DoD FLEX-4

Mechanisms to Provide Funds for Defense Laboratories for Research and Development of Technologies for Military Missions

Section 2363 of Title 10, United States Code

Office of the Under Secretary of Defense
for Research and Engineering

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*The Navy Appendix B is unavailable as it contains Controlled Unclassified Information; request for this document shall be referred to Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation)

1. Background

The purpose of this report is to provide an overview of the Fiscal Year (FY) 2019 Army, Navy, and Air Force efforts funded under the authority in 10 U.S.C § 2363. In FY 2019, the Secretary of Defense, in consultation with the Military Departments, formally made the decision to refer to the efforts under section 2363 authority as Department of Defense (DoD) Funding Laboratory Enhancements Across (X) Four Categories (FLEX-4).

Section 2363 authority was previously provided under section 219 of the National Defense Authorization Act (NDAA) for FY 2009,[1] as amended by section 2801 of the NDAA for FY 2010, and further amended by 10 U.S.C § 2363(a). Section 220 of the FY 2018 NDAA (Public Law 115–91) formally codifies this authority in 10 U.S.C. § 2363. The authority directs the Secretary of Defense, in consultation with the Secretaries of the Military Departments, to establish mechanisms under which the director of a defense laboratory may use an amount of funds coming into the laboratory for the following purposes:

A. To fund innovative **basic and applied research** conducted at the defense laboratory that supports military missions
B. To fund development programs that support the **transition of technologies** developed by the defense laboratory into operational use
C. To fund **workforce development** activities that improve the capacity of the defense laboratory to recruit and retain personnel with necessary scientific and engineering expertise to support military missions
D. To fund the **revitalization and recapitalization** (repair or minor military construction) of laboratory infrastructure and equipment

Initially, section 219 allowed laboratory directors to spend up to three percent of the budget available to them for the purposes described in the authority. Lab directors, in coordination with their science and technology (S&T) executive leadership, could determine the percentage of their lab funding to dedicate to section 219, as well as how to allocate that funding across these four areas. The authority proved very popular with laboratory directors, leading Congress to make enhancements to the authority in subsequent NDAAs.[2] Based on the most recent changes to the language, lab directors may allocate not less than two percent and not more than four percent of the funds available to the laboratory for this authority. The funding provided may be used at the discretion of the director of a defense laboratory in consultation with the S&T executive of the Military Department concerned.

[1] The FY 2009 NDAA states that DoD laboratories may use a percentage of funds available to them to conduct research and development and technology transition projects; fund revitalization, recapitalization, or minor military construction of laboratory infrastructure; and fund workforce development activities that enhance their capacity to recruit and retain scientists and engineers. For the purpose of this authority, "laboratory" or "laboratories" refer to a facility or group of facilities owned, leased, or otherwise used by the Military Departments for research, development, or engineering by employees of DoD.

[2] Section 212 of the NDAA for FY 2017 further modifies the authority by amending the amounts available to the laboratory director from "not more than three percent" to "not less than two percent and not more than four percent." The same section also makes the authority permanent and increases the upper threshold for minor military construction projects from $4 million to $6 million, and allows laboratory directors to charge customers a fee of up to four percent of the increased cost of performance fee in order to raise funds for use under the laboratories' section 219 authority. Finally, section 220 of the FY 2018 NDAA formally codifies section 219 authority in 10 U.S.C § 2363, while repealing Section 219.

DoD is critically dependent on technological advances to respond to emerging threats and to assure U.S. military superiority. However, since neither science nor threats are static, there is sometimes a misalignment of defense planning, budget cycles, and responses to rapidly evolving threats and opportunities. Section 2363 authority gives DoD laboratories additional flexibility to rapidly exploit scientific breakthroughs or respond to emerging threats outside of the normal budget cycle. This authority also allows labs to jump start longer-term initiatives to position themselves for key future advances, particularly through the funding of workforce development initiatives to build and shape the technical talent pool to address new and emerging technology areas. Additionally, laboratory revitalization and recapitalization projects can be used to orient and adapt the facilities and infrastructure footprint to new technology missions. This flexibility increases the rate of innovation and accelerates the development and fielding of needed military capabilities to address current and future problems.

With the repeal of section 219, this report is no longer a required annual congressional report. However, cognizant of the value of maintaining broad awareness of the use of this authority, the Office of the Under Secretary of Defense for Research and Engineering, Laboratories and Personnel Office, in consultation with the Military Departments, will: (1) collect information on achievements, best practices, lessons learned, and challenges; (2) release the information to the public in unclassified form; and (3) disseminate the information, if applicable, to appropriate civilian and military officials in classified form. This will allow the Department to maintain the drumbeat of collecting data and inputs on the usage of laboratory funding for research and development (R&D) of technologies for military missions, and factor it into longer-term budget planning and overall modernization efforts within the S&T enterprise.

Since the inception of the authority, the defense laboratories have invested more than $2 billion across the four categories listed above—investment that would not have been possible otherwise. This report covers FY 2019 activities by the Military Departments' laboratories. A comparative analysis is also included to track key trends across multiple years. The Military Department-wide funding under this authority during FY 2019 was $529.8 million, an increase of $70 million over last year's funding. This was due to a combination of both increases in funding available to the laboratories as well as changes in the percentage charged for the purposes of this authority.

2. Summary of FY 2019 Activities

In FY 2019, the Army, Navy, and Air Force used the DoD FLEX-4 authority to fund a variety of activities addressing DoD's scientific and engineering capabilities, science and technology personnel, and technical infrastructure critical to our Warfighters' effectiveness. Distinct trends in the Military Departments' investment approaches were discernable:

- The Army collected a total of $157.1 million across 255 projects/activities. This represents a 22 percent increase compared to FY 2018. In FY 2019, the Army funded 87 innovative basic and applied research projects compared to 78 in FY 2018, 35 technology transition projects compared to 24 in FY 2018, 64 workforce development activities compared to 49 in FY 2018, and 69 infrastructure revitalization/recapitalization projects compared to 78 in FY 2018. As in previous years, the Army spent the bulk of the DoD FLEX-4 funds on improving and updating infrastructure, which accounted for $79 million, or 50 percent, of all FLEX-4 funding.

- The Navy collected a total of $286.6 million across 1,529 projects/activities. This represents a 12 percent increase compared to FY 2018. In FY 2019, the Navy funded 480 innovative basic and applied research projects compared to 491 in FY 2018, 272 technology transition projects compared to 205 in FY 2018, 675 workforce development activities compared to 720 in FY 2018, and 102 infrastructure revitalization/recapitalization projects compared to 81 in FY 2018. The Navy spent the bulk of the DoD FLEX-4 funds on technology transfer, which accounted for $90.7 million, or 32 percent, of all FLEX-4 funding.

- The Air Force collected a total of $86.1 million across 51 projects/activities. This represents an 11 percent increase compared to FY 2018. In FY 2019, the Air Force funded 18 innovative basic and applied research projects compared to 15 in FY 2018, 25 workforce development activities compared to 23 in FY 2018, and 8 infrastructure revitalization/recapitalization projects compared to 10 in FY 2018. As in previous years, the Air Force spent the bulk of the DoD FLEX-4 funds on improving and updating infrastructure, which accounted for $37.3 million, or 43 percent, of all FLEX-4 funding.

Table 1 summarizes the implementation of this authority by the laboratories within the Army, Navy, and Air Force. Information on the projects and efforts executed by the Services can be found in Appendices A, B, and C.

Service	FY 2016 Funding	FY 2017 Funding	FY 2018 Funding	FY 2019 Funding	Description of FY 2019 Investments (Million = M)
Army	$82.7M	$101.8M	$124.6M	**$157.1M**	- **$36.7M** Basic and Applied Research programs - **$17.6M** Technology Transition - **$23.8M** Workforce Development - $**79.0M** Infrastructure Revitalization
Navy	$114.3M	$124.8M	$250.9M	**$286.6M**	- **$69.6M** Basic and Applied Research programs - **$90.7M** Technology Transition - **$77.6M** Workforce Development - **$48.7M** Infrastructure Revitalization
Air Force	$67.7M	$74.6M	$83.2M	**$86.1M**	- **$32.5M** Basic and Applied Research programs - **$16.3M** Workforce Development - **$37.3M** Infrastructure Revitalization

Table 1 – Summary of Activities

The Service-wide funding under this authority during FY 2019 was $529.8 million. Infrastructure revitalization constituted the largest investment at $164.9 million (32 percent). Basic and applied

research constituted the next greatest investment at $138.8 million (26 percent), followed by workforce development at $117.7 million (22 percent) and technology transition at $108.3 million (20 percent).

3. Trends

DoD FLEX-4 provided laboratory directors considerable flexibility to initiate S&T projects that are prioritized at the local level and that may not be directly mapped to defined requirements. This section reviews key trends in investments using these funds from FY 2014 to FY 2019. To illuminate these trends, an analytical approach proves useful to: (1) analyze changes in investment across fiscal years (total DoD investment as well as the individual investments from the Army, Navy, and Air Force that sum to this total) and (2) analyze changes in the investment patterns employed by the Military Departments—that is, their allocation of investments among activities that advance basic and applied research, technology transition, workforce development, and infrastructure revitalization. Taking this approach imparts an understanding of how the choices made in DoD FLEX-4 investment translate into specific improvements in performance across the Defense Laboratory Enterprise.

Each Military Department has continued to use discretionary funds to fund highest priority projects—those with substantial promise for generating and sustaining innovation throughout the Department's laboratory enterprise. Concurrently, each Military Department also regularly reviews new opportunities for implementation to find ways to improve the use of the authority. The ability to implement the authority in four discrete investment areas gives the laboratories the flexibility to make improvements based on mission needs and to tailor their programs accordingly.

