Committee's willingness to extend the authority each time it was close to expiration, to expand the authority, and to provide clarification of the Congress' intent in order to improve the program's effectiveness. I especially appreciate that your staff takes the time to meet with us here in Washington, D.C. and travel to our facilities and see firsthand how we are implementing this program. The cooperation across the Committee staff and with their colleagues in the Senate has resulted in a great program, and we are pleased to see that the Committee's FY17 National Defense Authorization Act makes this authority permanent and increases the amount we can collect from 3 to 4 percent.

The 219 Program has allowed me to allocate funds toward research efforts to address needs and requirements that arise faster than the normal budget planning cycle. This was recently highlighted by an investment to develop an Advanced Blast Load Simulator prototype. This research led to a working 4-ft by 4-ft prototype and a comprehensive and affordable plan to build the capacity to conduct controlled blast experiments on target surface areas of 12-foot by 12-foot. Previous attempts to build

this scale were technically challenging and cost-prohibitive. Conducting blast experiments of this size in a controlled laboratory environment will allow us to perform multiple experiments in a shorter period of time at significantly reduced cost and with improved accuracy. Full-scale field tests are expensive, time-consuming, and require valuable range time. While field tests will always be necessary, the simulator will ensure those tests are optimal and shorten the time required to provide solutions to save Soldiers' lives. This would not be possible without Section 219 authority.

In FY15 and FY16, the 219 Program allowed me to spend approximately $5 million/year to upgrade our facilities infrastructure at the four main ERDC sites and at our research facilities in Alaska. Improvements include airfield and pavement testing areas, backup generators and chemistry labs for projects that ensure we are able to properly maintain housing of animals and live organisms for experimentation and to upgrade and maintain our dominance in extreme cold environments. Each of these projects is relatively small compared to some of the multi-million dollar military construction projects you may see, but they have a big impact on the quality of research and capability of our engineers and scientists. I appreciate the flexibility this mechanism provides. Unfortunately, we have not yet been able to take advantage of the authority you provided in the FY14 NDAA that allows lab directors to accrue funds over multiple fiscal years to support larger infrastructure needs. We continue to work toward a way to implement processes that will allow us to do this in an accountable, auditable and sustainable fashion. Your staff are aware of this and are committed to working with us to address these challenges.

In conclusion, Army Chief of Staff General Mark Milley has stated that "we will do what it takes to build an agile, adaptive Army of the future. We will listen and learn … from the Army itself, from other Services, from our interagency partners, but also from the private sector … we will change and adapt." ERDC takes pride in the relationships we have built within the Army, with our Service partners and other federal agencies, as well as with academia and industry. These are our customers and stakeholders, as are Congress and the American public. It is for you we work, and we do not take lightly the trust that has been placed in us to solve problems critical to our Nation's security and the well-being of our Armed Forces and citizens.

The engineers and scientists, support personnel, and leadership of the U.S. Army Engineer Research and Development Center take extreme pride in what we do. I invite you all to visit us at any time to see this firsthand as you talk to our team. We come to work every day, knowing that what we do makes a difference – we save lives; we help safeguard our citizens at home and the world; and we protect and enhance the environment around us.

Thank you for your time. It has been my privilege to tell you about the greatest team of engineers and scientists, working for what I consider to be the best R&D organization in the world. The invitation to experience ERDC's research capabilities and meet our team face to face is always open.

Mr. Chairman, this concludes my statement. I would be happy to answer any questions you or other Members may have.

Dr. Jeffery P. Holland
Director, U.S. Army Engineer Research and Development Center, and
Director of Research and Development, U.S. Army Corps of Engineers

Dr. Jeffery P. Holland became the director of the U.S. Army Engineer Research and Development Center (ERDC) in January 2010. The ERDC director is located at the center's headquarters in Vicksburg, Miss. As director, Dr. Holland manages one of the most diverse research organizations in the world - seven laboratories in four states, with more than 2,500 employees, $1.2 billion in facilities and an annual program exceeding $1.1 billion.

ERDC R&D supports the Department of Defense (DoD) and other agencies in military and civilian projects. Principal research mission areas include Warfighter support, military installations, environment, water resources, and information technology. In addition to his position as ERDC director, Dr. Holland also serves as director of research and development and chief scientist for the U.S. Army Corps of Engineers. In this role, he develops policy, sets direction and provides oversight for Corps research and development, advising the Chief of Engineers on all matters of science and technology. Dr. Holland is also the lead for the Engineered Resilient Systems S&T initiative that supports improved acquisition, prototyping, and systems engineering across the Department of Defense.

Prior to his current position, Dr. Holland served for three years as deputy director of ERDC, assisting the previous director in the management of the multi-laboratory facility. He also served as the director of ERDC's Information Technology Laboratory, where he oversaw the development and sustainment of technological infrastructure to support ERDC and execution of a broad R&D and operational program in the areas of high-performance computing, high-bandwidth communications, computer-aided engineering, computer-aided design and drafting, geographic information systems, software engineering, scientific visualization, library services, animation, photography, video production and more.

CAREER CHRONOLOGY:
Jan 2010 - present: Director, U.S. Army Engineer Research & Development Center, Vicksburg, MS; Director, Research & Development, U.S. Army Corps of Engineers
Nov 2006 - Dec 2009: Deputy Director, U.S. Army Engineer Research & Development Center,
Dec 2001 - Oct 2006: Director, U.S. Army Engineer Research & Development Center, Information Technology Laboratory
Apr 2000 - Nov 2001: Technical Director, Hydro Environmental Modeling and Simulation, U.S. Army Engineer Research & Development Center, Coastal and Hydraulics Laboratory
1995 - 2001: Special Assistant to the Director, U.S. Army Engineer Research & Development Center, Coastal and Hydraulics Laboratory

COLLEGE:
PhD, Civil Engineering, Colorado State University
MS, Environmental and Water Resources Engineering, Vanderbilt University
BS, Environmental Engineering (with honors), Western Kentucky University

CERTIFICATIONS:
Registered Professional Engineer, State of Mississippi

AWARDS AND HONORS:
Federal Laboratory Consortium Director of the Year Award
Board of Trustees - Mississippi College
Alcorn State University Presidential Citation for Excellence

U.S. Army R&D Laboratory Management Award
U.S. Army Engineer Research and Development Laboratory of the Year Award (2007-2009)
Army Meritorious Civilian Service Award
Army Bronze Order of the de Fleury Medal
Army Silver Order of the de Fleury Medal
Meritorious Executive, Presidential Rank Award (2008)
Distinguished Executive, Presidential Rank Award (2014)

PROFESSIONAL MEMBERSHIPS AND ASSOCIATIONS:
American Society of Civil Engineers
American Geophysical Union
International Association of Hydraulic Research (Affiliate)
Military Operations Research Society

MAJOR PUBLICATIONS:
Dr. Holland has authored more than 100 publications.

- Landscape Erosion and Evolution Modeling, R.S. Harmon and W.W. Doe III, eds., Kluwer, 2001, pp. 517-534.
- Ecological Modeling for Resource Management, V.H. Dale, ed., Springer-Verlag New York, Inc., 2003, pp. 221-248.
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HOUSE ARMED SERVICES COMMITTEE
EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

WRITTEN STATEMENT OF
DR. EDWARD R. FRANCHI
ACTING DIRECTOR OF RESEARCH
U.S. NAVAL RESEARCH LABORATORY

BEFORE THE
EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE
OF THE
HOUSE ARMED SERVICES COMMITTEE
ON
DEPARTMENT OF DEFENSE LABORATORIES:
INNOVATION THROUGH SCIENCE AND ENGINEERING
IN SUPPORT OF MILITARY OPERATIONS

SEPTEMBER 28, 2016

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EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

INTRODUCTION

My name is Dr. Edward Franchi. With Dr. John Montgomery's retirement in August after 14 years of service as Director of Research at the U.S. Naval Research Laboratory (NRL), I serve as the Laboratory's Acting Director. I have been NRL's Associate Director of Research for Ocean and Atmospheric Science and Technology since 2008.

I want to thank you for the opportunity to talk about NRL's work, how it performs its science and technology mission, and some of the challenges it faces to the successful execution of that mission. I also want to express my appreciation to this subcommittee for the many important ways it has over the years supported the vital work of the Defense Department's laboratories.

NRL'S IMPACT

NRL was born from an idea conceived in 1915 by the great inventor Thomas Alva Edison. Concerned that America would be eventually pulled into World War I, Edison urged the government to:

> "Maintain a great research laboratory, jointly under military and civilian control. In this could be developed . . . all the technique of military and naval progression, without any vast expense. . . . At this great laboratory we should keep abreast with every advanced thought."

Edison, Assistant Secretary of the Navy Franklin D. Roosevelt and the Naval Consulting Board were together instrumental in ensuring that this idea became a reality on July 2, 1923. The principal speaker at the new facility's opening was Theodore Roosevelt, Jr., who had followed his father, Theodore, and cousin, Franklin, into the job of assistant secretary of the Navy. As the Naval Consulting Board recommended, NRL was placed administratively in the secretary's office, under the assistant secretary. This was done to allow it to become a research establishment *for the whole Navy*, in other words, a corporate laboratory.

At its most elemental, Edison's idea was that NRL, working in league with industry, and knowledgeable of naval needs, would help build American sea power through long-term, mission-related research and development, all with the purpose of defending the republic. For more than 90 years now, NRL has fulfilled the inventor's vision. This was recognized in 2005 when the Navy League's New York Council bestowed the Laboratory with the Roosevelts Gold Medal for Science. The Council noted that NRL had "helped make the U.S. Fleet the most formidable naval fighting force in the world," and called it "the Government's premier defense research laboratory."

Some examples of NRL's numerous achievements over the years include:

EARLY YEARS TO WORLD WAR II

- Discovery of the "skip-distance effect," which laid the foundation for modern HF wave-propagation theory and led to the acceptance of HF radio frequencies in naval communication
- Invention of the first U.S. radar, the XAF, which transformed naval, ground, and air warfare. It was fielded in time for duty in the great Pacific naval battles of World War II, contributing to crucial victories at Coral Sea, Midway, and Guadalcanal
- Development of first operational U.S. sonar, which transformed surface and undersea warfare

COLD WAR

- Pioneering the fields of space-based astronomy and x-ray astronomy, which led to the award of the National Medal of Science to NRL's Dr. Herbert Friedman
- Invention of America's first operational intelligence satellite (GRAB I), launched only 52 days after a U-2 aircraft was lost on a reconnaissance mission over the Soviet Union
- Development of Aqueous Film-Forming Foam, a firefighting agent used aboard U.S. aircraft carriers, by all branches of the U.S. armed forces, as well as by fire departments around the world
- Development of the original concept and prototype satellites (NTS-1 and NTS-2) for the NAVSTAR Global Positioning System, which led to the award of the prestigious Collier Trophy to NRL and the National Medal of Technology to NRL's Roger Easton
- Pioneering direct methods of molecular structure analysis, which led to the award of the Nobel Prize to NRL's Dr. Jerome Karle and the National Medal of Science to Dr. Isabella Karle

REGIONAL CONFLICT AND GLOBAL TERRORISM

- Development of the ALE-50 decoy, which is credited with saving several aircraft in the Kosovo campaign alone and earned the name "Little Buddy" from U.S. pilots
- Development of the InfraLynx system, which provided for assured communication capabilities during emergencies. It was deployed for events such as the Winter Olympics, Super Bowl, WMD training drills, and natural disasters such as Hurricane Katrina
- Development of *Dragon Eye*, a hand-launched 5.5-pound surveillance plane with the radar signature of a bird. Carried by U.S. Marines in a backpack, it was deployed in the battle for Fallujah. A model is on exhibit at the National Air and Space Museum.
- Development of CT-Analyst, a tool to provide first-responders with accurate, instantaneous, three-dimensional predictions of chemical, biological, and radiological agent transport in urban settings. It was deployed for both the 2009 and 2013 Presidential inaugurations.

