Outside Witness Testimony
"Driving Innovation through Federal Investments"
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The Johns Hopkins University Applied Physics Laboratory (APL) appreciates the opportunity to provide outside witness testimony to the U.S. Senate Committee on Appropriations. We commend the Committee Chair and Members for their support of research and development funding that safeguards our nation and its citizens, advances the frontiers of science, and creates the technologies that drive our economy and ensure America's global competitiveness.

The Applied Physics Laboratory is an independent, not-for-profit component of The Johns Hopkins University that has worked alongside federal government sponsors for more than 72 years. We are a University Affiliated Research Center (UARC) that is directly engaged in the application of science and engineering to solve some of our nation's most critical challenges in fields such as air and missile defense, space science and engineering, cyber security, nuclear security and deterrence, undersea warfare, homeland protection, and biomedicine and health care.

The Laboratory's dedicated scientists, engineers, and staff members focus on activities that are vital to sponsors in the Department of Defense, the National Aeronautics and Space Administration, the Department of Homeland Security, the Intelligence Community, and many federal agencies. We also maintain independent research and development programs that explore and advance emerging technologies and concepts to address future national priorities.

APL is distinctly different from other types of organizations that operate across the research and development landscape. As a UARC, we have comprehensive policies in place to prevent personal and organizational conflicts of interest. Thus, we are trusted with sensitive, proprietary technical information from government and commercial sources to provide our research sponsors with highly qualified, independent technical advice and engineering expertise to help them develop the most innovative, practical, and cost-effective solutions possible. In doing so, we substantially lower the technical and financial risks associated with complex, multi-generational systems development projects funded by the federal government.

We firmly believe that sustained federal investments in science and technology are vital to our national security, our economic prosperity, and the future of our nation. Federal investments in science and technology created the systems that ensure our nation's security today; they fuel the scientific discoveries and innovations that will serve our society and drive our economy tomorrow; and they create the marketplace that employs the American scientists and engineers who are vital to our nation's future.

The following examples illustrate the impact and substantial value of federal investments in science and technology at APL. They range from the development of technologies that protect our national security to major advances in health care, as well as others with defense and commercial applications. In most cases, these investments result in technologies that are transitioned to industry where they contribute to commercial innovations and our nation's economic growth.

Federal Investments in Science and Technology Drive APL Innovations

APL was established in 1942 as part of efforts to mobilize America's scientific leaders in support of the war effort. Our task was to develop better ways for U.S. Navy ships to defend themselves against deadly enemy air attacks. To that end, APL designed, built, and tested a proximity fuze that significantly increased the effectiveness of anti-aircraft shells, a development that was judged to be among the three most valuable technologies of the war (along with the atomic bomb and radar). After the war, APL's expertise in air defense, communications, missile technology, and guidance systems provided our nation a critical edge during the Cold War and led to many scientific and commercial breakthroughs.

In the early 1960s, APL scientists with federal funding developed Transit, the world's first satellite-based navigation system and the forerunner of today's modern Global Positioning System (GPS) technology. Initially designed and funded to help nuclear-powered Navy submarines pinpoint their locations around the globe, Transit innovations led to the development of many other technologies. Among them are the ultra-stable oscillator needed to maintain precise frequencies and time and the use of dual frequencies to overcome the signal-distorting effects of the Earth's atmosphere, both of which are essential for modern navigation and telecommunications.

In 1967, the Transit system was released to private industry and became the reference system for ocean navigation, oil surveying, international boundaries, and other critical measurements. Transit-related technologies also led to lifesaving innovations, including the control system for modern pacemakers, the implantable cardiac defibrillator, and medical delivery systems that were the forbearer to insulin pumps. If not for the federal investments in science and technology required to develop Transit, these important developments that have benefited society and our nation's economy would not have been possible.

Throughout the succeeding decades, federal investments in research and development at APL resulted in technologies that enhanced our national security and led to new innovations. As adversary missiles became more capable during the 1970s and 1980s, we developed the technologies that allow the U.S. Navy's major surface ships to integrate air defense systems. Two of these systems, Aegis and the Cooperative Engagement Capability, are today the foundation of Navy integrated air and missile defenses that protect our forward-deployed surface ships, and we continue to improve these critical systems.

The same missile-defense technologies used to protect Navy ships were applied six years ago in what became known as *Operation Burnt Frost* to eliminate the threat posed when an unstable satellite carrying dangerous frozen hydrazine fuel began to re-enter Earth's atmosphere. Given its potential to impact an urban area and cause widespread casualties, government officials tasked the Missile Defense Agency to use its Aegis capability to destroy the satellite. As technical lead for Aegis, we worked with Navy and industry partners to develop the approach, testing, and simulations required to ensure a successful intercept, all of which were completed within a matter of weeks.

By the beginning of the 21st century, our space science and engineering programs had delivered the first landing of a spacecraft on an asteroid, the first stereo images of solar flares, and instruments that provided evidence of water on the moon, Mars, and Mercury. The engineering expertise gained through the NASA-funded Near Earth Asteroid Rendezvous mission is leading to experimental missions to alter the paths of asteroids that could in the future threaten our planet with mass destruction.

Continued federal investments in APL's space science and engineering programs have fueled innovations that span our solar system and provide critical data to scientists and policy makers here on Earth. APL's

model of using advanced technology, focused teams, and effective program management ensures taxpayers get maximum value from these investments. In 2015, the APL-built New Horizons spacecraft will arrive at Pluto for the first reconnaissance of the Kuiper Belt – our solar system's last, true "undiscovered country" – capping the nine-year voyage of this technological marvel that was sustained through federal commitment to science and technology.