3.1 Aggregated Funding

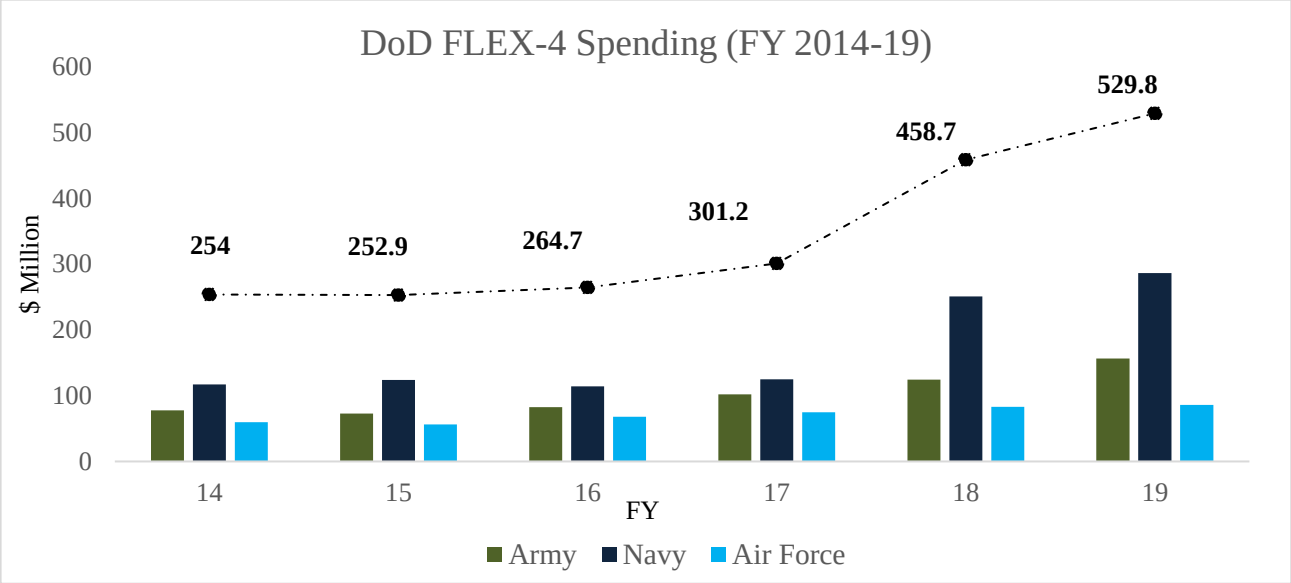


Figure 1 – Funding FY 2014–2019

FY 2014–2019 data reveals key trends in the use of discretionary funding (Figure 1). Total investment was relatively flat across all three Military Departments from FY 2014 to FY 2017. It spiked in FY 2018 resulting from increased funding for the Navy. FY 2019 saw an increase in funding across all three Military Departments.

The Army's spending levels remained comparatively stable, hovering around the $80 million mark between FY 2014 and FY 2016. However, in FY 2017, the Army's spending level rose a dramatic 23 percent over the previous fiscal year, likely the result of a new Army policy, implemented in 2017, that requires laboratories to apply the burden rate to all core Army S&T funding (budget activities one through three). In FY 2019, Army spending saw a 22 percent increase over FY 2018.

Although, the Navy allocated the least amount of funds to discretionary projects when the authority was first granted for FY 2010 that has since changed. In FY 2019, the Navy's discretionary spending under this authority reached historic highs, climbing 145 percent from FY 2014 levels to $286.6 million in FY 2019.

3.2 Investment Breakdowns

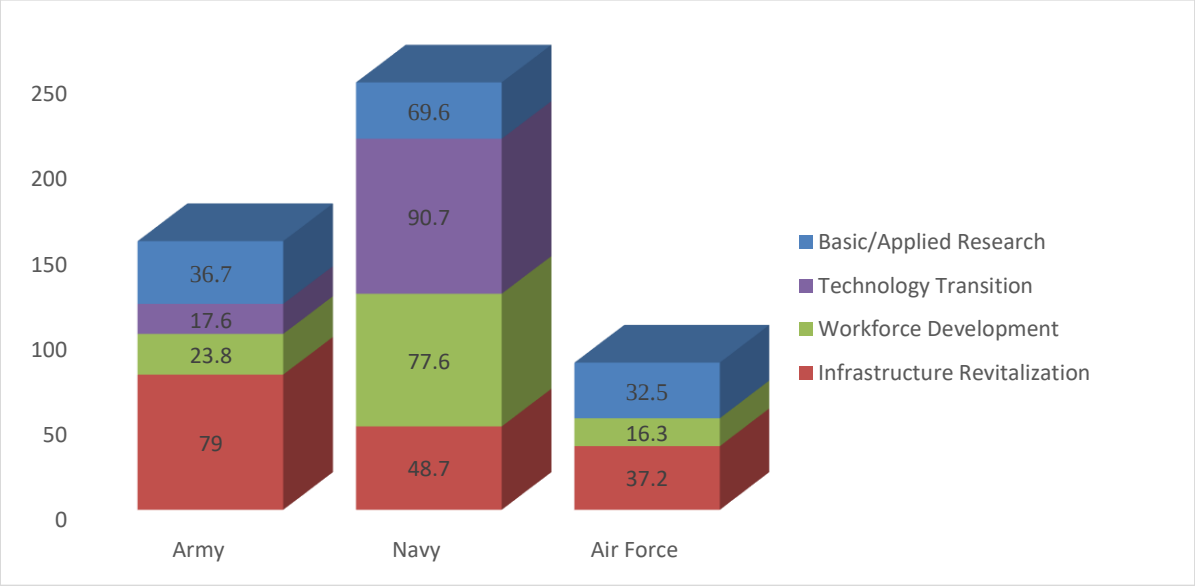


Figure 2 – FY 2019 Investment Breakdown by Military Department

Within each Military Department, the laboratories have clearly defined priorities. These priorities inform the approaches that the Military Departments take in leveraging the subject authorities to fund key investment areas. Figure 2 illustrates the preferences the Army, Navy, and Air Force give to investment areas when choosing how to allocate funds in: (a) basic and applied research, (b) technology transition, (c) workforce development, and (d) infrastructure revitalization.

- The Army focused its discretionary spending on 69 infrastructure revitalization projects, with investment of $79 million, to maximize the research capabilities at the laboratories. Over the past few years, the U.S. Army Combat Capabilities Development Command (CCDC) Chemical

Biological Center (CBC) has invested these funds in infrastructure master planning activities as well as in a building study for restoration and modernization. As a result of these investments, efforts will continue over the next year to facilitate the full design and execution of the military construction (MILCON) plan and the restoration of one of CCDC CBC's major, historic buildings to a modern laboratory facility.

- The Navy biggest spending amount was on technology transfer projects with an investment of $90.7 million. The authority provided a mechanism for the Navy to fund 272 technology transfer projects/activities that would not have been funded at the laboratories otherwise. The Navy's investment focused on fleet requirements; future and advanced technologies including artificial intelligence, machine learning, and autonomous systems; innovation; and collaboration opportunities for technology transition. One project of note was the technology transition of the Autonomous Environmental Tactical Decision Aid (AETDA) project. As part of the project, four workstations with AETDA were deployed to the Fleet for testing and evaluation under operational conditions. This project received the 2019 Naval Air Warfare Center Aircraft Division Naval Innovative Science and Engineering (NISE) Outstanding Project of the Year award in the technology transition category.

- With the smallest amount of funding, the Air Force focused the majority of its spending on eight infrastructure projects, investing $37 million on them in total. These funds continued to provide up to $6 million in MILCON/minor MILCON projects, focusing on research facility improvement projects that support the strategic R&D objectives of the Air Force Research Laboratory (AFRL) and the Air Force S&T 2030 Strategy. Facility projects absorbed another 43 percent of the FLEX-4 budget for FY 2019; near-year projections are expected at similar or rising levels. The Air Force investment leveraged existing infrastructure to create a national facility for the Skywave technology development project. These funds established a corporate AFRL security facility that meets the current and future demands for the Wright Site Corporate Secure Facility by placing multiple classified activities under one roof. The Air Force continued to build on the progress made in 2018 to restore the readiness of the force, increase lethality, and modernize cost-effectively.

The variation in preferred investment areas—across the Services as well as within a given Military Department year to year—underscores the utility of having flexible authorities in place that can be implemented based on a particular Service or laboratory need. As a whole, the Defense Laboratory Enterprise benefits by having the ability to invest in all four categories (Figure 3).

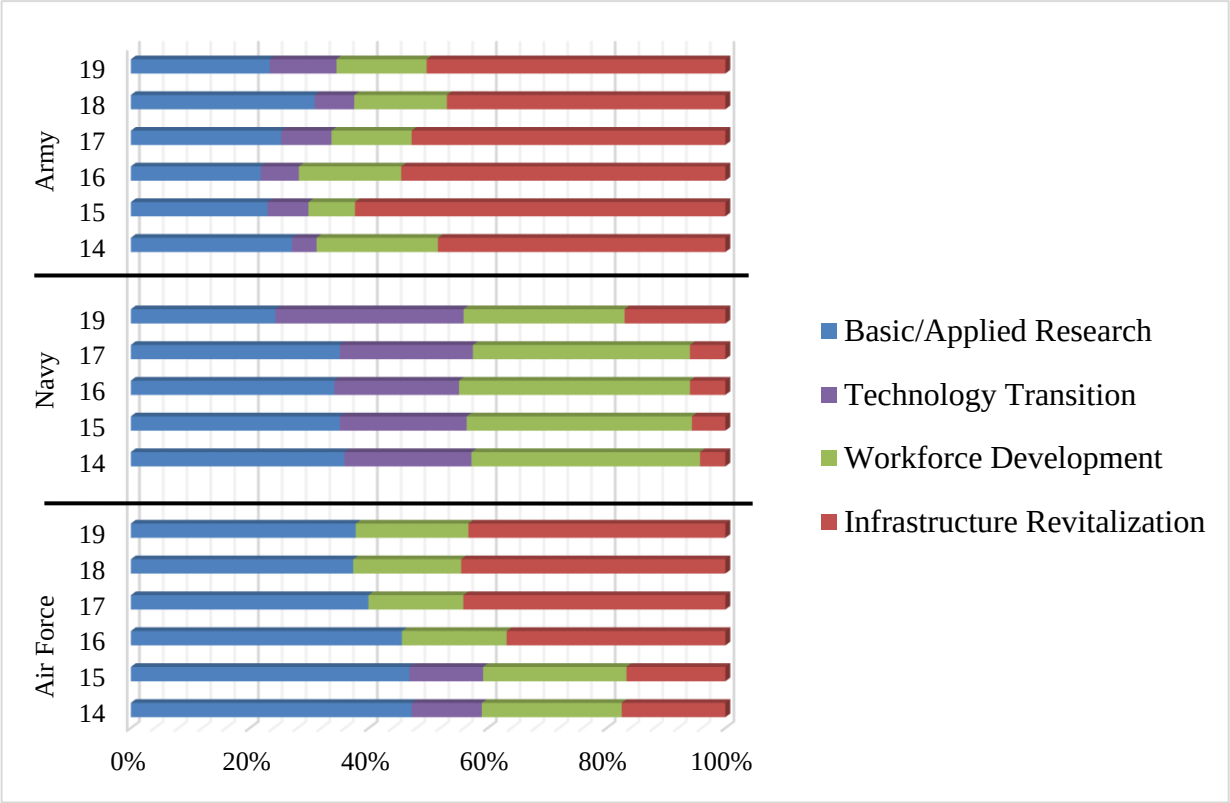


Figure 3 – Percentage Breakdown of Investment Area by Fiscal Year and Service

In FY 2019, the Army applied a total of $157.1 million to 255 projects and activities. The Army's sources of funds included a combination of Research, Development, Test, and Evaluation (RDT&E), Other Procurement Army, and Operations and Maintenance Army funding, in addition to reimbursable customer funding sources. During FY 2019, the authority provided a mechanism to fund many critical activities that otherwise would not have been funded, including numerous innovative in-house research projects, activities to commercialize and transfer dual-use technologies to industry partners, investments for upskilling the Army's civilian scientist and engineer workforce, and critical infrastructure investments to maximize the research capabilities at the laboratories.