FOCUS ON FUTURE WARFIGHTING CAPABILITIES

In the Naval S&T Strategic Plan, there are nine Naval S&T Focus Areas, within which there are defined specific Objectives and associated S&T Research Areas. NRL's S&T programs are mapped to the Focus Areas, Objectives, and Research Areas shown in the following tables.

Naval S&T Focus Area	Objective Categories	S&T Research Areas
Expeditionary and Irregular Warfare	• Battlespace Awareness • Irregular Warfare Operations • Expeditionary and Distributed Operations • Irregular Threat Countermeasures	• Data Visualization and Training • Efficient Processing • Tactical Networking • Over the Horizon Communications • Small Unit Communications Technologies • Cross-Domain Network Operations • Human Social, Cultural, and Behavioral Sciences • Pattern Recognition • Spectrum Protocol Content Awareness and Influence • Precision Target Identification and Location • Small Unit Air Defense • Networked Fires • Small Unit Water Purification • Small Unit Power • Fuel Efficiency • Vehicle Power Generation • Autonomous platforms and payloads • Psychometrics • Instructional Design and Technology • Machine Learning • Immersive Sciences • Explosive Hazard Defeat • Counter RPGs and ATGMs • Counter Tactical Surveillance and Targeting • Biometrics • Forensics • Personal Survivability • Vehicle and Personnel Signature Management • Vehicle Survivability
Platform Design and Survivability	• Mobility • Susceptibility/survivability • Optimized Payload Capabilities • At-Sea Sustainment • Affordable Fleet/Force Modernization	• Platform Design focused on efficiency, agility, and affordability • Autonomous and Unmanned Vehicle Mobility • Vehicle Structures and Materials • Platform Performance Models • Low Observable (LO) and Counter LO Technologies • Softkill Techniques • Automated Response and Recovery Technologies • Modeling and Simulation Tools • Modular/Affordable Platforms • Structural, Mechanical, and Electrical Support Infrastructure • Payload and Weapons Movement • Underway Replenishment • Interfaces and Standards • Sea Platforms • Air Propulsion • Air/Ground Vehicles • Functional Materials • Structural Materials • Manufacturing Science

Naval S&T Focus Area	Objective Categories	S&T Research Areas
Assure Access to Maritime Battlespace	• Achieve and Maintain Undersea Dominance • Improve Mobile Autonomous Environmental Sensing • Match Environmental Predictive Capabilities to Tactical Planning Requirements • Maximize Systems Performance via Adaptation to the Environment	• Anti-Submarine Warfare Surveillance • ASW Performance Assessment • Bio-sensors, Bio-processes, and Bio-inspired Systems • Electronic Warfare Attack • Functional Materials • Intelligent and Autonomous Systems • ISRT-ESM • Large Vessel Stopping • Littoral Geosciences, Optics and Biology • Marine Mammals • Marine Meteorology • Mine Neutralization • Nanometer Scale Electronic Devices and Sensors • Navigation & Precision-Timekeeping • Networked Sensors • Non-Lethal Weapons • Ocean Acoustics • Physical Oceanography • Solid State Electronics • Space Environmental Effects • Spacecraft Technology • Unmanned Air Vehicles • Unmanned Sea Vehicle Technologies • Naval Power Systems • Sea Platforms • Affordability/Reduced Platform Lifecycle Cost • Air/Ground Vehicles • Information Assurance and Anti-tamper • Intelligent and Autonomous Systems
Autonomy and Unmanned Systems	• Human/Unmanned Systems Collaboration • Perception and Intelligent Decision Making • Scalable and Robust Distributed Collaboration • Intelligence Enablers and Architectures • Novel Platforms and Integration	• Intelligent and Autonomous Systems • Unmanned Air Vehicles • Unmanned Sea Vehicle Technology • Unmanned Ground Vehicles • Human Robotic Interaction/Human Factors • Machine Reasoning, Learning, and Intelligence • Scene/Image Understanding • Biorobotics, Cognitive Science, and Neuroscience
Information Dominance - Cyber	• Communications and Networks • Computational and Information Construct • Full Spectrum Cyber Operations • Decision Making Superiority	• ASW Surveillance • Computational Decision Making • Bio-sensors, Bio-processes, and Bio-inspired Systems • Communications and Networks • Applied & Computational Analysis • Human Factors Organizational Design and Decision • Complex Software Systems & Information Assurance • Cyber Security & Information Operations S&T • Intelligent & Autonomous Systems • Spacecraft Technology • Optimization • Data Science • Command & Control and Combat Systems • Quantum Information Sciences

Naval S&T Focus Area	Objective Categories	S&T Research Areas
Electromagnetic Maneuver Warfare	• Spectrum Dominance • Advanced Electronics, sensing and response techniques	• Electronics Materials and Devices • Electronic Warfare • Multifunction Systems • Nano Electronics • Precision Time and Navigation • Quantum Measurement Architecture Devices • Radar & Electro-optical/IR Sensing • Surface/Aerospace Surveillance
Power and Energy	• Energy Security • Efficient Power and Energy Systems • High Energy and Pulsed Power	• Advanced Naval Power Systems • Air Platform Power • Bio-derived Materials and Systems • Functional Materials • Personal Power • Power Electronics • Power for Future Electric Weapons and Radars • Materials, Computation, and Prediction • Manufacturing Science
Power Projection and Integrated Defense	• Future Naval Fires • Integrated Layered Defense Across the Entire Detect-to-Engage Continuum • Extended Threat Neutralization Capabilities • Time-Critical Precision Strike	• Advanced Energetics • Air Platform Survivability • Directed Energy • Electromagnetic Guns • EW Attack • Expeditionary Firepower Torpedo Defense • Expeditionary Force Protection • Functional Materials • High Speed Weapons Technologies • ISRT-ESM • Mining • Non-Lethal Weapons • Precision Strike • Sea Platform Survivability • Solid-State Electronics • Affordability/Reduced Platform Life-Cycle Cost • Air/Ground Vehicles • Intelligent and Autonomous Systems • Manufacturing Science • Structural Materials • Materials, Computation and Prediction • Platform Affordability • Undersea Weaponry
Warfighter Performance	• Manpower, Personnel, Training and Education • Human-system Design and Decision Support • Bio-engineered Systems • Warfighter Health and Survivability	• Human factors, Organizational Design and Decision Research • Manpower and Personnel • Training, Education and Human Performance • Undersea Medicine • Bio-sensors, Bio-processes and Bio-inspired Systems • Casualty Care and management • Casualty Prevention

NRL is also focusing on the key technologies that encompass what defense leaders are calling a "Third Offset" strategy: cyber and space capabilities, unmanned systems, directed energy, undersea warfare, hypersonics, and robotics, among others. For example, the Laboratory is making important contributions to what may become the most revolutionary advances in naval power projection in decades — laser weapons and railguns. NRL scientists were the first to propose and simulate the use of incoherently

combined, high-power fiber lasers as the architecture for the Navy's new Laser Weapon System (LaWS). In 2014, LaWS was deployed in the Persian Gulf aboard the USS *Ponce*. At less than one dollar per shot, in testing it has downed an unmanned aerial vehicle and destroyed moving targets at sea. NRL's railgun program began in 2003 and has since become a critical element in the efforts to develop hypervelocity electric weapons for long-range fire support and ship defense. When the Navy deploys its first hypervelocity electric launcher, its overall success will be due in part to NRL's key contributions.

Rapid prototyping and experimentation is an important mechanism in transitioning S&T to demonstrations of operational capabilities. NRL contributes to the Navy's new rapid prototyping process where fleet needs are identified through the OPNAV and Secretariat organizations to energize the Naval Research and Development Enterprise (NRL and the Naval Warfare Centers) to develop best-of-breed solutions for demonstration and evaluation.

FACTORS FOR NRL'S SUCCESS

As the corporate laboratory of the Department of the Navy, NRL conducts basic research, translates the results of this research into technologies, and assists in the transfer of these technologies to other Navy Department, the Defense Department, federal, and industrial organizations for incorporation into effective operational military systems. The successful transition of these technologies supports NRL's corporate philosophy that a sustained and well-managed investment in multidisciplinary research and development leads to continual improvements to the nation's defense, helps prevent technological surprise by potential adversaries, and can lead to revolutionary and world-changing capabilities, such as sonar, radar, satellites, GPS, and, maybe soon, laser weapons and railguns.

The reasons for NRL's success include the fundamental imperatives — a high-quality workforce and satisfactory facilities. But there are eight other factors of vital importance that helped build and then maintain NRL's reputation as a world-class research laboratory.

- Broadly Based Multidisciplinary Program

  NRL's program includes more than 15 scientific disciplines and applied technology areas, including optics, chemistry, plasma physics, materials science, oceanography, acoustics, electronic warfare, radar, remote sensing, and space science and technology. This broadly based multidisciplinary approach allows for a better understanding of a problem and taps the creative synergy of diverse disciplines. Moreover, technical problems are becoming increasingly complex in nature. For this reason NRL established its Nano-science Institute, which conducts research at the intersections of

materials, electronics, and biology. NRL created its Laboratory for Autonomous Systems Research to support research in intelligent autonomy, sensor systems, power and energy systems, human-system interaction, and more.

Recently, using a methodology reminiscent of Project Hindsight (October 1969), the Office of the Secretary of Defense led a survey that quantitatively confirmed the benefits of a broadly based multidisciplinary program: NRL made 181 R&D contributions to 43 of the 83 current Major Defense Acquisition Programs (or MDAPs). The survey, however, likely undercounted contributions from early basic and applied research that found their way into these programs outside the knowledge of the survey respondents, which only replicated Project Hindsight's chief weakness.

Another quantitative metric showing the value of this approach to the warfighter is that NRL made 240 product transitions over a five-year period to various DoD agencies, which included 19 to Joint Agencies and 78 to other DoD agencies.

- Organizational Position

Public Law 79-588 created the Office of Naval Research (ONR) and placed it, along with NRL, within the Office of the Secretary of the Navy in 1946. Since then NRL has reported directly to the Chief of Naval Research (CNR). This preserved the original guidance from Edison and the Naval Consulting Board that NRL be placed where it could focus on the long-term needs of the Navy, rather than on short-term operational requirements.

- Strategic Guidance and Funding

NRL's programs address the capability gaps identified in the CNR's Naval S&T Strategic Plan. Department of Defense and Department of the Navy strategic documents provide the foundation for this plan. It is a broad strategy that articulates a general direction for the future, while retaining sufficient flexibility and freedom of action to meet emerging challenges. For its base program, NRL receives broad guidance from the CNR that also establishes level of effort. Using a rigorous internal review process, NRL then develops an annual comprehensive base program plan that is proposed to the CNR. The base program, funded directly by the CNR, is a vital key to NRL's success. Indeed, the importance of a supportive CNR to an innovative NRL program cannot be overstated.

- Navy Working Capital Fund (NWCF)

Reimbursable funding provided by Navy, Defense, and non-Defense customers through the NWCF helps to produce world-class research results at the lowest possible cost. In FY15, NRL executed more than $1.2 billion for more than 230 customers. This "executed" funding includes funds contracted to external performers, both public and private sector. Approximately 40% of NRL's funding comes from ONR.

The system works as follows: All costs of doing business are distributed proportionately as overhead charges added to the cost of a research work year and are paid by the customers of each project. Customers have the choice of funding or not funding individual projects on the basis of cost, scientific quality, and responsiveness to their needs, so it follows that NRL's researchers must compete by satisfying those needs. In 2015, NRL received funding from 184 DoD and non-DoD agencies, as well as from 53 industrial customers.

It should also be noted that the working capital fund also fosters decentralized decision making by placing the responsibility for program success on the technical abilities of each division superintendent and branch head. This is proper because technical decisions are best made at a level of authority closest to the expertise of the researchers.