The NASA-funded MESSENGER spacecraft, launched in 2004, today continues in its orbit around Mercury due to our investment in heat-deflection and -mitigation technologies, defying dire predictions that a scientifically productive mission to study the planet closest to the sun would cost billions. We are applying many of these ideas and technologies to another APL-designed and -built spacecraft, Solar Probe Plus, which is scheduled for launch in July 2018. Solar Probe Plus will fly through the sun's atmosphere to study the solar wind at its source – gathering data critical to forecasting space weather and its effects on Earth. The knowledge gained from these missions will lead directly to innovations in materials science, communications, and sensors that will benefit our society and economy.

Closer to home, APL leads the Defense Advanced Research Projects Agency (DARPA) initiative known as Revolutionizing Prosthetics – an ambitious effort to develop a realistic prosthetic arm for amputee veterans, many of them young, returning from wars in Iraq and Afghanistan. Federal investments in science and technology are making this "miracle" possible, funding teams of experts at institutions across the country in the areas of signal processing and pattern recognition, neuroscience, electrical engineering, cognitive science, and nanotechnology. After several years of exciting research, an arm is now being fitted on human patients for trials. A steady investment by DARPA, with the support of the Congress and the commitment of many world-class researchers, is allowing patients who are fully paralyzed to control a robotic arm through the power of thought alone. Amputees are now able to control the arm through enhanced neural interfaces that provide the sensation of touch and feel. The area of brain-computer interfaces, in particular, is poised for further revolutionary technologies and commercial applications.

Federal investments in science and technology also continue to make our nation more secure against the threat of biological attacks, disease outbreaks, and weapons smuggled through our nation's ports and transportation systems. Our ESSENCE (Electronic Surveillance System for the Early Notification of Community-based Epidemics) data-fusion capability identifies emerging biological threats over broad regions and can identify and track early-stage epidemics. The system is being used in most states and in several countries around the world, allowing governments to quickly detect the spread of disease. DARPA funding also allows APL to work with Johns Hopkins Medicine and Harvard University to develop bio-defenses against epidemics. This research effort, called Prophecy, rapidly accelerates the evolution of a virus (in a controlled environment) and determines how that virus might mutate, allowing time for the development of vaccines. And with Department of Homeland Security funding, our scientists and engineers are developing instruments that detect dangerous substances and devices at our nation's ports and transportation systems.

We are also leveraging federal investments in science and technology for a number of innovative dual-use technologies. A transparent bandage called Eye PATCH (Protection and Treatment for Combat Healing), which was developed for service members injured in combat, seals and begins healing a wound while the patient awaits higher-level medical care. Our "self-healing" paint, which features micro-scale spheres that open with fresh paint to cover damaged surfaces, has the potential to substantially reduce the billions of dollars spent each year on military maintenance and has tremendous commercial potential. Other federally funded advanced research programs at APL are pioneering new

technologies in cyber security, trusted computing, and infrastructure protection that will benefit our society and protect our economy in years to come.

To ensure these investments provide the maximum benefits to society and our economy, we have steadily increased our efforts to commercialize technologies developed with federal funding. Through APL's Office of Technology Transfer, we strategically identify and implement approaches to commercialize technologies developed at the Laboratory. We work collaboratively with The Johns Hopkins University, peer organizations, entrepreneurs, and businesses to commercialize federally funded technologies with commercial potential. During our most recent fiscal year, we filed 20 regular U.S. patent applications, seven foreign patent applications, and 50 provisional patent applications. We were issued 16 U.S. patents, executed 40 new license agreements, and started four new technology companies in Maryland.

The vast majority of these efforts span multiple years, with each successive advance built on the foundations of the previous ones. As pointed out by the Government Accountability Office and in many studies, stable funding is critical to effective and efficient project management. It also allows effective leveraging of previous advances within and across program areas to make steady progress in increasing our scientific knowledge and in making our nation and economy more resilient.

Finally, we know that education lies at the core of America's economic engine. Federal investments in science and technology create the marketplace that sustains America's intellectual base of scientists and engineers. APL has operated a professional graduate program for the Johns Hopkins University Whiting School of Engineering, focused on advanced education for engineers and scientists. More than 8,000 students have obtained master's degrees in eight different technical areas. With more than 2,000 students and 500 graduating with master's degrees each year, this is the largest professional engineering graduate program in the nation. Increasingly, these eight APL-based programs are partnering with commercial companies to develop tailored master's-level degree courses in a new initiative known as the Partnership Program. The fastest growing program, systems engineering, leverages APL staff expertise in developing complex, prototype systems.

Critical decisions leading to science, technology, engineering, and mathematics (STEM) careers are made by students while still in middle school. It is essential that these students and their parents are inspired to take on the challenges of difficult courses and degree programs by public successes, such as those from APL's scientific missions as well as from the visibility of a stable and exciting employment environment. APL maintains a robust set of programs designed to encourage young people to pursue careers in STEM; thus, we contribute to America's future competitiveness and broaden opportunities for our increasingly diverse society.

Conclusion

For the past seven decades we have relentlessly pursued advancements in science and technology to ensure our national security, create game-changing technologies, and encourage the next generation of scientists and engineers. Federal investments in science and technology ensure our nation's security and provide technologies that contribute to our economic growth. Scientific and technological competition from countries such as China and India is real, and our nation depends on steady and stable federal investments to maintain our technological edge in an increasingly dangerous and competitive world. We commend Members of the Committee for bringing this matter to the attention of the American public, and thank you for your sustained commitment to funding investments in science and technology.