In FY 2019, the Navy applied roughly $286.6 million to 1,529 projects. The NISE program implemented the subject authority for the Department of the Navy. In FY 2019, the NISE program invested in research projects, technical training, and other workforce development innovations to grow the technical capabilities of Navy scientists and engineers (S&Es). Around 189 S&Es began their journeys toward an advanced degree, and 85 S&Es obtained their advanced degrees. The program also invested in the development of the infrastructure necessary to support the rapid discovery, maturation, and transition of new science, technologies, and engineering innovations. As part of the investment strategy, many of the warfare centers and laboratory incorporated in their project selection processes a focus on closing the technology gap to defeat and deter future threats and adversaries. The guidance informing laboratories' priorities for project selection included the National Defense Strategy (NDS), the Chief of Naval Operations' Design for Maintaining Maritime Superiority, the Department of the

Navy's 30-year RDT&E plan, and the laboratories' individual missions, functions, and tasks. Finally, NISE investments supported the development and protection of the enterprise's intellectual capital. FY 2019 registered 132 patent actions, including 33 patent awards, 59 patent filings, and 40 patent disclosures.

In FY 2019, AFRL allocated a total of $86.1 million to 51 projects and initiatives. It collected these funds through an assessment of all AFRL core program elements, as well as program elements devolved to AFRL. An AFRL management decision funded technology transition through other budgets to allow the DoD FLEX-4 funds to focus on research and development, workforce development, and infrastructure improvements.

Approximately a quarter of the basic and applied research funding was used as venture funds for seedling initiatives serving as a proving ground for new concepts. Ongoing and new R&D funding represented about 38 percent of the FY 2019 DoD FLEX-4 budget. DoD FLEX-4 funds were applied to projects that enhanced recruiting, increased current and future workforce skills (including science, technology. engineering, and mathematics outreach), and supported the operational costs of AFRL institutes. Institutes executed the majority of the workforce development budget at about 70 percent of spending, with workforce development projects executing the remaining 30 percent. This category received about 19 percent of the FY 2019 DoD FLEX-4 budget. Infrastructure revitalization funds, including up to $6 million in MILCON/minor MILCON projects, focused on state-of-the-art research facility improvement projects to support strategic R&D objectives of AFRL and Air Force S&T 2030 Strategy. Facility projects accounted for 43 percent of the DoD FLEX-4 budget for FY 2019.

3.3 Implementation Challenges

Table 2 details the implementation challenges of this authority by the laboratories within the Services (see below).

Challenge	Service	Details
Funding	All	This authority does not change the obligation period on the funds. The funding limited by general budget regulations: a two-year obligation for RDT&E funding, a one-year obligation for operations and maintenance funding, etc. Therefore, DoD does not have the means to accumulate the funding authority for infrastructure revitalization.
	Army	In accordance with this authority, reimbursable customers with substantial reimbursable funding lack of understanding of the 10 U.S.C. 2363 rate and activities.
	Air Force	Refine use of a separate program element category for internally reprogrammed funding in the year of execution after receipt of the appropriation. This provides the AFRL Commander flexibility to align funds for this authority as needed.
Approvals	All	Implementation of infrastructure revitalization projects beyond $6 million requires Service Secretary approval, which can be challenging and time consuming to acquire.

Table 2 – Implementation Challenges

4. Across the Military Departments

This section summarizes investment approaches and highlights notable programs across the Military Departments (full reports on Military Department activities are included in Appendices A through C). Overall, the laboratories used a number of execution approaches to fund innovative basic and applied research projects, enhance their workforce development, enrich infrastructure revitalization, and improve technology transition. All of the efforts aimed at furthering U.S. technological advancements to respond to emerging and persistent threats and maintain the Nation's competitive advantage. Each of the Military Departments pursued its own implementation strategy to execute DoD FLEX-4 authority.

4.1 FY 2019 Army Activities (Full Report in Appendix A)

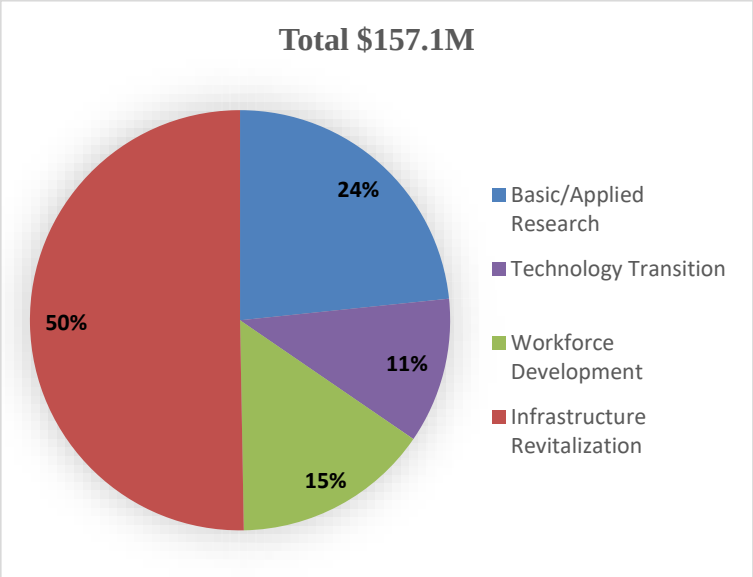


Figure 4 – FY 2019 Army Breakdown

The Army applied an overall burden of 2.73 percent to the funding deemed eligible by the organization's director for DoD FLEX-4 activities, collecting a total of $157.1 million (Figure 4). Individual organizations assessed a percentage between 2.0 percent and 3.6 percent. Participating Army organizations included the Science and Technology Reinvention Laboratories in the Army CCDC, the Army Engineer Research and Development Center, and the Army Space and Missile Defense Command/Army Forces Strategic Command Technical Center.

FY 2019 DoD FLEX-4 policy required laboratories to apply the rate to core Army S&T funding (Budget Activities one through three); application to other funding sources was optional. In FY 2020, in order to obtain funds to carry out activities authorized, the laboratories will be required to develop policies and guidance to leverage all funding sources of the Military Departments.

A summary of the Army's FY 2019 DoD FLEX-4 investment activity is provided in Table 3.

Investments	Number of Projects/Programs/Activities	FY 2019 Investment ($Million)
Basic and Applied Research	87	$36.7
Technology Transition	35	$17.6
Workforce Development	64	$23.8
Infrastructure Revitalization	69	$79
Totals:	**255**	**$157.1**

Table 3 – Army Investment Summary

As in past years, the bulk of the Army's DoD FLEX-4 funds were spent on improving and updating infrastructure. Funds allocated for infrastructure revitalization have steadily increased since FY 2010, rising from $10.9 million in FY 2010 to $58.4 million in FY 2018, then increasing 35 percent to $79 million in FY 2019.

During FY 2019, the DoD FLEX-4 authority provided a mechanism to fund several critical activities that otherwise would not have been funded, including numerous innovative in-house research projects; activities to commercialize and transfer dual-use technologies to industry partners; investments for enhancing the skills of the Army's civilian scientist and engineer workforce; and critical infrastructure investments to maximize research capabilities at the laboratories.

Several notable projects undertaken by Army organizations are summarized below (see Appendix A for a comprehensive overview of investments undertaken in FY 2019).

1. **Army Research Laboratory (ARL):** In the first-ever identification and demonstration of the ability to use and tune metallic, solid-state phase-change materials (PCMs), "Reversible Martensitic Transformations: A New Approach to Managing Thermal Transients" provided a critical breakthrough for the practical implementation of directed energy systems. This new class of PCMs provides an unprecedented two-orders-of-magnitude improvement in cooling figure-of-merit, pulse duration (latent heat), and/or duty cycle (charge and discharge rate), along with a 300 percent reduction in DE thermal management size and/or weight compared to state-of-the-art solid-liquid architectures, for more capable, compact DE assets on smaller platforms with increased continuous operation.

2. **ARL:** "Photonic Circuits for Compact (Room-Temperature) Nodes in Quantum Networks" has led to the design of a photonic circuit and architecture that has the potential to enable quantum information processing using bulk optical non-linearities. A patent application was submitted for this innovative design. ARL discovered a simple circuit that can in theory perform a correction for photon loss. This circuit is much simpler than existing constructions and may point to ways to further simplify future photonic quantum circuits.

3. **Aviation and Missile Center (AvMC):** The continued funding support for the "Manufacturing Technology Maturation and Transition Plan for Missile System Technologies" multi-year project is helping to ensure accelerated maturation and transition of technologies and processes developed within CCDC-AvMC and other defense laboratories and industry to improve the performance, sustainability, and affordability of both legacy and future missile systems.

4. **AvMC:** The center established the "Multi-Core Processor (MCP)" laboratory test beds, laboratory analytical tools, and infrastructure necessary to perform detailed MCP analyses and test evaluation procedures. The MCP laboratory has been successful in developing a set of high-level "draft" MCP safety and airworthiness qualification requirements and has coordinated these requirements with the Navy, Air Force, Federal Aviation Administration, industry, and several academic institutions.

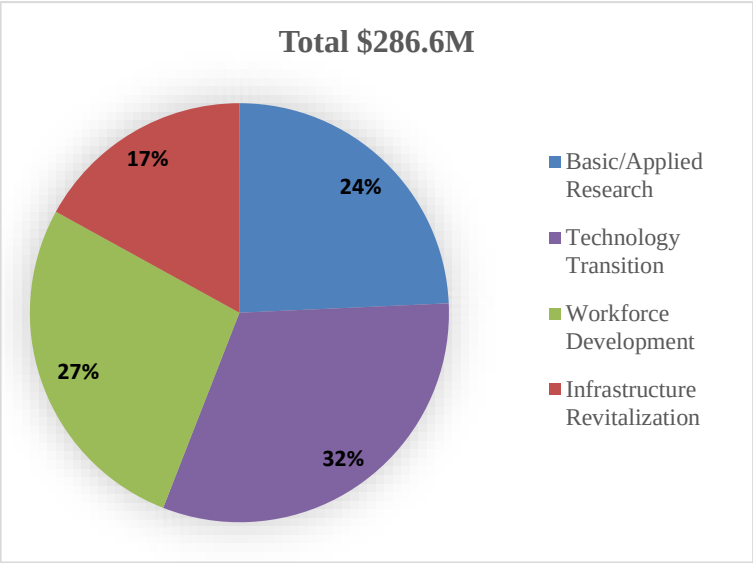
5. **C5ISR Center:** Building off the previous year's accomplishments, the "Cloud-Based Machine Learning for Electronic Warfare" project has expanded in-house expertise and started two pilot studies to provide foundational proofs-of-concept supporting the Future Vertical Lift Cross-Functional Team.

6. **Army Engineer Research and Development Center (ERDC):** The work performed under "Unlocking the Physics of Near-Surface Soil Mechanics" returned immediate results when the researcher received an unsolicited letter from a senior firefighter in Western Australia about the impact his work was having. Papers published on soil physics have changed the way the Australians do training for trench rescues, reducing set-up time and, more importantly, casualties. While not necessarily the intended result of the project, this success will transfer directly to a number of areas in the U.S. Army.