- Dual-Executive Management Model

For several decades one of the basic tenets upon which the excellence of the Laboratory has rested is the concept of the dual executive, whereby the Commanding Officer (CO) and the Director of Research (DOR) share management responsibilities. The success of this arrangement is most evident in the Laboratory's recognition among the best of the world's applied research laboratories. That stature, and the scientific, technical and support staff that enables it, represents the primary value of NRL to the Navy. One co-executive, a senior civilian scientist of recognized stature, selected by the Secretary of the Navy, ensures that the Laboratory is managed like its peer civilian research laboratories worldwide when viewed by industry, academia, and these other peer laboratories. At the same time, with a senior military officer as co-executive, NRL stands clearly to serve the U.S. Navy as a military organization that supports its long term needs for advanced science and technology. The dual executive arrangement, for all its complexities, has evolved over the years as the best solution for running NRL because there is no part of the laboratory structure that does not affect the quality of the research. *With this model, the paramount issue is always the importance of, and the well-being of, NRL, an issue that trumps the interests of both the CO and the DOR.*

- Continuity of Civilian Technical Leadership

A landmark White House study, chaired by David Packard [Report of the White House Science Council, May 1983], stressed that, "The quality of management is crucial to a laboratory's performance. Federal agencies must insist on highly competent laboratory directors." Indeed, the job of NRL's senior management is to choose areas in which to work, divest work that has become appropriate for other performers, serve as the final arbiter of scientific merit, and foster the basic conditions necessary for innovation. The latter includes a high-quality staff, challenging programs, productive partnerships, effective support services, satisfactory facilities, state-of-the-art equipment, and a reasonable degree of autonomy. History has shown that the stable continuity of NRL's senior civilian management is key to ensuring those conditions — just six civilian directors have guided the program since 1949. Such stability is vital for nurturing long-term basic research programs.

- A Collaborative Naval Research Enterprise

In a three-year period (2012-14), there were 507 "interactions" between NRL and other Navy laboratories. The interactions included, but were not limited to, panel and committee participation, shared research, and funded collaborations. There also were 266 interactions with Army laboratories and 188 with Air Force laboratories. Over a similar three-year period (2010-12) NRL researchers had 1,019 collaborations with 232 U.S. universities and research institutions in 48 states, and 193 with foreign universities and research institutions in 34 countries. NRL's relationship with the private sector is characterized by productive collaboration and mutual respect. In fact, Charles Townes, Nobel Laureate and former vice president of the Institute for Defense Analyses, commented on that relationship when he said, "NRL is important to all of us — to defense industry and to science."

NRL also participates in Cooperative Research and Development Agreements (CRADAs), with five companies supported by Small Business Innovation Research / Small Business Technology Transfer funding in FY 15 and three in FY 16. The sources of funding were the Department of Energy and DoD agencies. Technologies include development of new optical fibers, solar cells and photovoltaic cells. NRL also has thirty-four active licenses for products of importance both to DOD and the commercial sector. Of the eight new licenses in FY15, seven were to small businesses. Products under development include: a manufacturing method for wafer bonding of thinned electronic materials and circuits to high performance substrates; high-performance interband cascade lasers for gas sensing, food processing, infrared countermeasure; a software-based technique for analyzing ultraviolet photoluminescence images of SiC wafers for manufacturing quality control; and phthalonitrile-based polymers with high temperature thermosets that remain strong at temperatures up

to 500ºC and are easily processed into shaped fiber reinforced composites for use in aircraft, ship, automotive, and wind blade structural components.

- Facilities Management Authority

In 2003 the Chief of Naval Operations (CNO) consolidated his organization from eight claimancies (facility-owning commands) down to one: the Commander, Navy Installations (CNI). The CNO's action applied to his organization alone, so the property and base operating support (BOS) functions of the four naval warfare centers were placed under CNI ownership [CNO message 271955Z, March 2003]. The CNO's directive did not apply to the Marine Corps and NRL, both of which have separate and independent reporting chains. The Laboratory reports to the CNR, and ultimately to the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN(RD&A)) and the Secretary of the Navy. In fact, Navy Secretariat policy mandates that NRL manage its own real property and BOS functions because it is "a Secretary of the Navy corporate activity that has been assigned unique Navy-wide and national responsibilities." In order to "protect the unique corporate status of the NRL", this policy stipulates that, "Real property and BOS functions imbedded inseparably with the research and industrial functions at NRL will remain with the Commanding Officer" [ASN (RDA) letter to Deputy Chief of Naval Operations (Logistics), October 2, 1997]. BOS functions not deemed "imbedded inseparably" (i.e., the guard force, some facility support functions, and Morale, Welfare, and Recreation facilities and functions) were transferred by NRL to NDW.

The Base Realignment and Closure Commission understood the risks of applying inappropriate management methods to R&D. In 2005, it rejected a proposal to absorb NRL's facilities and BOS functions into a joint-base operated by CNI's Naval District Washington region. The commissioners ruled 8-0 that "NRL's continued control of laboratory buildings, structures, and other physical assets is essential to NRL's research mission", and they endorsed the ASN (RDA)'s 1997 policy by codifying it in law [Defense Base Realignment and Closure Commission, Final Deliberations, August 25, 2005, 57; and "A Bill to Make Recommendations to the President Under the Defense Base Closure and Realignment Act of 1990," Q-70.].

In short, the above eight factors are vital and must be preserved. Two additional factors — a high-quality workforce and satisfactory facilities — are, of course, fundamental factors for NRL's record of excellence, but they differ from the other eight in that constant attention and persistent effort is required to ensure that they do not become a cause for scientific stagnation and decline.

CHALLENGES TO MISSION ACCOMPLISHMENT

THE WORKFORCE CHALLENGE

NRL has a world-class workforce of 1,567 scientists and engineers (S&Es) that has in recent years included 11 members of the National Academies of Sciences and Engineering (7 retired and 4 onboard), more than 870 PhDs, 163 fellows of prestigious professional societies, two recipients of the National Medal of Technology (in 2005 and 2012), and more than 170 postdoctoral fellows. From FY11 to FY15, NRL's S&Es generated 4,193 refereed journal articles (with a cumulative 40,857 citations), 546 patents issued, and 513 invention disclosures. *This high quality workforce is the biggest reason for NRL's sustained success*. However, this workforce must be constantly renewed, especially as the rate of retirements grows. To be successful in sustaining this renewal, NRL must preserve a creative environment despite the challenges. *This is critical to its long-term health because a creative environment attracts the new talent*.

Managing, motivating, and renewing a creative scientific and engineering workforce within the federal government is not easy. A government laboratory never has been able to match the scale of compensation offered by industry or the degree of autonomy offered by universities. Historically the government has offered sufficient compensation and superior "psychic" income, such as important and challenging work, reasonable autonomy, organization reputation, state-of-the-art equipment, high quality colleagues, etc. Over time, however, it has become more difficult to compensate high quality talent sufficiently and the "psychic" income has degraded due to aging facilities, a low regard for public service, and less responsive personnel management systems. Two demographic factors also contribute to the difficulties in recruitment: the aging of the baby boomer generation, and a shrinking number of U.S. citizens obtaining scientific and technical degrees.

Therefore, other approaches have become critical to the continued viability of the DoD's laboratories. To help stem the decline in brainpower and maintain a high quality standard (average S&E GPA = 3.60), NRL uses three primary vehicles provided by the U.S. Congress: the Naval Innovative Science and Engineering (NISE) program (Section 219), Laboratory Demonstration Program, and Direct Hire Authority, along with other recruiting tools.

- NISE Program (Karles Fellowships and Karles Invitational Conference)

Since March 2010, NRL's primary use of NISE is workforce development through the Karles Fellowship program. Named after two of NRL's most distinguished and world-recognized scientists,

Drs. Jerome and Isabella Karle, the program provides funding for highly accomplished scientists and engineers at any degree level within a year of graduation and a minimum GPA of 3.5. The fellowships provide funding for two years to conduct a specific program of research appropriate with the candidate's background and the NRL division. NISE funding to NRL typically allows for approximately 25-30 fellows each year. The two-year duration provides time for the fellows to establish their credentials at NRL, develop their own research programs to adapt to NRL's NWCF operating model, and integrate themselves into NRL research community.

The Karles Fellows program continues to be successful. As a brief example, FY15 Karles Fellows had an average GPA of 3.76, published almost 75 peer-reviewed papers, and submitted 8 patent applications. In FY17, NRL expects to execute NISE by funding Karles Fellows in various fields including cybersecurity, quantum systems and electronics, cognition for autonomy, synthetic biology, neuroelectronics, electromagnetics, materials by design, and others. NRL expects to hire fellows as the opportunities present during the year.

NISE also provides funding for the annual Karles Invitational Conference, established in 2011. The conference brings together distinguished scientists and engineers working at the frontiers of research in a particular area with the goals of examining the most recent advances and stimulating new directions for research, and finding interdisciplinary collaborations. The 6th Karles Invitational Conference took place in August 2016 and was focused on 3D additive manufacturing.

- Laboratory Demonstration Project (Demo)

The U.S. Congress has, over the years, helped to reform the inherently ponderous Government personnel system by authorizing various special hiring and salary authorities, and exempting the DOD's R&D organizations from its most onerous and time-consuming processes and procedures. The most sweeping of these reforms was codified in Section 342 of the fiscal year 1995 National Defense Authorization Act (NDAA), which created a series of "Science and Technology Demonstration Labs" within the family of R&D labs operated by the Services.

NRL implemented Demo in September 1999. It has been highly successful in meeting the goals of: maintaining the quality of the NRL workforce in the scientific and engineering disciplines, as well as administrative specialist/professional and support positions; more timely processing of personnel actions; increased retention of high-level contributors and wider distribution of salaries; and increased satisfaction with human resources management processes by employees and managers. The most

recent employee survey conducted in the fall of 2014, indicated 84.6% of respondents are in favor of the Demo.

NRL is a member of the OSD Laboratory Quality Enhancement Program (LQEP), Personnel Subcommittee which is working to implement authorities in the NDAA 2014, Section 1107(h), including:

- Exercise to the fullest extent, authorities provided under DoD STRL Personnel Demonstration Projects to include: authority to pay performance and other cash awards without regard to pay freezes or award restrictions; and authority to adopt, with reasonable adaptations, demonstration project authorities previously approved by any STRL through notification to appropriate DoD / component officials and the laboratory's workforce.
- Freedom from hiring restrictions provided appropriate funding is available.

- Direct Hire Authorities

Since Congress provided various direct hire authorities for portions of the S&E workforce starting in FY09, NRL hired or is in the process of hiring almost 500 people (427 advanced degree, 62 bachelor's degree, 7 veterans), representing 67% of the possible workforce size-based allocation (496 of a possible 744) in spite of the 2013 hiring freeze.

- NRL Pipeline for Future Employees

The Navy has a rich history of providing educational opportunities for students of all ages. These opportunities begin with naval-relevant outreach programs at the kindergarten through high school grade levels. They continue through internships and other programs in post-secondary schools, supporting student advancement into post-doctoral work and continue through all stages of professional development. In short, there is no more valuable investment we can make in Naval S&T than in the minds of our current and future workforce. A portion of that investment takes shape in our internship programs.

The Science and Engineering Apprenticeship Program (SEAP) program is an eight-week paid internship opportunity for high-school students. Throughout the apprenticeship interns gain real-world, hands-on experience and research skills under the guidance of a mentor. These internships introduce high-school students to the Naval Science and Technology environment. Recent SEAP student research areas included: corrosion preventive compound analysis, pathogen carriage by fleas

in Kenya, manufacturing ball bearings using additive manufacturing, high altitude balloon design, wave energy testing; nanocomposite analysis, and collision avoidance for collaborative Unmanned Aerial Vehicles.