7. **ERDC:** Researchers were awarded a U.S. patent, "Method of Recycling Chitosan and Graphene Oxide," as a result of work funded under the "Advanced Graphene Enabled Technologies for Perfluorinated Alkylated Substances (PFAS) Treatment and Enhanced Concrete" project. In addition to the patent, ERDC is now leading the National Defense and Resilience Panel at the Graphene Innovation and Research Conference, and has developed three prototypes for PFAS treatment with demonstrations at Hurlburt Field Air Force Base (AFB), Florida; Misawa AFB, Japan; and U.S. Marine Corps Camp Butler, Japan.

8. **ERDC:** The "Total Watershed Decision Support" team is assisting the Army Science Board in the development of an initiative on a risk-informed continental-scale hydro-terrestrial capability to improve Army Corps of Engineers effectiveness.

4.2 FY 2019 Navy Activities (Full Report in Appendix B*)



In FY 2019, the Navy invested $286.6 million in 1,529 projects; FY 2018 investment was $250.9 million. The Navy warfare centers and laboratory increased their funding rate from one percent to two percent for DoD FLEX-4 activities. They achieved this uniformly implementing a customer fee to all reimbursable tasking under the Naval Working Capital Fund, then channeled into the NISE program. Not only did the Navy increase investments in basic and applied research and workforce development, but it also increased and made comparable investments in technology transition (Figure 5).

Figure 5 – FY 2019 Navy Breakdown

*The Navy Appendix B is unavailable as it contains Controlled Unclassified Information; request for this document shall be referred to Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation)

The Office of the Assistant Secretary of the Navy (Research, Development, and Acquisition) established the NISE program to implement the FY 2009 NDAA section 219 legislation. Utilization of this funding through the NISE program has provided the laboratory directors with the resources necessary to maintain the scientific and technical vitality of Naval in-house laboratories and centers, as well as to increase the rate of recruitment and retention of laboratory and center personnel in critical skills areas of science and engineering. By supporting high-value, potentially high-risk R&D, funds provided by the NISE program have also played an important role in keeping the Navy on the technological edge.

The Navy's DoD FLEX-4 programs in FY 2019 included 1,529 projects across all the Naval warfare centers and laboratory (Table 4). Investments flowed to four program types: innovative basic and applied research ($69.6 million); technology transition ($90.7 million); workforce development programs ($77.6 million); and infrastructure projects for revitalization ($48.6 million). The Navy applies a two percent burden rate on all of its funding.

A summary of the Navy's FY 2019 DoD FLEX-4 investment activity is provided in Table 4.

Investments	Number of Projects/Programs/Activities	FY 2019 Investment ($Million)
Basic and Applied Research	480	$69.6
Technology Transition	272	$90.7
Workforce Development	675	$77.6
Infrastructure Revitalization	102	$48.7
Totals:	**1529**	**$286.6**

Table 4 – Navy Investment Summary

The NISE program delivers unprecedented value to all DoD labs by providing opportunities for S&Es to perform innovative, world-class research in areas of critical importance to the Navy. Information about all the projects and efforts executed by the Naval Research and Development Establishment can be found in Appendix B*.

Several notable projects undertaken by Navy organizations show the breadth and depth of FY 2019 investments.

1. **Naval Air Warfare Center Aircraft Division (NAWCAD)**: The objective of "Autonomous Environmental Tactical Decision Aid " was to execute the design, implementation, testing under mission operational conditions, and demonstration of fleet worthiness through successful mission operation of a tactical decision aid that uses high-performance computing systems to improve airborne anti-submarine warfare mission planning—specifically focused on improving performance estimates for probability-of-detection. This project received the 2019 NAWCAD NISE Outstanding Project of the Year award in the technology transition category.

2. **Naval Surface Warfare Center (NSWC) Carderock Division, NSWC Philadelphia Division, Naval Undersea Warfare Center Division (NUWC), Keyport, Naval**

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Information Warfare Center (NIWC), Atlantic: The collaborative team in partnership with the Marine Corps Warfighting Lab defined, organized, and conducted the 21st Century Maneuver, Logistics, and Force Protection Advanced Naval Technology Exercise (ANTX East 19) in direct support of the NDS and the Fight the Naval Force Forward ANTX Campaign. The exercise focused on expeditionary advanced base operations.

3. **NSWC Panama City, NSWC Indian Head, NIWC Pacific (NIWCPAC):** The collaborative "Mission Ready Unmanned Assault Amphibious Vehicle (MR U-AAV)" project was initiated to equip the Marine Corps with an organic and sustainable unmanned amphibious vehicle integrated with a lane-breaching system to provide a "fight tonight" capability for the fleet. In FY 2019, the MR U-AAV team successfully completed the first unmanned land and amphibious operations with two AAV variants.

4. **NIWC Atlantic:** Swarm Puck will provide a low-cost autopilot swarm package (Puck) capable of performing collaborative behaviors with interchangeable sensor systems on heterogeneous unmanned swarms. In FY 2019, the team designed a system architecture capable of operating heterogeneous systems in a swarm configuration and completed network analysis of alternatives to determine optimal intersystem communication for Puck systems.

5. **NIWC Atlantic, NIWC Pacific:** The "Digital Thread Additive Manufacturing" project is developing and testing a dedicated additive manufacturing (AM) network enclave across Fleet support sites globally. This network would connect 3D printers, store printable models, and store AM reference materials such as lessons learned and best practices.

6. **Naval Research Laboratory:** The "Ultra-Low Cross Polarization in Wideband Phased Arrays" project discovered that an imbalance of electrical currents within the intrinsic notch topology was responsible for the loss of polarization control. The principal investigator used this insight to economically reconfigure the existing notch topology to appropriately balance those problematic currents with an innovative slicing technique, rather than pursue new radiator designs that would lead to a lengthier acquisition process with higher costs and risks.

4.3 FY 2019 Air Force Activities (Full Report in Appendix C)

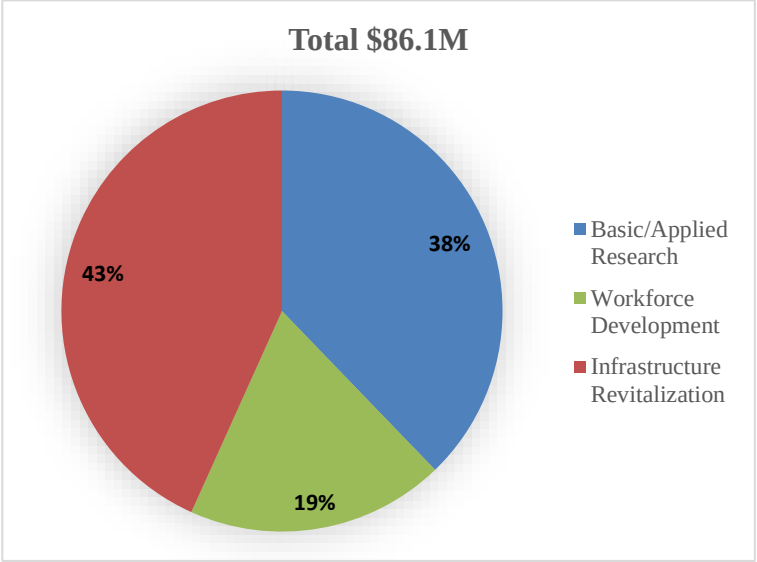

Figure 6 – FY 2019 Air Force Breakdown

In FY 2019, AFRL allocated a total of $86.1 million for DoD FLEX-4 projects and initiatives (Figure 6). This authority provides the Commander, AFRL, in consultation with the Air Force S&T Executive, the flexibility to rapidly exploit scientific breakthroughs or respond to emerging threats. This flexibility increases the rate of innovation and accelerates the development and fielding of needed military capabilities to address current and future problems.

A summary of the Air Force's FY 2019 DoD FLEX-4 investment activity is provided in Table 5.

Investments	Number of Projects/Programs/Activities	FY 2019 Investment ($Million)
Basic and Applied Research	18	$32.5
Technology Transition	0	$0.0
Workforce Development	25	$16.3
Infrastructure Revitalization	8	$37.2
Totals:	**51**	**$86.1**

Table 5 – Air Force Investment Summary

The Air Force did not invest any DoD FLEX-4 funds in technology transition in FY 2019. While this is a notable departure from the funding choices made by the Army and Navy, the allocation of resources was nonetheless consistent with the Air Force's overall approach to DoD FLEX-4 funding: spending heavily on infrastructure revitalization and innovative basic and applied research while spending less on technology transition and workforce development.

Several notable projects undertaken by Air Force organizations show the breadth and depth of FY 2019 investments (see Appendix C for a full report on Air Force DoD FLEX-4 investments in FY 2019).

1. The "Photonic Agility in Contested Environments" project seeks to create transformational laser radar capabilities for non-traditional platforms in contested environments and across multiple domains. The project is replacing large and heavy optical components with fast,

agile electro-optical components, including tunable flat lenses, laser beam steering devices, and dynamic filters and mirrors.

2. The use of high-temperature materials, while enabling, is a major source of risk for hypersonic flight. The overarching objective of the "Enriched Understanding of Hypersonic Materials" project is to gain a complete understanding of materials interactions in hypersonic environments. This will lead to more accurate models of materials performance and input into life-cycle models for high-temperature materials in sustained hypersonic flight.

3. The "Micro-Comb Technologies for Timing, Sensing, EW, and Quantum Applications" project looks to develop optical integrated circuits to add capabilities in broadband signal processing, quantum communication, and precision timing. Signals of interest are increasing in bandwidth, density, and modulation complexity. To stay ahead of these advancements, two techniques—folding and channelizing the spectrum—are key to next-generation systems that will be able to identify these signals.

4. "Sensors for Low Cost Attritable Aircraft Using Additive Manufacturing Technology" is a Commander's Research and Development Funds project focused on exploiting/developing AM capabilities and design tools to embed optimized intelligence, surveillance, and reconnaissance functionality into attritable Air Force platforms. Progress has been made toward demonstration of a prototype array antenna fabricated using existing AM capabilities. Test fixtures based on the XQ-58A Valkyrie Low Cost Attritable Strike Demonstrator (LCASD) platform have been fabricated for integration of the prototype array antenna and evaluation of prototype array survivability in the LCASD aerodynamic load environment. Progress has also been made in development of multiphysics design and optimization tools, integrating Government-owned and Government-developed software tool sets, as well as development of new AM polymer materials and flexible conductive inks to improve the electromagnetic and structural performance of low-cost 3D-printed structures relevant to attritable radio-frequency sensors.

4.4 Appendices

The Service appendices include:

- Appendix A: Army projects/activities investments in FY 2019
- *Appendix B: Navy projects/activities investments in FY 2019
- Appendix C: Air Force projects/activities investments in FY 2019
- Appendix D: Acronyms list

*The Navy Appendix B is unavailable as it contains Controlled Unclassified Information; request for this document shall be referred to Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation)

Appendix A: Army Projects/Activities Investments in FY 2019

Point of Contact Information:
Dr. Matt Willis, matthew.p.willis.civ@mail.mil, (703) 697-0682

Funding Mechanism:
The Army applied an overall burden of 2.73% to the funding deemed eligible by the organization's director for 10 USC 2363 activities with individual organizations assessing a percentage between 2.0% and 3.6%. Participating Army organizations included Science and Technology Reinvention Laboratories (STRLs) in the Army Futures Command Combat Capabilities Development Command (AFC CCDC), the U.S. Army Engineering Research and Development Center (ERDC), and the U.S. Army Space and Missile Defense Command/Army Forces Strategic Command (USASDMC/ARSTRAT) Technical Center.

In Fiscal Year 2019 (FY19), the Army collected a total of $156,428 K for 10 USC 2363 activities, a 22% increase as compared to FY18. Table 1 provides a breakdown of all funds collected through the 2.73% application from research, development, testing and evaluation (RDT&E) and science and technology (S&T) funding, other procurement Army (OPA) funding, Operations and Maintenance Army (OMA) funding, and reimbursable customer funding sources. Table 2 provides any additional funding the laboratory director excluded from 10 USC 2363 collection. Funding specifically excluded from 10 USC 2363 activities included Congressional marks, certain reimbursable customer sources, OMA/OPA, Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), and RDT&E. The FY19 10 USC 2363 policy required laboratories to apply the 10 USC 2363 rate equitably to all funding sources and customers.

Table 1. Army Funding Breakdown

Funding Sources	FY19 Funding Amounts ($K)
Appropriated Army S&T (6.1-6.3)	$2,361,090
Appropriated Army RDT&E (6.4-6.7)	$361,713
Appropriated Other (OPA, OMA, OCO, etc.)	$196,517
Total FY19 Direct Funding	$2,919,320
10 USC 2363 Funding	$82,477
% of Direct Funding	2.83%
Customer / Reimbursable	$2,816,895
10 USC 2363 Funding	$73,952
% of Customer Funding	2.63%
Total FY19 Funding	$5,736,215
Total 10 USC 2363 Funding	$156,428
% of Total Funding	2.73%

Table 2. Excluded Funding Breakdown

Funding Sources	FY19 Excluded Funding Amounts ($K)
Congressional Marks	$1,161,405
Reimbursable Customer	$353,080
OMA / OPA	$ 252,012
SBIR / STTR	$81,474

RDT&E (6.4 – 6.7)	$98,712
Other Excluded Categories*	$1,803,820
Total FY19 Excluded Funding	**$3,570,503**

* Other excluded categories include, but are not limited to, funding for the Student Loan Repayment Program, Engineer and Scientist Exchange Program, major force protection, overseas contingency operations, permanent change of station expenses, Foreign Military Sales, Defense Research Engineering Network (DREN), Army Working Capital Fund, civil works, patent and/or copyright royalties, and awards.

Investments:
In FY19, the Army funded eighty-seven (87) innovative basic/applied research projects, thirty-five (35) technology transition projects, sixty-four (64) workforce development activities, and sixty-nine (69) infrastructure revitalization/recapitalization projects. A summary of the 10 USC 2363 investment activity is provided in Table 3. Please note that the total investment in Table 3 does not match the 10 USC 2363 funds collected in Table 1 due to the two-year RDTE fund expiration.

Table 3. Investment Summary

Investments	Number of Projects/Programs/Activities	FY18 Investment ($K)
Innovative Research	87	$36,671
Technology Transition	35	$17,640
Workforce Development	64	$23,772
Infrastructure	69	$79,073
Totals:	**255**	**$157,156**

Success Stories:

During FY19, the 10 USC 2363 authority provided a mechanism to fund many critical activities that otherwise would not be funded, including numerous innovative in-house research projects, activities to commercialize and transfer dual-use technologies to industry partners, investments for upskilling the Army's civilian scientist and engineer workforce and critical infrastructure investments to maximize the research capabilities at the laboratories. Success story highlights include:

1. **(Armaments Center (AC))** The use of 10 U.S.C § 2363 funding has allowed CCDC AC to address infrastructure gaps such as the need for increased capacity for classified workspace and flexible high bay space. Section 2363 funds allowed CCDC AC to fund critical lab equipment and secure video teleconferencing (SVTC) equipment which will be used in a classified facility, Bldg 472. These funds also allowed for project planning and design of additional classified and flexible high bay facilities to be constructed in upcoming years.

2. **(AC)** CCDC AC's Lean Six Sigma Competency Office (LSSCO), realized a cost avoidance/savings of $29.8M. These cost savings were realized after training 45 employees, who were able to use continuous process improvement strategies on various efforts, which include the CCDC AC Strategic Roadmap for Autonomous and Semi-Autonomous Armaments Systems with integrated Artificial Intelligence, the CCDC AC Baldrige effort, as well as the DoD Ordnance Technology Consortium (DOTC).

3. **(Army Research Laboratory (ARL))** As a result of a $150K investment in an innovative research project (Reversible Martensitic Transformations: A New Approach to Managing

Thermal Transients), the first-ever identification and demonstration of the ability to use and tune metallic, solid-state phase change materials (PCMs) was shown providing a critical breakthrough for the practical implementation of Directed Energy (DE) systems. This new class of phase change material provides an unprecedented two-orders-of-magnitude improvement in cooling figure-of-merit, pulse duration (latent heat), and/or duty cycle (charge and discharge rate), along with a 300% reduction in DE thermal management size and/or weight, compared to state-of-the-art solid-liquid architectures, for more-capable, compact DE assets on smaller platforms with increased continuous operation.

4. **(ARL)** An investment of $150K in another innovative research project (Photonic Circuits for Compact (Room-Temperature) Nodes in Quantum Networks) has led to the design of a photonic circuit and architecture that has the potential to enable quantum information processing using bulk optical non-linearities. A patent application was submitted for this innovative design. ARL discovered a simple circuit that can in theory perform a correction for photon loss. This circuit is much simpler than existing constructions, and may point to ways to further simplify future photonic quantum circuits.

5. **(Aviation and Missile Center (AvMC))** The Artificial Intelligence 2363 Program is a "2363" funded effort intended to help prepare the Aviation Engineering Directorate workforce for the coming wave of advanced technology that falls broadly under the label "Artificial Intelligence" (AI). It is working to analyze various operational scenarios for Army Aviation that include advanced CONOPS, meaning: that range of Future Vertical Lift concepts that extend current progressive strategies and bring new ones: MUM-T, advanced teaming, digital wingman, cockpit R2D2, etc. The functionality required to implement these advanced capabilities can be analyzed to determine the possible range of AI tech necessary. The AI2363 Program has already achieved in the main areas of its focus including Workforce Development, Collaboration, and AI Technology. Georgia Tech Professional Development course was offered in Huntsville in an effort to socialize the work in Advanced Tech to interested individuals and provide new analytics, techniques, algorithms, and more to advance the AI2363 program. The program has allowed for collaboration with Joint Forces including the Air Force, NASA, DARPA, OSD, and the Army AI Task Force. The AI Technology is being used to close the loop and synergize the use of our current resources to inform final outcomes. This aided in the development of Use Cases by the program to improve and gain understanding for processes, requirements, documentation, and experience gained through participation in current progressive Acquisition Programs (UCS software infrastructure, AMCS/IDM, FARA, FLRAA, Gray Eagle, and others).

6. **(AvMC)** The Development of Aviation Data Science Technologies 10 USC 2363 Investment is being utilized to transition data science technologies into engineering processes to inform health state awareness. Specifically, the Aviation Engineering Directorate (AED) has developed an H-60 Oil Cooler Spectrum Reconstruction model, which provides PM Utility, AED, and other stakeholders a method to fill in missing frequency spectrum data. Integration of this model into existing engineering processes is ongoing. It is noteworthy that for the first time the entire H-60 CBM data set is now hosted on supercomputers at the Engineering Research and Development Center. In addition, we developed "big data" search and query tools. As a result of these efforts, engineers are now able to efficiently assess health state awareness of H-60 aircraft.

7. **(AvMC)** The continued funding support for the Manufacturing Technology Maturation & Transition Plan for Missile System Technologies multi-year project is helping to insure accelerated maturation and transition of technologies and processes, developed within CCDC-AvMC and other defense laboratories and industry, improving the performance, sustainability and affordability of both legacy and future missile systems. Execution of this effort is equipping both CCDC-AvMC Missile S&T subject matter experts (SMEs) and Program Executive Office

Aviation (PEO MS) customers with an understanding of manufacturing technology gaps, risks and the investment requirements to 1) reduce the sustainment costs of legacy systems and 2) meet/improve the affordability metrics of future designs at the appropriate time horizon. Development and implementation of this plan will increase support to Army Modernization Priorities, highlighting major manufacturing technology thrust areas, capability enhancers and disciplines offering step-function increases in performance and continued theater overmatch.

8. **(AvMC)** The 10 USC 2363 funding support to stand-up the CCDC AvMC Energy Laboratory (AEL) initiated by the Engineering Directorate senior management has transformed a warehouse industrial storage/operations facility into a robust working environment. This new working environment has provided the optimal environment for CCDC AvMC Energy Laboratory personnel to provide crucial support to Program Manager Offices with innovative hybrid energy solutions beyond PM Generator (E2S2) mission, fulfilling aviation and missile PMO critical power needs. As an example, the Autonomous and Robotic Remote Refueling Point (AR3P) is being developed and managed within the AEL with collaboration with the Aviation Development Directorate (ADD). The AR3P system supports the Army's "Demand Reduction" initiative and both the Aviation and the Maneuverability Systems Centers of Excellence. A “dry engagement” of a Mosquito UAS was accomplished on 13 Sep and witnessed by members of PEO Aviation and OASD Operational Energy lead. A Cold Refuel of a UH-60L aircraft is scheduled for Dec 2019 at ADD- East in Ft Eustis VA.

9. **(AvMC)** T-Funding was provided to Hampton University to purchase supplies and provide tuition assistance to a team of 3 researchers who completed their senior Capstone Design Project entitled, “Automated UAV Charging Station. They built a prototype system that could automatically remove the battery from a commercial quadcopter, insert it into an open slot in a charging station and reinstall a charged battery into the drone. They successfully demonstrated mostly hands-free operation of the system and won 2nd place at a local inter-university design competition. The project created enthusiasm amongst the team members for Army relevant unmanned systems research while providing them with valuable experience in performing research, documenting requirements, designing a cyber-physical system, and implementing and testing a cost effective prototype.

10. **(AvMC)** As a result of 2363 funding, ADD was able to fund development of a novel vacuum chamber rotor test capability. That will allow investigation into and hopefully correction of important experimental measurement uncertainty issues in rotor testing. The new test stand will be used to assess and attempt to correct for centrifugal forces effects on embedded rotor blade pressure and strain sensors in FY20. In addition the vacuum chamber test rig is enabling basic research planned for FY20-23 in advanced embedded sensor networks. Ultimately providing key validation data for analytical rotor structural models.