The Naval Research Enterprise Internship Program (NREIP), similar to SEAP, is a ten-week long paid research internship opportunity for the undergraduate and graduate. NREIP interns gain real-world, hands-on experience and research skills, under the guidance of a mentor. These internships introduce post-secondary students to the Naval Science and Technology environment. NREIP interns have proven to be an excellent source of future Naval Research Enterprise employees. Students conduct research in a wide range of areas including: cyber analytics, 3D printing applications, underwater archaeology, taxonomic analysis, digital forensic analysis, flight training devices, virtual reality technologies, and psychology of unmanned systems.

In addition to NREIP and SEAP, NRL executes an internship program for Historically Black Colleges and Universities/Minority Institutions undergraduates. These research interns are active participants and conduct hands-on laboratory research under the guidance of senior NRL staff. At the conclusion of the program, students prepare written reports and make brief presentations describing their summer's work. In addition to conducting scientific research, the interns attend scientific and skill-set seminars on laboratory safety, ethics in science and engineering, job search skills, and resume writing.

NRL provides postdoctoral scientists and engineers the opportunity to pursue research on problems, largely of their own choice, that are compatible with and contribute to the overall effort of NRL. For recent doctoral graduates, this is an opportunity for concentrated research in association with selected members of the permanent NRL staff, often as a climax to formal career preparation. This relationship enhances the quality of the Laboratory's research activities, acquaints participants with Navy capabilities, and provides a potential path to full time employment.

NRL also participates in the Summer Faculty Program, which provides S&E academic faculty opportunities to participate in research of mutual interest for a period of 10 weeks. Participants may be appointed as a summer faculty fellow, as a senior summer faculty fellow, or as a distinguished summer faculty fellow. Weekly stipends are paid, travel expenses are reimbursed, and fellows may be allowed to bring an undergraduate or graduate student to the lab to assist with the summer research (and also receive a student stipend).

THE FACILITIES CHALLENGE

NRL's most serious challenge is the need to modernize an aging infrastructure so that the Laboratory can continue to meet the emerging needs of our future Naval forces. This is especially important as the pace of S&T advancement accelerates rapidly across the rest of the world and near peer competitors arise to challenge American naval superiority. Various facilities and laboratories are experiencing excessive leaks, heating and air conditioning problems, and other infrastructure failures. While this is to be expected given the average age of the buildings at the NRL main campus is 59 years old, it is further compounded by inadequate investment in new facilities and major repairs of existing facilities. For many reasons military construction funding for the DoD laboratories has declined steadily over the years. Similarly, funding shortages and other difficulties for executing facilities repairs and modernization efforts have not kept pace sufficiently addressing the facilities deterioration and essential modernizations. NRL continues to work within the DON and DoD to address these issues as it is critical that the facilities be improved so that we can attract and retain qualified personnel to work at NRL, and provide state of the art research and technology solutions in facilities adequately suited for current and future requirements. NRL fully supports the various initiatives to revitalize the DoD laboratories, including the use of "Section 219" authorities for minor construction, the proposed increase in the minor construction threshold from $4 million to $6 million (or higher), and any increases in major military construction funding for new facilities.

CONCLUSION

NRL is important because of what it does, but it is indispensable for what it is — a government laboratory. The federal government ultimately bears sole accountability for national missions and public expenditures, so decisions concerning the types of work to be undertaken, when, by whom, and at what cost should be made by government officials responsible to the president. The government therefore must be a smart buyer and be capable of overseeing its contracted work. For this the government uses its "yardstick." In technical matters, this measure is the collective competence of its scientists and engineers. Their advice must be technically authoritative, knowledgeable of the mission, and accountable to the public interest. William Perry, former secretary of defense, underscored that necessity when he stated that the government "requires internal technical capability of sufficient breadth, depth, and continuity to assure that the public interest is served." A detailed discussion on the many ways that NRL and its sister DoD laboratories fulfill, and go beyond, the Government's "yardstick" requirements can be found in "Breaking the Yardstick: The Dangers of Market-Based Governance," *Joint Force Quarterly*, (JFQ Issue 55,4th Quarter 2009), 126-135.

I invite each of you to visit the Naval Research Laboratory, located a short drive from the Capitol. Thank you for your time today, your interest in NRL's work, your concern for defense science and technology, and support of the DoD laboratories and their missions. I look forward to answering any questions you may have.

Edward R. Franchi
Director of Research, (Acting)
Associate Director of Research, Ocean and Atmospheric Science and Technology Directorate, Naval Research Laboratory, United States

In August 2016, Dr. Franchi became the Acting Director of Research at the Naval Research Laboratory.

Dr. Franchi has been the Associate Director of Research for the Ocean and Atmospheric Science and Technology Directorate at the US Naval Research Laboratory (NRL), where he is responsible for providing executive direction and technical leadership for six research divisions in the fields of acoustics, remote sensing, oceanography, marine geosciences, marine meteorology, and space science. Additional, he is responsible for coordination of all NRL Science and Technology (S&T) projects related to Undersea Warfare. Dr. Franchi is an internationally recognized expert in underwater acoustics research and anti-submarine warfare and mine warfare technology.

His personal research focuses on underwater acoustics scattering and reverberation. He has played major roles in Navy low frequency active sonar programs. He has served as the Panel Chairman of The Technical Cooperation Program's (TTCP) multinational Panel on ASW Systems and Technology from 2003 to 2009. He represents the United States to the NATO Maritime Science and Technology Experts Committee and served as its Committee Chairman from 2010 to 2014. In 2011, he was appointed to the NATO Science and Technology Reform Implementation Team.

Dr. Franchi graduated from Clarkson University in 1968, with a Bachelor of Science degree in mathematics. He received his Master of Science (1970) and Doctorate (1973) degrees both in applied mathematics from Rensselaer Polytechnic Institute.

Dr. Franchi received the Presidential Rank Award of Meritorious Executive in 2003. He received the TTCP Personal Achievement Award in 2011 in recognition of his significant contributions and strategic vision in leading the TTCP ASW Panel. He received the National Partnership for Reinventing Government Award in 1998 for contributions to the development of the NRL Personnel Management Demonstration Project. He has received numerous Letters of Appreciation from Flag Officers for his research contributions over the years. He was elected to Pi Mu Epsilon, the Honorary National Mathematics Society, while an undergraduate at Clarkson University. Dr. Franchi is a member of the Acoustical Society of America and past member of the Mathematical Association of America. From 2004 to 2013, he has volunteered his time to serve on the Board of Directors of the NRL Federal Credit Union.

STATEMENT BY
DR. PHILIP PERCONTI

ACTING DIRECTOR

UNITED STATES ARMY RESEARCH LABORATORY

BEFORE THE

EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

OF THE

HOUSE ARMED SERVICES COMMITTEE

ON

THE UNITED STATES ARMY RESEARCH LABORATORY'S ROLE IN ADVANCING SCIENCE AND TECHNOLOGY FOR THE AMERICAN SOLDIER

SECOND SESSION, 114TH CONGRESS

SEPTEMBER 28, 2016

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

STATEMENT BY
DR. PHILIP PERCONTI

ACTING DIRECTOR

UNITED STATES ARMY RESEARCH LABORATORY

Chairman Wilson, Ranking Member Langevin, and distinguished members of the Subcommittee. As the Acting Director of the Army Research Laboratory (ARL), thank you for the opportunity to discuss the critical support Army Science and Technology (S&T) provides in support of key military operations. My intent is to provide the Committee with an operational picture of the Army's S&T pipeline and then focus on ARL's unique role as the Army's corporate research laboratory. This will cover about 75 percent of the Army's S&T portfolio, and thus it does not include space and missile defense or the medical research programs.

Enabling Readiness Through Science and Technology (S&T)

Army Chief of Staff General Mark A. Milley has made readiness the Army's top priority, followed by the future force and taking care of Soldiers. As the preeminent ground combat force in the world, the Army's definition of readiness must include meeting today's urgent operational needs while ensuring decisive overmatch for the force of the future. Predictable and consistent funding is absolutely essential for the Army to build and sustain current readiness and progress toward a modern, capable future force. Without such funding the Army will have to reduce funding future readiness in modernization and infrastructure maintenance, and continue programmed end-strength reductions. As the Army's lead technology integrator, the Research, Development and Engineering Command's (RDECOM) strategy for understanding emerging threats and the operational requirements that next-generation systems will face are shaped by the strategic guidance from the Office of the Secretary of Defense (OSD); the technical and programmatic oversight of the Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT)); the Army Materiel Command (AMC); and the various members of the Army requirements and acquisition communities.

RDECOM has developed a global S&T ecosystem in order to deliver capabilities that unburden, empower and protect the Soldier. This includes leveraging thousands of domestic and international partnerships within a global presence to identify, sponsor and collaborate on technologies important to the Army no matter where they are developed. At the same time, RDECOM collaborates with the Training and Doctrine Command's (TRADOC) Army Capability Integration Center (ARCIC) concept and requirement developers. RDECOM's scientists and engineers understand the science that underpins future technology development, realistic timelines and development costs. TRADOC, through the Capability Needs Analysis (CNA) processes, identifies the capability gaps and risks facing the current and future force.

Once needs are identified they are incorporated into ongoing and new research efforts across the Army S&T laboratory enterprise, which includes ARL and the Research, Development and Engineering Centers (RDECs) in their commodity areas: Communications-Electronics RDEC (CERDEC), Natick Soldier RDEC (NSRDEC); Tank Automotive RDEC (TARDEC); Aviation and Missile RDEC (AMRDEC); Armaments RDEC (ARDEC); and the Edgewood Chemical Biological Center (ECBC). Integrated technology solutions mature through these partnerships to transition to Programs of Record (POR) and ultimately to the force.

These capabilities and associated technology development efforts are not restricted solely to Army needs. RDECOM develops technologies to address the Army Warfighting Challenges, which are the enduring first-order challenges, the solution to which will improve the combat effectiveness of the current and future force. The Command also provides foundational capabilities for the Joint Warfighter across the entire spectrum of its operations. These capabilities include chemical-biological defense, combat feeding, combat vehicle prototyping, future vertical lift, ground and air active protection systems, and night-vision capability, among others.

In collaboration with ASA(ALT), RDECOM develops, aligns and synchronizes the Army's S&T portfolio to ensure acquisition programs capitalize on the most promising technology advancements. RDECOM's matrixed engineers provide critical technical

support to the Program Managers (PMs) and Program Executive Officers (PEOs) for approved programs, to include transitioning mature technology for system development and demonstration and, subsequently, to acquisition. RDECOM also provides critical engineering services to the PEOs and PMs with its Prototype Integration Facilities (PIFs). The PIFs design, prototype and integrate technologies to validate design in the development of hardware, conduct performance assessments throughout the life cycle, and rapidly integrate engineered solutions in response to Soldier/acquisition customer requirements. Operating as a single entity, the PIF Enterprise (PIFe) delivers competitive prototypes, and identifies manufacturing processes and efficiencies to ease the transition of designs to the factory and enables our PEO and PM partners to understand the "should" cost of production.

RDECOM provides critical lifecycle management support within the Army Materiel Command's (AMC) Materiel Enterprise. Working directly and indirectly with the Life Cycle Management Commands and the Army Sustainment Command, RDECOM synchronizes the continuous engineering support to modernize of technology already in the field.

By performing discovery research, technology development and engineering across the lifecycle, RDECOM develops the scientific and engineering expertise to enable the Army to be a smart buyer in its acquisition programs.

In addition, promising technology and knowledge will transition to the Warfighter through our industrial partnerships whereby novel concepts are embodied as field-ready materiel solutions. This also occurs by transitioning solutions through the nation's other R&D organizations.

The Army Research Laboratory

ARL's role in the Army S&T ecosystem is to act as the Army's corporate research laboratory by pursuing discoveries, innovations, and transition of technological developments that are geared toward acting on opportunities in power projection, information, lethality and protection, and Soldier performance.

ARL is made up of a diverse team of people who are excited, dedicated and focused on achieving the mission of empowering, unburdening, and protecting the Soldier and the Joint Warfighter. In FY15, ARL had a total workforce of 2,980, including active duty military and contractors. Of that, 1,849 are federal civilians with 1,316 classified as scientists and engineers. The laboratory currently has 150 post-doctoral researchers on staff, an increase from 48 in 2014, and 94 in 2015. The lab also employs 461 women and 135 veterans acquired through our competitive career program. Furthermore, the workforce is highly recognized. A sampling of the awards that laboratory employees received over the last two years include two Presidential Early Career Award for Science and Engineers; 47 elected Fellows to external scientific organizations; eight OSD Laboratory University Collaboration Initiative program winners; Lifetime Achievement Award by National Training and Simulation Association, and the Ralph P.I. Adler Award for Lifetime Achievement. ARL has also become a leader in S&T educational outreach and is shaping future generations of Americans in key markets across the nation to drive future discovery and innovation. ARL's robust Science, Technology, Engineering and Math (STEM) program is engaged in outreach initiatives from kindergarten through college. Programs such as Junior Solar Sprint, Gains in the Education of Mathematics and Science, eCYBERMISSION and Junior Science and Humanities Symposium are energizing youth throughout the nation.

As a Department of Defense Science and Technology Reinvention Laboratory, ARL has benefitted greatly from the congressional authorities granted in Public Law 110–417 Section 219 (a), Mechanisms To Provide Funds for Defense Laboratories for Research and Development of Technologies for Military Missions. These authorities give ARL an agile and fast capability to maximize our potential for the discovery, innovation and transition of leading-edge foundational research in support of strategic land-power dominance. The 219 authority for facilities revitalization enables ARL to maintain world-class laboratories. ARL fully utilizes the 219 authority, except in the transition of technologies, with $31.3 million in FY 15 investments. These funds supported 22 projects in innovative research, two projects in workforce development and 18 infrastructure projects. In FY16, we have invested $31.7 million in 20 innovative research projects, two workforce development projects and 19 infrastructure projects.

When combined with the Direct-Hire Authority (DHA), 219 Authority gives ARL the ability to attract, train and then retain the best and brightest engineers and scientists our country has to offer. In the last two years DHA has allowed ARL to hire 256 federal employees in critical fields such as neuroscience, electronics, computer science, and materials and aerospace engineering, as well as hiring physicists, biologists, chemists, mathematicians and social scientists.

ARL's discoveries and innovations have led to the transition of new knowledge, ideas and concepts that inform and shape requirements for new warfighting capabilities. ARL discoveries, knowledge and technologies inform and provide material for more advanced development at the RDEC level. Jointly with the RDECs, we plan research programs that are aligned and synchronized to meet emerging Army requirements. ARL takes on the highest risk, research-intensive engineering projects, while our RDEC partners support the needs of existing PORs using established engineering principles, and provide disruptive technology innovations through extramural (6.2 - 6.3) research programs. ARL and our RDEC partners work to give Army acquisition decision makers the confidence to know that technology is ready for demonstration and transition to industry for manufacturing. S&T enables readiness for today's Army and is now developing capabilities for the Army of the deep future.

ARL's Approach to Winning in a Complex World

In a world where the only constant is change, the most reliable indicators point to a future where U.S. and coalition land forces will have to project power across air, land, maritime, space and cyberspace in contested and denied environments against traditional, unconventional and hybrid adversaries.

To address this complex operating environment, ARL underwent a top-down review of its mission and vision that resulted in a new technical strategy that identifies the scientific, technical and analytical areas that ARL believes to be of vital importance to the Army of the future. The review is serving as the framework upon which the laboratory's S&T investments are based. The ARL Research Management and Leadership Strategy creates a shared vision of the future technical landscape, defining

ARL's long-term scientific agenda, encouraging more cross-directorate research and collaboration across the organization, academia, and industry. Major emphasis is placed on getting the right science and then getting the science right by identifying knowledge gaps, prioritizing research to address those gaps and then in a systematic way identifying the resources to ensure the facilities and equipment, and most importantly the expertise are available to perform the research.

The strategy also establishes eight S&T Campaigns that operate in concert to provide ARL with a robust technological framework – Extramural Basic Research; Computational Sciences; Materials Research; Sciences-for-Maneuver; Information Sciences; Sciences-for-Lethality and Protection; Human Sciences; and Assessment and Analysis.

The S&T Campaigns provide the framework for strategic planning and resourcing to ensure people, facilities and equipment are properly aligned, with emphasis on collaborative research. The campaigns are synchronized across the enterprise to execute nine Essential Research Areas (ERAs) the laboratory must address to support the Army of 2050. These areas take into account key campaign initiatives and core campaign technical competencies or enablers, across ARL's entire S&T portfolio. Every S&T Campaign supports one or more of the ERAs; however, the ERAs do not cover ARL's entire research portfolio, and they are not meant to. The ERAs provide the context and the impetus for the research ARL must do to meet the S&T objectives for the Army of 2050 and the Army's efforts towards DOD's third offset strategy. The ERAs are Human Agent Teaming; Artificial Intelligence and Machine Learning; Cyber and Electromagnetic Technologies for Complex Environments; Distributed and Cooperative Engagement in Contested Environments; Tactical Unit Energy Independence; Manipulating Physics of Failure for Robust Performance of Materials; Science for Manufacturing at the Point of Need; Accelerated Learning for a Ready and Responsive Force; and Discovery.

Equally important, ARL works together with the other services' labs using a number of initiatives to align our plans and programs, to eliminate redundancy and to provide

mutual support wherever possible. Much of this work occurs through the OSD Communities of Interest (COIs). COIs provide a forum for coordinating S&T strategies across the DoD, sharing new ideas, technical directions and technology opportunities, jointly planning programs, measuring technical progress, and reporting on the general state of health for specific technology areas. A great example of the service labs working together is the Tri-Service Quantum Science and Engineering Program that will exploit expertise at the joint service laboratories to prototype a scalable quantum network, develop and entangle practical quantum memories, and demonstrate a high-sensitivity sensor application across the network.

Discovery and Innovation at ARL

The Army needs a high-quality, inquisitive, agile foundational research program with focus on the deep future. Both the changes resulting from globalization and the needs of the future Army are uncertain.

The Army of 2050 will operate in a rapidly changing environment of hitherto unparalleled complexity. In response, under the leadership of Dr. Thomas Russell, ARL implemented a new Open Campus business model in 2014 to pursue leading-edge foundational research with an emphasis on collaboration that enables the continuous flow of people and ideas between government, academia and the private sector. This model creates a 21st century research culture that is agile and effective, that could serve as a model to transform the entire U.S. Defense Laboratory Enterprise away from a high-walled, closed and "siloed" research community, to one that emphasizes mutual reliance and interdependent collaborative research as a critical element of national security.

Open Campus focuses on three major initiatives to create the S&T ecosystem necessary to meet future national security challenges: 1) modern government workforce management and policies for the 21st century; 2) shared facilities among government, academia and the private sector; and 3) a collaborative S&T ecosystem that encourages an entrepreneurial and innovative cultural environment. Through the Open Campus framework, ARL scientists and engineers work side-by-side with colleagues from academia, government and industry at ARL facilities. In turn, ARL's scientists and

engineers participate as visiting researchers at collaborators' institutions to fully leverage the expertise, capabilities and facilities of ARL and its partners. ARL is committed to a goal of having 10–15 percent of its research staff on rotational assignments outside the laboratory at partner locations, with at least that number of collaborators actively participating at ARL locations.

ARL is working aggressively to create the framework necessary to support these new avenues of global collaboration. ARL's use of Cooperative Research and Development Agreements has expanded dramatically with academic, corporate and small business institutions. It is being established at the institution-wide level, rather than with single investigators, to protect the intellectual property of all partners, while dramatically streamlining the collaboration process. Over the last year, the number of agreements with academia and industry has doubled, from 60 to over 180, with 175 more in negotiation. These agreements have leveraged over $23 million from the Army's collaborative partners. The total number of Open Campus participants has also doubled from over 200 to beyond 500 participants who are collaborating onsite in ARL laboratories. The implementation of enhanced, layered security practices has allowed more than 54 international collaborators from 19 countries to work alongside Army researchers within the installation.

This is in addition to the sizeable portion of funding that is allocated to contracts with small businesses. Over the past three years, ARL has awarded more than $637 million in contracts to small businesses in 40 states and the District of Columbia. Additionally, ARL fully supports the Small Business Innovation Research and the Small Business Technology Transfer programs. Over the past three years, ARL has provided nearly $122 million to small businesses in 30 states through these programs.

Conclusion

Future land power dominance will rely heavily on significant S&T advances. This is particularly true in support of power projection, protected information, lethality and protection superiority, and Soldier performance augmentation, areas that will serve as the technological cornerstones that ensure the Army's control of the battlespace.

Exploitation of emerging S&T discoveries, innovations and transition of developments in these critical areas will enable a ready and robust expeditionary Army force that is uniquely positioned to shape events in peace, and prevent or rapidly end conflict.

Through preventing conflict, shaping the operational environment and winning the nation's wars, the future Army – America's principal land force – will provide future commanders with decisive land power across the range of military operations in the homeland and abroad.

A trained Army requires modern equipment to win – the third component of readiness. An unintended consequence of the current fiscal environment is that the Army has not equipped and sustained the force with the most modern equipment and has already begun to fall behind near-peer competitors.

Within fiscal constraints, the Army is investing in modernization, while rebuilding readiness and producing a more capable, leaner and globally responsive Army. We will continue working with our partners to align research, development and engineering efforts to develop the technologies that support the Army's priorities. We will focus S&T investment priorities to provide the innovative technologies to close capability gaps, address emerging threats, reduce acquisition and sustainment costs, and change the nature of the fight.

On behalf of my colleagues, thank you. Your work is vital to ensuring ARL remains the Nation's premier laboratory for our land forces. You are essential partners in executing our mission for America's Army.

Dr. Philip Perconti
Director (A), US Army Research Laboratory
Adelphi, Maryland

Dr. Philip Perconti is a member of the Senior Executive Service and serves as the Acting Director of the U.S. Army Research Laboratory (ARL), the Army's premier laboratory for basic and applied research and analysis. ARL conducts research and analysis in weapons and materials, sensors and electron devices, computational and information sciences, human research and engineering, vehicle technology, and survivability and lethality analysis. ARL's Army Research Office executes the Army extramural basic research program in scientific and engineering disciplines. The Laboratory consists of approximately 2,000 civilian and military employees with an annual budget of over $1 billion.

Prior to this, Dr. Perconti served as the Director of the Sensors & Electron Devices Directorate of the ARL. He was responsible for leading and transitioning the Army's primary basic and applied research programs in sensors, electronics, sensor information processing, and power and energy technologies. In addition, he led ARL's S&T campaign for Materials Research. His duties included operation of unique electronics and photonics materials fabrication and characterization facilities that enable world-class, Army-relevant, component research and development. He was also responsible for planning, executing and balancing mission and customer program needs to ensure science and technology dominance for the Army.

CAREER CHRONOLOGY:
Feb 2013 – Apr 2016, Director, Sensors and Electron Devices Directorate, US Army Research Laboratory
Jan 2000 – Jan 2013, Director, Science and Technology Division, US Army CERDEC Night Vision and Electronic Sensors Directorate (NVESD)
Apr 1996 – Jan 2000, Director, Electronics & Photonics Technology Office, National Institute of Standards & Technology (NIST)
May 1990 – Apr 1996, Branch Chief, Imaging Technology, US Army CERDEC Night Vision and Electronic Sensors Directorate (NVESD)

COLLEGE:
D.Sc., Electrical & Computer Engineering, The George Washington University
M.S., Electrical & Computer Engineering, Johns Hopkins University
B.S., Electrical & Computer Engineering, George Mason University

AWARDS AND HONORS:
Fellow of the Military Sensing Symposium (MSS)
U.S. Army Achievement Medal for Civilian Service
HKN- Electrical Engineering Honor Society

PROFESSIONAL MEMBERSHIPS AND ASSOCIATIONS:
Steering Group – OSD Community of Interest for Advanced Electronics
Chairman, Military Sensing Symposium, Passive Sensors Committee
The Technical Cooperative Program Sensors- Multi-Sensor Integration Panel
Institute of Electrical and Electronics Engineers

MAJOR PUBLICATIONS:
Dr. Perconti has published extensively on many aspects of military sensing and countermine/counter IED technology. He has authored and co-authored over 50 publications, including three book chapters. He holds two patents.