11. **(AvMC)** As a result of 2363 funding, CCDC AvMC was able to fund the Missile Fundamentals Class of FY19. This initial class was extremely successful. The Missile Fundamentals Class is a workforce development tool that offers engineers early within their careers the opportunity to learn missile basics from Subject Matter Experts (SMEs). The Missile Fundamentals Class provided an overview of the mathematics, physics and evolution of missile technology for the total missile system, allowing many entry- and early-level engineers exposure that they might not have obtained in their functional area. This information has resulted in more well-rounded engineers who understand how their technical area impacts the total missile system. The inaugural year had students from four of the five CCDC AvMC directorates: the Aviation Engineering Directorate (AED), the Engineering Directorate (ED), Systems Simulation, Software and Integration Directorate (S3I), and Weapons Development & Integration Directorate (WDI). The

Missile Fundamentals Class provided the students an opportunity to utilize their newly learned skills in a final project that focused on the Army modernization priorities in Long Range Fires, Air and Missile Defense, and Soldier Lethality. Based upon feedback from the students, this course has provided insight into multiple aspects of the valuable work being done at CCDC AvMC, and also provided an understanding of how the components or technologies they work on fit into the overall missile design. People are the Army's greatest asset. This course has helped to build a talented, well-trained and educated workforce which will increase the capability of the CCDC AvMC organization.

12. **(AvMC)** FY19 2363 funds were utilized to renovate and remodel Building 5400, D135 Datalinks lab. All electrical power and network lines and outlets have been replaced and upgraded to enable safe and efficient operation of all lab equipment in support of improvement and development of current and emerging Datalink capabilities. The overall renovation monies also replaced and upgraded the Open Storage Area and conference rooms to enable more professional and efficient coordination between engineers and stakeholders. In addition, the renovation replaced the air control components to allow consistent heating and cooling throughout the lab. These improvements to D135 facilitate the testing and development of current and emerging Datalink technical capabilities in revolutionary ways which will allow the warfighter to safely, efficiently and securely achieve their mission on the battlefield.

13. **(AvMC)** The 10 U.S.C. § 2363 funding enabled the AvMC to establish the Multi-Core Processor (MCP) laboratory test beds, laboratory analytical tools, and infrastructure necessary to perform detailed MCP analyses and test evaluation procedures. The MCP laboratory has been successful in developing a set of high level "Draft" MCP safety and airworthiness qualification requirements and has coordinated these requirements with the Navy, US Air Force, FAA, Industry, and several academic institutions. The MCP lab has also been successful in co-hosting three tri-service workshops to foster collaboration and coordination among the DoD services, Academia, and industry. The workshops have focused on the qualification issues, qualification requirements, and verification methods for the use of MCPs in safety critical applications. If the 10 U.S.C. § 2363 funding was not authorized, the AvMC would not have been able to develop and validate the high level MCP safety and airworthiness qualification requirements. Establishment of the MCP laboratory has led to a significant increase in capability for the AvMC to be able to evaluate and characterize interferences within MCP architectures.

14. **(C5ISR) Cloud-Based Machine Learning for EW:** Building off the previous year's accomplishments, this project has expanded in-house expertise and started two pilot studies to provide foundational proofs-of-concept supporting the Future Vertical Lift (FVL) Cross-Functional Team (CFT). The first proof-of-concept is a modulation recognition algorithm using RF-enabled lab hardware; this demonstration lays the groundwork for future real-time RF/EW machine learning processing. The second proof-of-concept is a Synthetic Aperture Radar (SAR) Automated Target Recognition (ATR). The algorithm resulting from this effort uses state-of-the-art machine learning techniques to build a modern solution for Army SAR ATR. The expertise and technology acquired as a result of this funding has provided an important foundation to meet C5ISR Center's emerging mission and to support outside customers. This effort is being tracked by the Army Artificial Intelligence CFT, PEO Aviation, PEO IEW&S, DTRA, and HQDA-G2 as a directed need within the future Multi Domain Operations fight against peer and near peer advisories.

15. **(C5ISR) Radio Frequency Communications (RFC) Laboratory 403/405 Upgrades:** By leveraging the 2363 authority over the past three fiscal years, C5ISR Center Space and Terrestrial Communications Directorate executed preliminary design, final design, and construction contract award for a $1,965K complete laboratory renovation (of which $1,198K

was FY19 2363 funding). This effort will provide flexibility and efficient use of lab space to maximize support to ongoing and future missions. Additionally, the flexibility provided by the renovations will streamline laboratory operations and provide the ability to showcase the laboratory and its capabilities to current and future customers. The significant Return on Investment (ROI) will bolster the success of this project even more.

16. **(C5ISR) Modernization of Automatic Target Recognition Laboratories, $1,400K** Procured and matured tools to support establishment of an image and signal processing development environment. Assets needed for the machine learning necessary to realize advanced signal and image processing have been established. Capabilities have been achieved for the optimization of image collection. These capabilities will become the basis for current and future algorithm development and evaluation. This activity directly supports Army modernization goals for aided target recognition and offers a formally unrealized environment for the testing and development of novel signal and image processing approaches.

17. **(Chemical Biological Center (CBC))** CCDC CBC's internal program for low-investment, high-risk investments has made significant return on investment over the last seven years. The Innovative Development of Employee Advanced Solutions (IDEAS) program has had a total of $3.15M of Section 2363 since its inception. CCDC CBC has been able to take those small projects and turn them into a total of $33.7M of investments from other agencies to support projects, programs and transitions for the Warfighter. A major example includes the Array Configurable Of Remote Network Sensors (ACORNS) which has been used in multiple demonstrations with Warfighters such as the Chemical Biological Operational Assessment (CBOA) and the Joint Warfighter Assessment (JWA) 19 and has been transitioned and integrated into larger programs at DTRA and the JPEO-CBRND.

18. **(CBC)** CCDC CBC's investment to create capabilities in synthetic biology called Biological Engineering for Advanced Materials Solutions (BEAMS) completed its third year in FY19. With a focus on workforce development through lectures and competitions, infrastructure upgrades and research projects, BEAMS has increased the capacity of CBC to develop engineered solutions with biology. Research projects include bio-templated carbons for a more renewable carbon source for filtration, developing novel small molecules for light harvesting and energy storage and enzyme trapping within porous materials to make more robust biological systems. The work has transitioned to a DARPA program for the scale-up and testing of bio-templated carbon materials for the adsorption of toxic chemicals, storage of oxygen, and obscuration.

19. **(CBC)** Over the past few years, CCDC CBC has invested Section 2363 funds in infrastructure master planning activities as well as a building study for the restoration and modernization (R&M) of building E3330, a major laboratory and administrative building at CCDC CBC. The original building was built in 1941 with an addition added in 1954. Due to these efforts and investments, that R&M project is now above the cut line for MILCON in FY20. Planning and full design efforts will continue over the next year to facilitate the execution of the MILCON planning and restoring one of CCDC CBC's major and historic buildings to a modern laboratory facility.

20. **(ERDC)** Section 2363 funding has allowed ERDC to experience success across all four funding areas. Significant accomplishments have been achieved in Basic and Applied Research. Under the Quantitative Threat Detection Using Artificial Intelligence project, ERDC developed a Java prototype that generates synthetic data for various uses. Initially, it was used for geospatial data analysis in high terrorism regions of Afghanistan, but later, more parameters were added (currently 43), and the prototype can be customized for various applications. It is being used by other in-house initiatives for trajectory analysis and data disaggregation.

21. **(ERDC)** The work performed under Unlocking the Physics of Near-Surface Soil Mechanics, yielded immediate results when the researcher received an unsolicited letter from a Senior Firefighter in Western Australia, about the impact his work was having. Papers published on soil physics have changed the way the Australians do training for trench rescues, reducing set up time and more importantly, casualties. While not necessarily the intended result of the project, this success will transfer directly to a number of areas in the U.S. Army.

22. **(ERDC)** Under Technology Transition, ERDC researchers were awarded a U.S. Patent, "Method of Recycling Chitosan & Graphene Oxide," as a result of work funded under the Advanced Graphene Enabled Technologies for Perfluorinated Alkylated Substances (PFAS) Treatment and Enhanced Concrete project. In addition to the patent, ERDC is now leading the National Defense & Resilience Panel at the Graphene Innovation & Research Conference, and has developed three prototypes for PFAS treatment with demonstrations at Hurlburt Field AFB, Misawa AFB, and USMC Camp Butler in Japan.

23. **(ERDC)** The Terrain and Signature Physics Integration Center developed a web services capability for ERDC's patented Environmental Awareness for Sensor and Emitter Employment (EASEE) software, which models the impacts of complex terrain and weather on all types of signal propagation and sensor performance. By employing a RESTful (Representational State Transfer) framework, EASEE Web Services can receive queries with information regarding parameters for an EASEE calculation and return, for example, feature layers regarding the locations of optimized sensors, or coverage layers indicating probability of detection ranges. This new web services capability enhances interoperability between C3I systems and provides a mechanism to tie ERDC signal modeling capabilities into Army Computing Environments such as the Command Post Computing Environment (CPCE), and emerging tactical network data resources and delivery platforms such as ERDC's Geospatial Repository and Data (GRiD), the Air Force Research Lab's Tactical Assault Kit, and the Army's Integrated Visual Augmentation System (IVAS).

24. **(ERDC)** The Total Watershed Decision Support team is assisting the Army Science Board in their development of an initiative on a risk-Informed continental-scale hydro-terrestrial capability to improve Corps of Engineers effectiveness to be briefed to the Secretary of the Army in January. The initiative brings together a system of system modeling, data assimilation, and risk-informed analyses. Collaboration across government agencies and Corps' organizations is key to the effort that has a proposed $470 mill budget.

25. **(ERDC)** Section 2363 funding applied to a number of work force development projects has resulted in ERDC's employee engagement index in the annual Federal Employee Viewpoint Survey increasing by one percent. The funding used for the CP-16 Program has enabled ERDC to receive 37 Department of Army Intern slots. This is an increase of over 300% and will save the Corps of Engineers approximately $3.6 M.

26. **(ERDC)** After spending $6 M on a new secure building for the Information Technology Lab in FY18 (currently under construction), spending for lab revitalization was reduced in FY19. One significant accomplishment was the creation of the ERDC Future Workforce Development FORWARD Center. The Center has a large multi-purpose room with audio/visual capabilities available for meetings for groups up to 60, and a large robotics field is available to ERDC researchers who need an indoor space to work on and exercise all manner of robotics and unmanned ground vehicle systems.

27. **(Ground Vehicle Systems Center (GVSC))** The investment in continued technical training for our engineers and scientists has enabled GVSC to stay at the forefront of technical knowledge and capabilities to execute our core competencies for S&T and Army customers. In FY19 GVSC invested heavily in academic training; technical training for Cyber Security, Hybrid & Electric Vehicle Systems, Software, Mobility, Powertrain, Robotics; building our competency in autonomy and Artificial Intelligence (AI); and a training project in materials welding. These are focus areas for our future S&T investments, and needs requested from our Army customers. The training conducted is positioning our technical associates to provide the best capabilities and customer support to the Army for our Ground Vehicles.

28. **(GVSC)** The continued investments in Mobile Simulators will enable large-scale virtual experimentation to support Company level (80-120 soldiers) operational modeling. The Soldier-in-the-loop operational virtual experimentation informs Next Generation Combat Vehicles (NGCV) concept of operations and vehicle requirements. These investments will allow GVSC to meet the NGCV Cross Functional Team need for a Company sized experiment 4Q FY2020.