WITNESS RESPONSES TO QUESTIONS ASKED DURING THE HEARING

SEPTEMBER 28, 2016

RESPONSES TO QUESTIONS SUBMITTED BY MR. LANGEVIN

General MCMURRY. AFRL conference attendance is now delegated to supervisory level approval. June 2016 Guidance empowers leadership to make the best decision at the optimum levels for employees and members to attend science and technology conferences. AFRL has experienced a savings of over 700+ man-hours due to not having to complete travel packages each time someone wants to attend a conference. Quicker and more appropriate approval authority—now at the level in which the approver is very aware of the benefits to the organization. In addition to the obvious benefit of giving our S&Es a chance to excel at their jobs, a significant secondary benefit is the re-establishment of some level of trust that our S&Es and their supervisors are able to figure out for themselves which conferences they should and can afford to attend. This in turn supports the organization's mission and allows for professional growth of S&Es. Our S&Es and their immediate supervisors can again manage to their budgets and requirements. An additional benefit to the government is the S&Es ability to book travel earlier, which in some cases allows them to take advantage of lower travel costs, leading to cost savings to the government. Attendance by our AF SMEs at these S&T conferences is necessary in order to maintain and advance the leading/cutting edge of technology to support the AF warfighters.

However, despite the tremendous improvements made to attend Non-DOD Hosted conferences, the approval process for DOD-Hosted conferences over $100K continues to be burdensome and time-consuming. AF Conference Business Rules added that all co-sponsored conferences that have 50% or more government speakers be approved by SAF/AA. This policy has no dollar amounts, making any interchanges with industry and academia with a registration fee and scheduled agenda impossible. The approval packages takes months for the many coordination's before it reaches SAF/AA. Small and low cost local events sponsored with non-profit organizations, industry, and universities should be approved (if at all) at the local leadership level based on the value to the local community as well as to the local military organizations. [See page 13.]

Dr. HOLLAND. The current Army policy on conference attendance is "Army Directive 2016–14 (Army Conference Policy)" dated 4 May 2016. This policy establishes the final approval authority for attending conferences hosted by non-Department of Defense organizations (non-DOD conferences) based on the estimated total Army expenditures in support of the conference.

This Army policy permits any General Officer or SES in the chain of command to approve participation in a non-DOD conference where total Army expenditures are less than $100,000 and fewer than 50 personnel within his or her purview are attending. This authority cannot be delegated further. Non-DOD conference attendance where Army expenditures are in excess of $100,000 or more than 50 personnel from a single organization are participating must be approved by the Secretary of the Army (SA), Chief of Staff of the Army (CSA), or the Administrative Assistant to the Secretary of Army (AASA) as appropriate. Attendance at non-DOD conferences exceeding $500,000 in costs to the Army are generally prohibited, although the SA may grant a written waiver.

The U.S. Army Corps of Engineers (USACE) conference policy supplements the Army conference policy and provides further guidance impacting Engineer Research and Development Center (ERDC) attendance at non-DOD conferences. At this time, the Corps policy is in draft form but is the operating policy as directed by USACE HQ 8 August 2016. The USACE policy requires me to approve all conference attendance of ERDC personnel (SES lab Directors do not have approval authority) and limits my approval authority to $50,000 total expenditures and less than 50 attendees. The USACE Commanding General (CG) must approve conference attendance when we exceed $50,000 in total expenditures. The CG must also approve any OCONUS conference attendance.

Prior to the May 2016 update to conference policy, the procedures for attending non-DOD conferences were considerably more stringent. For example, under the policy dated 8 July 2015, the USACE CG was only authorized to approve attendance at non-DOD conferences with costs less than $20,000. Requests with higher costs had to be routed to the AASA (up to $75,000) or the SA. In addition, previous poli-

cies required lengthy request packets and record keeping requirements even for events with very low costs to the government.

The limitations on conference attendance over the last few years significantly reduced the numbers of scientists and engineers attending conferences. The goal of reducing conference expenditures and conference participation was accomplished. Unfortunately, those restrictions had a significant negative impact on our ability to share and learn information from our colleagues in the scientific community.

The lengthy, convoluted process, effectively limited participation of Scientists and Engineers who were invited as speakers or panel members. Our scientists were discouraged by the amount of time, preparation and paperwork needed to obtain approval to attend a conference. As a result, our conference attendance dropped dramatically. While our most senior and accomplished members were approved to speak at conferences, our new and young scientists and engineers had almost no opportunity to hear them or any other top people in their field. Non participation left a feeling of uncertainty within the Science and Engineering community and our status and recognition as subject matter experts and ability to grow innovation was jeopardized. Where we once were chairing scientific panels and had younger scientists "waiting in the wings," our inability to commit to attendance in advance led conference organizers to seek other scientists and engineers to fill those panels.

The Army policy that came out in May simplified the conference approval process, even with the additional restrictions of the Corps. Our scientists and engineers are now encouraged to participate in more conferences and they are eagerly accepting these opportunities. We have seen a significant increase in conference attendance requests since the release of the May Army guidance and those requests are being approved in a much timelier manner. I believe, with time, our scientists and engineers will be back to attending those conferences that will keep them on the cutting edge of technology and as recognized subject matter experts in their fields. [See page 13.]

Dr. FRANCHI. A. Non-DOD conference attendance that cost $100K or less requires Department of the Navy/Assistant for Administration approval. Requests for conference travel are signed and submitted by the Naval Research Laboratory (NRL) Director of Research (DOR) to Department of the Navy/Assistant for Administration (DON/AA). Each conference travel request submitted to DON/AA for approval by the DOR requires: 1) Conference Request Memorandum—A required document by DON/AA signed by the DOR certifying that the conference attendance/participation is essential to NRL's mission 2) Conference Attendance Request (brief sheet)—Overall conference/travel details with a cost analysis (i.e. purpose of conference, value to the organization and how it advanced the DON mission, impact if disapproved, cost estimates and dates of travel) 3) Agenda—if available, or an abbreviated conference agenda. 4) In keeping with SECNAV policies and the ALNAV 046/16 (Ref. (a)) to be fiscally responsible, NRL requires that participation at conferences be limited to those with an active role. An active role is defined as: a. A traditional speaking or responsibility role at a conference (ex. Invited speaker, poster presenter, conference chairperson, etc.), and/or b. Participants will be attending relevant technical/scientific sessions in order to capture cutting edge scientific/technical information paid for by others for the benefit of the Navy and to more effectively shape the directions of their research, and/or c. Participants will be reviewing the research presented by other researchers in their field and will be seeking qualified peer researchers for potential collaboration as means of amplifying the products of the Navy's research investments, and/or d. Participants manage large research portfolios and it is imperative that the individuals understand the state-of-the-art in the research fields for which they are responsible. They can benefit from research conducted by others so that they may more effectively direct their research programs to the best benefit of the Navy, avoid duplication, and identify potential collaborators or highly qualified candidates for hire.

B. Non-DOD conference attendance exceeding $100K requires both Secretary of the Navy (SECNAV) pre-approval and approval. The SECNAV conference approval process consists of: 1) A conference pre-approval data call by DON/AA for preliminary attendance and exhibit costs. This is due approximately three quarters before the start date. The exact due date is listed in the Monthly Upcoming SECNAV/UNSECNAV Conferences List issued by DON/AA. 2) Commands submit formal requests to attend the pre-approved conference (90 days in advance of the conference start date).

C. Current DON Conference Guidance: 1) ALNAV 046/16, dated 27 June 2016 2) DOD Conference Guidance Version 4.0, dated 26 June 2016 3) OMB Memo M–12–12 of May 11, 2012, Subj: Promoting Efficient Spending to support Agency Operations 4) Conference Management SECNAV website: https://portal.secnav.navy.mil/orgs/DUSNM/DONAA/CPEM/SitePages/DON%20Conferences.aspx

SECNAV is responsible for conference policy for the DON. DUSN (M) is responsible for implementing the policy and will issue operating guidance for conference management within the DON. [See page 13.]

Dr. PERCONTI. The Army's most recently published policy on conference attendance was put in place May of 2016, permitting the first Senior Executive Service supervisor in an employee's chain of responsibility to approve conference participation outside of the Department of Defense for Army expenditures of less than $100,000 when fewer than 50 employees will be attending. When the expenditure exceeds the $100,000/50 employee ceiling, it requires the approval of either the Secretary of the Army, Chief of Staff of the Army or the Administrative Assistant to the Secretary of the Army, as appropriate. This new policy has greatly improved RDECOM's overall participation in scientific and technical conferences.

The last few years of limited conference attendance has significantly reduced ARL's ability to lead and influence the scientific community in support of Army priorities, and has had similar impacts on other parts of RDECOM as a whole. Within ARL alone conference publications went from a high of 1,497 conference papers published in 2012 to a 43 percent decline after restrictions in 2013, with 848 papers published. Only 20 percent of these papers were presented by ARL staff as a result of the strict conference attendance guidelines. Several years of limited conference attendance has kept leading experts away from discussions about cutting-edge research that came out during that timeframe; it impacted the natural synergy among colleagues that boosts scientific discovery and it impacted ARL's influence in industries where the laboratory typically leads. The drain on innovation is something that we are working hard to overcome using the Open Campus Initiatives to foster closer collaborations with academia and industry at the earliest stages of research. The most recent policy changes have made approvals for conference attendance quicker and easier, with more lead time for those participating. This has significant impact on Army readiness, both current and future, by allowing RDECOM to better drive the national research and development agenda to address Army and joint Warfighter needs. [See page 13.]

QUESTIONS SUBMITTED BY MEMBERS POST HEARING

SEPTEMBER 28, 2016

QUESTIONS SUBMITTED BY MR. WILSON

Mr. WILSON. Can you tell us for the past three years what your time-to-hire is for each of the various types of direct hire? How does that compare in the same timeframe for traditional government hiring processes?

General MCMURRY. AFRL utilizes the legislated Direct Hire authorities for most of our Scientist & Engineering (S&E) hiring, which does not require job posting. The Direct Hire authority has enabled AFRL managers to hire scientists and engineers in less than 3/4th the time of traditional hiring methods. In order to provide a comparison between Direct Hire and conventional hiring, we measured the date a hiring request arrived in the personnel office to the date of tentative offer to a candidate:

- Direct Hire—11 days
- Conventional Hire—44 days

RPAs—Request for Personnel Actions
DHA—Direct Hire Authority
DHA–Adv—Advanced Degree
DHA–Bach—Bachelor's Degree
DHA–Vet—Veteran
EHA—Expedited Hiring Authority
Others—Conventional Hire

AFRL Direct Hire Timelines (FY14–16)

FY14

Hiring Authority	# of RPAs Submitted	Average # Days from RPA Initiated to Tentative Offer	Average # Days from RPA Initiated to Effective Date
DHA-Adv	80	28.9	65.6
EHA	44	31.9	66.7
Others	125	64.6	87.2

FY15

Hiring Authority	# of RPAs Submitted	Average # Days from RPA Initiated to Tentative Offer	Average # Days from RPA Initiated to Effective Date
DHA-Adv	114	20.7	60.6
DHA-Bach	68	22.0	55.8
DHA-Vet	2	16.0	60.0
EHA	42	21.8	68.0
Others	151	56.9	83.8

FY16

Hiring Authority	# of RPAs Submitted	Average # Days from RPA Initiated to Tentative Offer	Average # Days from RPA Initiated to Effective Date
DHA-Adv	111	15.6	63.9
DHA-Bach	53	17.2	60.9
DHA-Vet	3	34.2	63.3
EHA	40	37.5	76.1
Others	136	66.3	87.4

Mr. WILSON. This committee has sponsored and the Congress has passed numerous personnel management authorities for the laboratories. The implementation of many of these authorities, such as the direct hire for students from the FY15 NDAA, are still undergoing administrative review and have not been implemented.

From your perspective, what is causing such long delays in implementation?

What impact are these long delays having on lab operations?

The office of the Under Secretary for Personnel and Readiness P&R is responsible for implementing these workforce authorities. Do you feel like P&R is placing sufficient focus or attention on these laboratory workforce issues? What more could or should they be doing?

General MCMURRY. We appreciate the work of Congress to provide continued improvements in personnel authorities. These authorities allow AFRL to be as competitive as possible with industry in attracting top scientists and engineers. AFRL is working with OUSD(P&R) to use all of these authorities provided us to their full extent. Unfortunately there have been very long delays in obtaining many of our legislated authorities. The reason appears to be the fact that OUSD(P&R) no longer has a dedicated office to manage the alternative personnel systems (demonstration projects).. This coupled with significant internal review, to include Office of General Counsel review on most actions, and conflicting guidance, has hampered timely implementation of these authorities.

The delay in approving the legislated student direct hire authority delayed AFRL's plans to establish a robust student hiring plan during the CY16 student hiring timeframe. Past STEM student hiring has been minimal due to quality of applicants, missing documentation that disqualifies qualified applicants, inability to target specific schools, etc. associated with the Pathways program. Through our K–12 STEM Outreach efforts we are establishing an apprenticeship program that will place high school students with technical mentors to accomplish STEM projects. The Student Direct Hire would provide an effective mechanism to continue these students through their college careers.

AFRL had an individual who retired from Google, and was instrumental in establishing Google Maps, that wanted to volunteer with us. Our current Federal Register Notice (FRN) allowed for retired military and civilians to volunteer but not private citizens. The lack of approval on a minor modification we requested in November 2016 resulted in a loss of this valuable, free asset.

The lack of approval of the AFRL FRN for flexible term appointments and temporary promotions has prevented us from using these flexibilities. Considering the requested publication of the aforementioned AFRL FRN for flexible term appointments and temporary promotions was sent to OUSD(P&R) in November 2015, the AFRL minor modification to our Voluntary Emeritus Corps authority was sent in November 2016 and the FY15 and 16 legislated authorities have yet to be approved by OUSD(P&R), I would prefer the system was more responsive. A dedicated staff, a definitive determination when a FRN is needed and a clear, concise process for approval of demonstration project and legislative authorities would be helpful.

Mr. WILSON. Can you tell us for the past three years what your time-to-hire is for each of the various types of direct hire? How does that compare in the same timeframe for traditional government hiring processes?

Dr. HOLLAND. For the past three years, the U.S. Army Engineer Research and Development Center (ERDC) has been able to use its Direct Hire Authorities (DHA) to reduce the time it takes to successfully recruit in the Science, Technology, Engineering and Mathematics (STEM) fields by over 50 percent. The majority of ERDC's

new Direct Hires are graduating students in the science and engineering fields, and an important factor in the successful recruitment of these students is getting a job offer commitment early in the academic year before graduation. Therefore, the most telling measure of the positive DHA impact is the "Initiation to Commit" time, which is a measure of the time between the first steps in the recruit action until the recruit accepts a tentative job offer (pending their graduation in good standing). The average commit times for the last three fiscal years are 21.3 days for ERDC's DHA actions and 44.6 days for our traditional Competitive actions. This critically important 21 day commit time compares even more favorably to the U.S. Army Corps of Engineers (USACE) average of 62 days and the Army average of 81 days over the past three years for Competitive hires. It is clear that the DHA allows the ERDC to target and successfully recruit the best and brightest candidates available in the very competitive STEM fields.

Mr. WILSON. This committee has sponsored and the Congress has passed numerous personnel management authorities for the laboratories. The implementation of many of these authorities, such as the direct hire for students from the FY15 NDAA, are still undergoing administrative review and have not been implemented.

From your perspective, what is causing such long delays in implementation?

What impact are these long delays having on lab operations?

The office of the Under Secretary for Personnel and Readiness P&R is responsible for implementing these workforce authorities. Do you feel like P&R is placing sufficient focus or attention on these laboratory workforce issues? What more could or should they be doing?

Dr. HOLLAND. Management responsibilities in the Office of the Under Secretary of Defense for Personnel and Readiness (P&R) for Alternate Personnel Systems, which includes the Laboratory Demonstration Programs in the Science and Technology Reinvention Laboratories (STRLs), are not assigned to any one office in P&R. Previously, there was one office which focused entirely on Alternate Personnel Systems. This was of great benefit to the STRLs to expedite the publishing of Federal Registers, when needed. The current plan for utilizing personnel demonstration authorities, Department of Defense Instruction 1400.37, includes specific timelines for review of actions by the Components and P&R and is satisfactory to allow Laboratory Directors to utilize the authorities. We are encouraged that P&R is now reviewing this plan and hopeful of positive results to improve and streamline processes to meet Demonstration Project objectives.

Direct hire for students is a very beneficial authority that will allow us to immediately hire students without going through the cumbersome, time-consuming, and restrictive national advertising of these positions. We have robust outreach programs with local schools in four states and Educational Partnership and Cooperative Research and Development Agreements with over 80 colleges and universities. The ability to directly hire students will afford us the opportunity to promote early interest in Science, Technology, Engineering, and Mathematics (STEM)-related fields to bring to bear the best talent to solve the interdisciplinary problems that we address.

The NDAA 2016 includes provisions to assist in the reshaping of the workforce; specifically, Voluntary Separation Incentive Payments (VSIP). Not having this results in our inability to be able to quickly eliminate skills that are no longer needed and acquire new technical capabilities in response to evolving requirements. We are extremely grateful for the support provided by P&R to expand the scope of this flexibility to ensure full utilization of these authorities.

Mr. WILSON. Can you tell us for the past three years what your time-to-hire is for each of the various types of direct hire? How does that compare in the same timeframe for traditional government hiring processes?

Dr. FRANCHI. The average time for Direct Hire for Advanced Degrees to receive a tentative offer from date of receipt of RPA in the NRL Human Resources Office (HRO) is 2 calendar days. To receive a firm offer is 15 calendar days from date of receipt of RPA in the NRL HRO.

The average time for Direct Hire for Bachelors to receive a tentative offer from date of receipt of RPA in the NRL HRO is 2 calendar days. To receive a firm offer is 13 calendar days from date of receipt of RPA in the NRL HRO.

The average time for Direct Hire for Veterans to receive a tentative offer from date of receipt of RPA in the NRL HRO is 13 calendar days. To receive a firm offer is 34 calendar days. The reason for delays include waiting for veterans documentation.

Direct Hire authorities waive the requirement to publish individual vacancy announcements, evaluate candidates, and issue certificates of eligible candidates; whereas direct hire authority allows managers to submit name requests immediately after identification of a qualified candidate. NRL HRO reviews selection

packages to ensure eligibility requirements are met and makes tentative offers within three calendar days of receipt of the RPA.

For traditional delegated examining used to fill NRL positions, it takes on average 97 calendar days from date of receipt of RPA in the NRL HRO to give a tentative offer and 120 calendar days from date of receipt of RPA in the NRL HRO to give a firm offer. The length of time is increased because of the time it takes to prepare job analysis, advertise the position, evaluate the candidates, issue the certificate of eligible candidates, and interview the candidates.

Competition for high-quality S&T candidates in private industry is fierce. Industry is often able to make job offers to candidates on-the-spot. Under traditional hiring methods, it could take 85 plus days to advertise the position, wait for a certificate, and make an offer and by then, candidates may have decided to accept a position elsewhere. With Direct Hire, NRL is able to give a tentative offer within three days of receipt of a hiring action in the Human Resources Office, and a firm offer is typically made within 15 calendar days of receipt of the hiring action which allows NRL to be more competitive with private industry.

See below for S&T hiring statistics for NRL.

FY 2016 EXTERNAL S&T HIRING STATS

Type of Recruitment	# Less than BS	# BS Hires	# MS Hires	# Phd Hires	Total # Hires	*Avg # days to Tent offer	**Avg # days to Firm Offer
Direct-Hire Authority Advanced Degree	N/A	N/A	18	50	68	2	15
Direct-Hire Authority Bachelor's Degree	N/A	17	1	1†	19	2	12
Direct-Hire Authority Veteran's	1	0	0	0	1	29	67
Delegated Examining	4	0	0	0	4	97	111

† PhD was in different field than BS/MS (nonqualifying for position)
* Average time from date recruitment action is received in HRO to tentative offer
** Average time from date recruitment action is received in HRO to tentative offer

FY 2015 EXTERNAL S&T HIRING STATS

Type of Recruitment	# Less than BS	# BS Hires	# MS Hires	# Phd Hires	Total # Hires	*Avg # days to Tent offer	**Avg # days to Firm Offer
Direct-Hire Authority Advanced Degree	N/A	N/A	16	43	59	2	15
Direct-Hire Authority Bachelor's Degree	N/A	28	N/A	N/A	28	2	15
Direct-Hire Authority Veteran's	1	0	2	1	4	6	22
Delegated Examining	3	0	0	0	3	72	87

* Average time from date recruitment action is received in HRO to tentative offer
** Average time from date recruitment action is received in HRO to tentative offer

FY 2014 EXTERNAL S&T HIRING STATS

Type of Recruitment	# Less than BS	# BS Hires	# MS Hires	# Phd Hires	Total # Hires	*Avg # days to Tent offer	**Avg # days to Firm Offer
Direct-Hire Authority Advanced Degree	N/A	N/A	18	41	59	2	15
Direct-Hire Authority Bachelor's Degree	N/A	2	N/A	N/A	2	1	10†
Direct-Hire Authority Veteran's	0	4	3	0	7	4	12†
Delegated Examining	0	4	3	0	4	121	162

† Implemented 8/8/14 at NRL
* Average time from date recruitment action is received in HRO to tentative offer
** Average time from date recruitment action is received in HRO to tentative offer

Mr. WILSON. This committee has sponsored and the Congress has passed numerous personnel management authorities for the laboratories. The implementation of many of these authorities, such as the direct hire for students from the FY15 NDAA, are still undergoing administrative review and have not been implemented.

From your perspective, what is causing such long delays in implementation?

What impact are these long delays having on lab operations?

The office of the Under Secretary for Personnel and Readiness P&R is responsible for implementing these workforce authorities. Do you feel like P&R is placing sufficient focus or attention on these laboratory workforce issues? What more could or should they be doing?

Dr. FRANCHI. Thank you for granting these authorities in the past. Since 2009, NRL has hired 459 scientists and engineers and committed to an additional 43 hires this calendar year using Direct Hire for Advanced Degrees (405 hired/26 committed), Bachelors (48 hired/16 committed) and Veterans (6 hired/1 committed). When DOD STRLs received the authority for Direct Hire for Advanced Degrees, we were able to use the authority within five months of NDAA passage using DOD "implementation guidance". A Federal Register Notice (FRN) was not required to begin using this authority.

When DOD STRLs received authority for Direct Hire for Bachelors and Veterans, we were able to use this authority within eight months of NDAA passage using a FRN. This FRN was drafted by DOD STRLs and together DOD STRLs and the Defense Civilian Personnel Advisory Services (DCPAS) finalized the FRN. DOD OGC determined that a FRN was required for these new authorities; therefore, the Direct Hire for Advanced Degrees was included in this FRN.

The NDAA FY2015, Section 1105, signed into law December 19, 2014, gave DOD Science and Technology Reinvention Laboratories (STRLs) a STEM student direct hire authority (DHA). Over the past 23 months, OSD, in conjunction with the Laboratory Quality Enhancement Program (LQEP) Personnel Subpanel Lead, and Components, have been working towards issuing a FRN for this DHA. Currently, OSD is working with the LQEP Personnel Subpanel Lead and DCPAS to reconcile language regarding probationary periods and removal of student interns. Once a final version of the revised language is mutually agreed upon by the STRLs and OSD the revised final FRN will be sent to the Component and STRL POCs and the FRN will begin formal coordination for approval and publication in the Federal Register.