29. **(Soldier Center (SC))** The Bootstrap program has made many modest investments into concepts and technology that can assist the Soldier. For example, a project is designing and creating a prototype body armor female front plate, which will better conform to the female shape. This is creating a conformal fit between female soldier and hard ballistic plate, thus minimizing vulnerable gaps, improving comfort, mobility, and proper placement on the torso.

30. **(SC)** Outcomes from the Research Equipment and Instrumentation Initiative are providing significant impact to the Soldier Center mission. For example under Research Equipment and Instrumentation, the Combat Capabilities Development Command Soldier Center has been able to purchase a ground surveillance radar system, which will substantially improve our ability to develop and test technologies and materials for signature management of Soldiers and their equipment. This is a core mission area across multiple Directorates and efforts within Combat Capabilities Development Command Soldier Center. Without this new capability, these development efforts would require the use of outside resources for testing.

31. **(SC)** 10 U.S.C. § 2363 funds were used for the initiation of the Engineering Innovation Center. Funding facilitated the purchase of new Additive Manufacturing/3D printing equipment for the Engineering Innovation Center. In addition, in this first year of operation, the funding paid for support to the development of a number of projects some of which are now in evaluation in the field. The Rapid Aviation Maintenance Shelter solar cover was a quick reaction solution/prototype to address the heat issues occurring with Apache Helicopters on the tarmac. Operators/Maintainers wanted a lightweight, easily erectable, mobile solar protection system. The fabric and frame wheeled prototype was designed and produced in 3.5 months and is currently being assessed at Ft. Campbell. Another item, a “shooters mat”, is an item desired to provide an easily carried, camouflaged shooters’ position that could accommodate two snipers simultaneously and would marry up to a standard Modular Lightweight Load Carrying configuration. The Engineering Innovation Center used the 10 U.S.C. § 2363 funding to design and develop the prototype which is currently being assessed in the field.

32. **(SC)** The Engineering Innovation Center also designed and fabricated a cold temperature “Gelbo” Arm. A Gelbo arm is used to twist and pull materials to simulate how they perform in outside environments. With the military looking at Arctic operations, there is a need to assess how fabrics perform in these very cold environments and a desire to have a portable system. This cold temperature Gelbo Arm was designed to operate down to -60F and is small (18” X 8” X 8”) and quite portable. In addition, under the Soldier/Squad Integrated Protection Demonstration effort, tremendous impacts have been made.

33. **(SC)** On 20-22 August 2019 Combat Capabilities Development Command Soldier Center, Expeditionary Maneuver Support Directorate, G9 and G3/5 members conducted a Squad Holistic Lethality Demonstration Wargame Soldier Touch point event at Combat Capabilities Development Command Soldier Center. The three-day event was comprised of a Wargame Exercise, Combat Capabilities Development Command Soldier Center Familiarization overview and Squad Holistic Lethality Demonstration and Combat Capabilities Development Command Soldier Center Science & Technology efforts were highlighted. Soldiers from Maneuver - Capabilities Development and Integration Directorate Ft. Benning, Georgia and 52nd Brigade Engineer Battalion 2nd Infantry Brigade Combat Team, 4th Infantry Division Ft. Carson, Colorado and Combat Capabilities Development Command Soldier Center supported the three-day event. Squad Holistic Lethality Demonstration has identified that soldier and squads lack integrated and synchronized protection solutions. Advanced suites of technology solutions provide the squad additional standoff through improved situational awareness, enhanced mobility, camouflage and holistic protection. These technology suites expand the bubble of protection by providing the ability to outmaneuver enemy forces by increasing the time between the identification/detection of the squad from enemy sensors. Ten down-selected Combat Capabilities Development Command Soldier Center technologies were tested by 16 Soldiers in a Red on Blue scenario along with a White cell adjudication process. The event also identified technology gaps or products Combat Capabilities Development Command Soldier Center scientists and engineers should be working on. The benefit of soldier touch point data is to determine integrated synchronized protection solutions that correlate to mission success. This will serve to enable squads with enhanced organic capabilities and inform concept operations for the future squad 2028-2040. Squad Holistic Lethality Demonstration continues to inform other Soldier Lethality efforts and is a test bed for inclusion in larger Army/DOD demonstrations. A presentation of proposed Courses of Action for future Squad Holistic Lethality Demonstration efforts in FY20 was delivered to Combat Capabilities Development Command Soldier Center senior management on 30 September 2019. CSA priorities #1 Readiness, #2 Future Army and #3 Take Care of the Troops; and CCDC Priority #1 Integrated Technology Development & Engineering Services.

34. **(SC)** Revitalization and Recapitalization 10 U.S.C. § 2363 funding is enabling major improvements for Combat Capabilities Development Command Soldier Center and Simulation and Training Technology Center. A design & construction contract has been awarded to fully repair & upgrade spaces in Bldg. 4 which is one of the organization's main workspaces/labs that houses employees from multiple directorates and the support staff. This project was developed in conjunction with the Corps of Engineers, and we succeeded at awarding this large project within budget, and on schedule. This effort helps develop new secure space for Combat Capabilities Development Command Soldier Center, as well as consolidating space for multiple directorates, significantly improving our ability to meet our mission requirements.

35. **(SC)** We have made significant progress towards modernizing several of our small laboratories, to include our Engineering Innovation Center / Additive Manufacturing Facility, and our Engineering Collaboration Space.

36. **(SC)** 10 U.S.C. § 2363 funding has enabled and postured the success of the additional space, medical testbed and the GPU Cluster for Simulation and Training Technology Center. Space is precious and the ability to maximize space in any work environment is an effort and accomplishment multiplier. As Cross Functional Teams need and breathe from collaborative spaces, such is the need at Simulation and Training Technology Center. Not only do we have our military and governmental business partners but so to do we have a varied array of academia. This space is now truly collaborative and vastly expands our opportunity to train and

conduct effective training and operations. The modular design enables fluid seating, collaboration space, and simple floor space eliminating static, one dimensional meetings or training. Detailed medical research and analysis is a cornerstone to the critical care of our Soldiers. The branch bought and conducted preliminary integration and assessments with three different haptic gloves: HaptX, BeBop, and VRGluv to attain this fidelity. We continue to conduct formal testing for usability and training effectiveness. The results will shape the future of our testbed and its eventual effectiveness in Soldier support. Without the 10 U.S.C. § 2363 funds, this research and knowledge transition was severely hampered and did not have the ability to assess multiple gloves across multiple levels of medical care. The purchase of GPU Cluster server computers will provide significant improvement to the organization's infrastructure that would have otherwise not been able to have been completed without 10 U.S.C. § 2363 funding. This infrastructure improvement has led to an increased capability for the organization supporting 6.2 research in the area of Artificial Intelligence (AI). The GPU Cluster will also support research in the subset, Deep Learning (DL) to develop state-of-the-art artificial neural networks for "free-thinking" autonomous agents for virtual and constructive simulation training.

37. **(SMDC)** The use of 10 U.S.C. § 2363 funding in FY19 continued to have a significant impact on improving the TC's laboratory infrastructure leading to increased capabilities in several areas. We updated the Area Development Plan (ADP) of the Space and Directed Energy Technology Complex and completed an environmental assessment of the area. We initiated designs of temporary locations for lab space until the permanent locations can be constructed at the complex. Emphasis was placed on establishing capabilities and lab infrastructure across our core competencies of space, directed energy, and strategic weapons technologies in support of the Army's modernization priorities of Long Range Precision Fires, Assured Positioning, Navigation, and Timing, and Air and Missile Defense.

38. **(SMDC)** Additionally, several operations and maintenance upgrades were completed to the Aerophysics Research Facility. These included the completion of safety and operating procedures for the light gas gun and investment in new instrumentation for research of phenomenology related to hypervelocity impact and hypervelocity flight in the earth's atmosphere. Funding from 10 U.S.C. § 2363 was also utilized to continue improving and increasing the capabilities of our Payload Demonstration Laboratory and Positioning, Navigation, and Timing (PNT) Resiliency Laboratory (PRL). The use of these funds significantly accelerated our infrastructure development while providing increased capabilities across our space S&T mission as well as increased opportunities for our technical workforce to get hands-on experience.

39. **(SMDC)** As a strategic investment in FY19, the Quantum Entanglement and Space Technologies (QuEST) laboratory was established to pursue research aimed at space qualifying components, sub-components, and systems for quantum communications experiments. Notional experiments will be used to identify the specific components to be addressed. Where appropriate and possible, commercial off-the-shelf technology will be used and ruggedized/space-qualified as needed. This was made possible, in part, by leveraging of 10 U.S.C. § 2363 funds.

40. **(SMDC)** The acquisition of a high-end oscilloscope for the Concepts Analysis Lab (CAL) enabled our scientists and engineers (S&Es) to have the capability to capture waveforms up to 23 GHz on four channels. The S&Es have used it to characterize the phase offset on an analog to digital conversion system within the phase and amplitude compensation system recently designed for a major distributed aperture radar and bi-static communications project. The CAL was able to very accurately adjust the phase of multiple waveforms, in order to get specific phase offsets for the compensation system to measure. The oscilloscope was also used to determine if some of the signal generators in the CAL needed to be calibrated, as it has a high

sampling rate in comparison to other oscilloscopes, allowing the user to see portions of the received waveform that are invisible to most oscilloscopes. Another acquisition in the CAL included the installation of the Stratasys F370 3D Printer. This 3D printer uses a range of materials such as Polylactic Acid and Acrylonitrile Butadiene Styrene plastics, allowing production of complex parts with flexibility and accuracy. The printer includes advanced features like Fast Draft mode for truly rapid prototyping, and soluble support material to prevent design compromise and hands-on removal, all designed to shorten product development cycle. Finally, the acquisition of a high performance computer for the CAL enabled our S&Es to initiate research in machine learning and artificial intelligence for small satellite and high energy laser applications.

Challenges:

There are two challenges that Lab Director's typically cite as impediments to fully implementing 10 USC 2363 authority in Army Laboratories. The first is communication with reimbursable customers regarding the 10 USC 2363 rate and activities executed in accordance with the authority. The Office of the Deputy Assistant Secretary of the Army (Research and Technology) (DASA(RT)) will be working with the laboratories operating with substantial reimbursable funding to gain a better understanding of implementation challenges with reimbursable funding. The second major challenge is using funds to meet larger infrastructure requirements at the lab. Collecting funds at the S&T Executive level (in accordance with 10 USC §2363(a)(2)) may alleviate the challenges regarding investing in larger infrastructure projects.