Without Direct Hire for STEM students, NRL has experienced a significant decline in our student programs. In FY12 (the last year we were under the Student Career Experience Program (SCEP)/Student Temporary Employment Program (STEP)), we hired 171 students, compared to this Fiscal Year in which we hired 92 students (a 46% decrease in hires). Student participation decreased by 62% (we had 429 STEP/SCEP participants in FY12 and 161 Pathways Intern participants in FY16). Pathways requires an announcement and the ability to select the candidate from a certificate, causing a significant delay between the time a hiring manager finds a candidate until the individual may be hired, if the candidate is still available and within reach on the certificate.

Unfortunately, I cannot provide insight into the operations in OSD. All I would say is that the additional workforce authorities would be helpful for us at NRL and we are working closely with DOD and DON offices.

Mr. WILSON. Can you tell us for the past three years what your time-to-hire is for each of the various types of direct hire? How does that compare in the same timeframe for traditional government hiring processes?

Dr. PERCONTI. The average time to make a job offer to a candidate during these last three years using Direct Hire Authorities is 30 days, compared to a historical 150 to 180 day-average using traditional hiring mechanisms. The time-to-hire decrease has significantly helped us to bring on student interns and post-doctoral candidates who bring fresh perspective and ideas to the programs at ARL.

Mr. WILSON. The Army Research Lab has been advocating an open campus concept to try to better bring together commercial and academic innovators to work collaboratively with Army scientists.

How is that effort coming along?

Do you have the right authority and funding to support academic faculty to come to the lab and conduct collaborative research with government scientist and engineers?

For the others, are any of you looking at a similar concept to help spur public-private collaborations?

Dr. PERCONTI. ARL's Open Campus business model has begun to foster a dynamic, cooperative science and technology ecosystem that links government assets with the global research community. Collaboration is centered on mutual scientific interest and investment by all partners. The goal is to lay out the technical program and invite experts in the community to interact, create transformative projects and reach shared goals. Open Campus started as a pilot program. The concept has since morphed into a new business model for Defense science and technology.

Interest in ARL's Open Campus continues to grow. This is made evident by the more than 634 researchers from academia and industry, including 53 from 20 countries, who have moved into and out of the Laboratory under the umbrella of Open Campus. One hundred ninety-five Cooperative Research and Development Agreement projects are active, and 195 additional projects are in staffing. ARL estimates that approximately $40 million of in-kind research has been performed by our open campus collaborators.

The authorities granted through this committee help ARL to accelerate innovation by facilitating closer partnerships derived from Open Campus initiatives. ARL continues to pursue opportunities for Open Campus improvements at Adelphi, Maryland and at the Aberdeen Proving Ground (APG). At APG, initial plans are being explored for new Open Campus facilities for unclassified high performance computing, and facilities for Human Sciences, Sciences for Maneuver, and Materials Sciences. These new facilities are needed to establish a research park-like setting that provides a strong pull for collaborative foundational research at an APG location specifically supporting freedom-of-movement. The Open Campus vision to accelerate Army innovation, facilitated by proximity, using collaborative partnerships between government, industry and academia will not happen unless MILCON funds become available.

Mr. WILSON. This committee has sponsored and the Congress has passed numerous personnel management authorities for the laboratories. The implementation of many of these authorities, such as the direct hire for students from the FY15 NDAA, are still undergoing administrative review and have not been implemented.

From your perspective, what is causing such long delays in implementation?

What impact are these long delays having on lab operations?

The office of the Under Secretary for Personnel and Readiness P&R is responsible for implementing these workforce authorities. Do you feel like P&R is placing sufficient focus or attention on these laboratory workforce issues? What more could or should they be doing?

Dr. PERCONTI. ARL does not have sufficient insight into the office of the Under Secretary for Personnel and Readiness to report for the record what challenges might hinder the implementation of personnel management authorities for personnel systems such as the laboratory demonstration projects in the Science and Technology Reinvention Laboratories (STRL).

However, certain circumstances and choices do impact the laboratory's personnel readiness. The first is the lack of dedicated P&R staff to manage STRL personnel demonstration projects. This leads to a lack of institutional knowledge about the unique flexibilities and features permissible under the demonstration projects, which makes it difficult to hire technical staff in a competitive job market. There are also multiple layers of management oversight involved in staffing the implementing guidance.

Second, the implementation process guidance needs more clarity as it concerns the Federal Register Notice requirement. According to USD (P&R), Civilian Personnel Policy Office, a Federal Register Notice is required in order to implement personnel management authorities granted through legislation, rather than a memorandum that delegates authority and provides implementing guidance. These two documents are similar on the surface, but it may take around two years to implement a Federal Register Notice, while the memorandum may take only two months. It is unclear why a Federal Register Notice, versus a memorandum of instruction/implementation is required to implement legislation. Definitive and written guidance on this requirement will aid in the implementation of legislation.

ARL has been also been negatively impacted in relation to student hiring. Authorities granted by the FY14 (manage workforce to budget) and FY16 (flexible length, renewable term appointing authority and other work force shaping authorities) NDAA, would lift existing personnel restrictions, and allow ARL to begin hiring a larger portion of the federal STEM workforce into flexible-length, renewable, time-limited appointments. Incorporating the speed and agility that would come from fully implementing personnel management authorities for the laboratory would improve the ability of the workforce to match its technical skill set with changing technological trends, missions, and threats, as well as to efficiently manage budget-driven reductions in workforce. It would also enhance the innovative capacity of the ARL by promoting flow of talent between the federal government and academic and industry partners.

QUESTIONS SUBMITTED BY MR. NORCROSS

Mr. NORCROSS. Please explain how you separate the "inherently governmental work" you do in the government labs from work industry should do and how this provides for any competition in accordance with Better Buying Power?

General MCMURRY. AFRL does not award contracts for inherently governmental services (IAW FAR 7.503). The degree of government involvement and expertise necessary to keep sufficient oversight and control of government operations varies by function and situation, depending on such factors as delegation of approval authority, complexity of operation, geographic dispersion of the activity, regulatory authority, and consequence of default. To preclude ceding governmental control and authority of Inherently Governmental functions to the private sector, AFRL conducts a risk assessment on activities proposed to be accomplished by the private sector. This risk assessment for the activity considers such factors as a need for informed, independent judgment, government oversight and the exercise of substantial discretion when applying Federal Government authority. This assessment results in a manpower certification which ultimately determines the activity as inherently or non-inherently governmental. The manpower certification is required, prior to contract award, for all activities performed by the private sector. Once the activity has been determined to be non-inherently governmental, the activity is competitively awarded via a contract. AFRL fully embraces the Better Buying Power competition initiatives, specifically in the areas of market intelligence, fair opportunity competition on Multiple Award Indefinite Delivery Indefinite Quantity contracts and reduction in the reliance of sole source bridge contracts. Through these initiatives, AFRL achieved a 96% competition rate in FY15.

Mr. NORCROSS. Please explain how you separate the "inherently governmental work" you do in the government labs from work industry should do and how this provides for any competition in accordance with Better Buying Power?

Dr. HOLLAND. The Office of Federal Procurement Policy Letter 11–01 of 2011 defines inherently governmental work and is the guiding policy that separates what we do from what Industry should do. The Engineer Research and Development Center (ERDC) contracts with the private sector and academia to support its Science and Technology (S&T) mission, in areas that do not constitute inherently governmental work.

ERDC has a stringent review processes in place, with government management and oversight, of all service contracts, to promote healthy competition in line with the Better Buying Power 3.0 program. These business processes, in conjunction with its overarching S&T strategy, allow ERDC to ensure fiscal responsibility while meeting mission requirements today and into the future.

Mr. NORCROSS. Please explain how you separate the "inherently governmental work" you do in the government labs from work industry should do and how this provides for any competition in accordance with Better Buying Power?

Dr. FRANCHI. As the corporate laboratory of the Department of the Navy (DON), the U.S. Naval Research Laboratory (NRL) conducts basic research, translates the

results of this research into technologies, and assists in the transfer of these technologies to other DON, Department of Defense (DOD), federal, and industrial organizations for incorporation into effective operational military systems. The successful transition of these technologies supports NRL's corporate philosophy that a sustained and well-managed investment in multidisciplinary research and development (R&D) leads to continual improvements to the nation's defense, helps prevent technological surprise by potential adversaries, and can lead to revolutionary and world-changing capabilities, such as NRL's pioneering contributions that led to sonar, radar, satellites, GPS, and, maybe soon, laser weapons and railguns.

As a government laboratory, NRL is a part of the DOD's internal technical capability—the cadre of government S&Es who perform R&D. Their hands-on expertise distinguishes them from the much larger acquisition workforce, which is the primary focus of the DOD's Better Buying Power initiatives.[1] These S&Es provide authoritative advice to the acquisition workforce, which is in turn responsible for managing procurement programs. The two communities serve a common purpose, but they operate within different environments, with different requirements and skills.

Specifically, the DOD's laboratories represent a critical and unique resource for solving the scientific and engineering problems, deficiencies, and needs of the Military Departments. They exist to achieve—in cooperation with universities and industry—a level of technological leadership that shall enable the DOD to develop, acquire, and maintain military capabilities needed for national security. This collaboration with industry and academia is productive and has resulted, from FY11 to FY15, a cumulative total of 75 new Cooperative Research and Development Agreements, 21 new licenses, 513 invention disclosures, 546 patents issued, 7,600 publications, 4,193 refereed journal articles and 40,857 citations.

In particular, this degree of collaboration is vital because industry will not take on the full range of necessary work because many areas hold limited opportunities for profit, and specialized defense technologies often have little or no applicability to commercial products. In addition, R&D is expensive, the time to achieve success is long, the work is often very risky, and the payoff (especially from research) is usually not immediate.

Mr. NORCROSS. Please explain how you separate the "inherently governmental work" you do in the government labs from work industry should do and how this provides for any competition in accordance with Better Buying Power?

Dr. PERCONTI. As it applies to the U.S. Army Research Laboratory (ARL), the Office of Federal Procurement Policy Letter 11–01 of 2011 defines inherently governmental work as those items that guide program priorities. As it pertains to RDECOM, government officials take a leading role in managing, overseeing and performing research in areas that are critical to Army mission requirements, e.g. armor, advanced energetics, etcetera. Often, ARL leads in technology areas that have limited market potential or return-on- investment for the private sector. In such areas, the Army must perform in-house research to enable new warfighting capabilities and to counter emerging threats. ARL has developed a technical strategy influenced by the near-, mid- and far-term needs of the Army as outlined in strategic documents such as the Army Operating Concept and in the Army Warfighting Challenges. Within this S&T strategy, ARL has identified research areas in which it will lead, and those which are addressed either by collaborating with or following research occurring in industry and academia. Through ARL's Open Campus business model, the organization is working even more closely with industry and academic partners to leverage resources and focus efforts towards Army-specific applications at early stages of technology development. ARL offers a variety of collaboration mechanisms promoting competition consistent with Better Buying Power 3.0. By focusing the Army's S&T resources with this strategy, ARL ensures fiscal responsibility while shaping the technology investments necessary for the future force

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[1] Better Buying Power (BBP) 3.0 reflects the "commitment to continuous improvements in the defense acquisition system. Under the overarching theme, *Achieving Dominant Capabilities through Technical Excellence and Innovation,* we are strengthening our efforts in innovation and technical excellence while also continuing the Department's efforts to improve efficiency and productivity that began under BBP 1.0 and 2.0" [ref: USD (AT&L), "Better Buying Power Fact Sheet", 2015. http://www.acq.osd.mil/fo/docs/BBP3.0FactSheetFINAL.PDF].