Performance:

A. ***Innovative Basic & Applied Research***. In FY19, the Army funded 87 innovative research projects with an annual investment of $36,671 K:

1. **(AC) Fusion Cell, $1,972K**

   The Fusion Cell fuses threat intelligence, global emerging technology trends, and U.S. Military operational challenges and needs, with CCDC AC capabilities to create an adept culture of proactive posture, rapid response, and unparalleled support to the Warfighter and the community. The CCDC AC Fusion Cell activities and initiatives directly support CCDC AC's position as a critical national asset, vital to national security. Fusion Cell activities also drive strategic and technical direction, informing the Army Modernization initiatives, Cross Functional Teams, as well as the Combatant Commands and Joint Services in the development of new doctrine and operational concepts, such as Multi Domain Operations (MDO). During 2019 the CCDC AC Fusion Cell formed priority initiatives, and associated teams focused on Threat Based Planning, Operational Speed of Battle, and Wargaming in order to ensure that Armament Systems designs and acquisition plans are postured for timely fielding and optimal performance in the Future Operating Environments (FOE) expected 2025-2050.

2. **(AC) Idea Catalyst, $1,000K**

   In FY19, Innovation opportunities were pursued based on alignment with customer requirements, needs, and gaps, and alignment with enterprise strategic objectives. Innovation opportunities across the enterprise were pursued by the CCDC AC Chief Innovation Officer. CCDC AC has a robust, formal structure for innovation which allows it to manage and pursue opportunities for innovation and enable success. The intent of this comprehensive program is twofold: 1) accelerate the integration of the latest available technologies to deployed systems, and 2) develop

unique defense-specific technologies where industry solutions are not currently available. During FY 19, CCDC AC implemented six key efforts to manage innovation for the enterprise. The implementation of these six key innovation management efforts resulted in an increased response to technological change, greater access to resulting improvements, and the increased incorporation of innovation needs into the acquisition life cycle.

3. **(AC) National Research Council (NRC) Fellowship, $97K**

National Research Council (NRC) Research Associate Dr. T. Frater joined CCDC AC in support of 6.1/6.2 funded research in ionic liquid and deep-eutectic electropolishing and electroplating. This research is aimed at the development of new electroplated coatings for weapons systems, as plug and play replacements for hexavalent chromium as inner bore coatings. The work aligns with Army Modernization priorities for readiness and Future Army in support of the Long Range Precision Fires and Next Generation Combat Vehicle CFTs. Dr. Frater is developing methods for the electrodeposition of tantalum and niobium coatings from deep-eutectic ionic liquids with the goal of understanding the effects of the plating solution on the plated metal. Dr. Frater has just begun his work, but it is anticipated that his research will lead to peer-reviewed journal publications, government technical reports, and presentations at national and international conferences. His plans include further structure-function analysis of deep eutectic solvents for electroplating and electropolishing, and alloy deposition.

4. **(AC) Community College of Morris (CCM) Innovation Center, $39K**

The Picatinny Technology Innovation Center is a cooperative effort between CCDC AC and CCM, with support from the County and State. It provides a mechanism to bring technology collaboration partners (primarily small businesses) into facility space at Picatinny. This serves DoD goals and statutory requirements to accelerate technology transfer and commercialization of CCDC AC research, both in exploring technical areas of importance to CCDC AC's military mission, and its mission to further commercialization of technical innovations arising from CCDC AC's laboratories. Picatinny Innovation Center tenants are engaged in Cooperative Research and Development Agreement (CRADA) relationships with CCDC AC's scientists and engineers (S&E's) including, but not limited to, novel power sources, lighter weight polymer ammunition, pyrotechnics, advanced materials, advanced sensors and guidance, and systems engineering.

5. **(ARL) Distributed and Reconfigurable Beamforming for Targeted Communication (DSI), $1.75M:**

In the emerging contested and constrained EM battlefield, robust, distributed beamforming will be an essential multi-domain capability needed to evade and confront near peer adversaries. The subject research we are pursuing focuses on a beamforming array composed of autonomous mobile agents, which coordinate their positioning and antenna element radiation to provide a directional communication link. Distributing the antenna elements across mobile agents makes the enabled system smaller, lighter, and rapidly reconfigurable. Demonstrating the described system experimentally, as well as simulating control of such a system, are major objectives for this project.

6. **(ARL) Fermented Vegetation Efficiently Running Artificial Muscle (FeVERAM) (DSI), $1.5M:**

The goal of the FeVERAM project is to develop chemically-powered, artificial muscles (CPAMs) that are strong enough for large arm/leg muscles. Ideally, FeVERAM's CPAMs will run efficiently and quietly, and on energetic chemicals that can be produced in the field from locally-sourced materials. Long-term, the FeVERAM CPAMs will increase Soldier lethality by integrating into infantry support systems, such as robotic "mules," human exoskeletons, robotic "point-men," and artillery spotters. Adding autonomous AI and self-refueling to FeVERAM's CPAMs will enable remote scouts and airbases for vertical-lift UAVs deeply embedded in enemy-controlled territory.

7. **(ARL) Human-in-the-Loop Reinforcement Learning for Rapidly Adaptable Human Agent Teams (DSI), $923K:**

   The subject research focuses on developing mathematical models and frameworks that enable Soldiers to directly interact with artificially intelligent, autonomous technologies to quickly adapt their behavior in response to environmental and adversarial dynamics. The overall objectives are to provide Soldier-autonomy teams with: (1) Greater Soldier-autonomy and team resilience with robust, adaptive performance; (2) Fast, dynamic team reconfiguration to match capabilities to mission requirements; and, (3) Faster and more informed decision-making.

8. **(ARL) Understanding Blue Whirl Combustion for Fuel-Flexible Energy Extraction (DIRA), $680K:**

   The goal of this research is to harness blue whirl combustion as a fuel-flexible means of extracting energy from a wide array of liquid fuels for energy and power applications by the U.S. Army. The subject project investigates the physics underpinning blue whirl combustion through experiments and modeling, the knowledge of which will enhance its scalability and stability across a broader range of liquid fuels than can be accomplished by existing technology. The technology can be used to extract energy from locally available fuel sources on the battlefield, such as biomass and contaminated fuels, enabling extended operational endurance without resupply.

9. **(ARL) 3D Printing a Stretchable Power System (DIRA) $150K:**

   ARL has long been at the forefront in stretchable inductor technology enabling wireless charging of wearable sensors and actuators for Soldier protection and enhancement. The subject project conducts research that builds on ARL’s 3D printing resources to directly 3D print an inductor that will easily integrate into practical systems, such as shoe soles, gloves, and other wearable systems in a Soldier's kit. The project is intended to allow the integration of lighter weight and lower burden electronics onto the Warfighter.

10. **(ARL) Computational Laser Origami (DIRA), $150K:**

    George Mason University collaborators successfully demonstrated for the first time a computational approach to deconstruct and unfold a 3D CAD model into 2D geometry. The subsequent 2D geometry was coded into a DXF file and sent to ARL. ARL researchers were able to fold this geometry with a laser back into a 3D physical, metal component. ARL sinuous antennas were used as demonstrators. One related paper and one patent application were generated. This is relevant for the Warfighter, because it provides a means to 3D print complex, thin metal components in a 10-100x faster timeframe versus traditional powder bed 3D printing. Year two will focus on collaboration with the Brigham Young University Compliant Mechanisms group to demonstrate significantly more complex mechanisms.

11. **(ARL) Fast Real-Time Data-Driven Reinforcement Learning Control of Swarm Networks: A Hierarchical Decomposition (DIRA), $150K:**

    The subject research complements and enhances several of ARL's efforts supporting the Army's Modernization Priorities, such as Next Generation Combat Vehicles (NGCV) and Network C3I. In support of the NGCV priority, the proposed research provides theoretical foundations for a new research direction; i.e., online, data-driven approach for autonomous maneuvering and sensing using large-scale distributed agents. The research develops novel data-driven approaches that will allow autonomous agents to coordinate their positioning and transmission in an organized step-by-step fashion, enabling covert communication with receivers. For both applications, the data-driven execution will guarantee robustness against model and environmental uncertainties.

12. **(ARL) Infrared Optical Field Induced Stark-Shift Upconversion in Quantum Dots (DIRA), $150K:**

    The first demonstration of luminescent upconversion of infrared (IR) radiation in the 8-12 um long-wavelength spectral band using visible quantum dots was successfully performed. The interaction of the classical electric field of IR light incident on quantum dots can lead to carrier excitation and emission due to charge transfer under the quantum confined Stark effect. For quantum dots with a visible bandgap, this upconverted luminescence can be detected using commercially-available imaging technology. Research in this frequency range has the potential to enable gate-able, room-temperature IR detectors and modulators, with capabilities in concealed object detection and secure communications in contested environments that do not require liquid nitrogen cooling. This effort is carried out with collaborators at the Massachusetts Institute of Technology, leveraging a project under ARL's Institute for Soldier Nanotechnologies (ISN) program.

13. **(ARL) Multi-Functional Materials for Energy and Power (DIRA), $150K:**

    This project is seeking to develop computational capabilities that will help to position the Army to leverage additive and other emerging manufacturing techniques to rationally design 3-D, multi-functional materials and devices, from 3-D battery electrodes to conformal sensors and neuromorphic computing hardware. We are developing theory and associated software tools to guide the design of 3-D structures that are simultaneously subject to multiple transport and mechanical performance criteria. The methods that we are developing within this effort are 5-6 orders of magnitude faster than existing techniques, can be used to accelerate existing topology optimization schemes, and further open up the possibility for computationally efficient generative design of multi-functional materials. Through computational efficiency and theoretical clarity, ARL intends to accelerate the development of the referenced advanced technology for the Warfighter and reduce the associated costs.

14. **(ARL) On Data-Driven Saak Transform: Theory and Applications (DIRA), $150K:**

    This research is focused on developing a new approach for SaaK transform as an innovative mathematical frame-work for neural network architecture that may provide a solution to radically change methods of intelligent data perception, representation, and processing. The research produces new theory and knowledge for the science of machine learning, with real-world utility and algorithms for Army critical applications and new capabilities.

15. **(ARL) Photonic Circuits for Compact (Room-Temperature) Nodes in Quantum Networks (DIRA), $150K:**

So-called "quantum networks" can provide the Warfighter with unprecedented communications security. The Army will only benefit from this potential if future quantum network devices have low SWAP. This project is focused on making significant advances in the science required for the future development of low SWAP quantum devices for secure communications.

16. **(ARL) Piezoelectrically Modulated Photonic Integrated Circuits (DIRA), $150K:**

This project combines high-performance piezoelectric materials (from ARL) with high-performance silicon nitride optical waveguides on a chip (from U.C.S.B. collaborator) to create strain-based optical modulators in silicon nitride that increase modulation frequency by 1000x and reduce power consumption by 1000x. These improvements in performance will also be leveraged to create new photonic switches and circulators in silicon nitride that are not currently possible. The described optical modulators in high performance silicon nitride can be used for chip-scale quantum systems for Soldier-portable atomic clocks and quantum-based sensors; solid-state optical gyroscopes for munitions, capable of operating through shock and vibration environments; and high performance optical communication systems.

17. **(ARL) Plasma Surface Tailored Smart Surface Aluminum Nanoparticles (DIRA), $150K:**

The referenced project’s objective is to make energetic aluminum nanoparticles as energetic additives formed by helium or argon plasma-treat of commercial Al nanoparticles, followed by formation of a specific oxide, aluminum iodate hexahydrate (AIH) via mixing the particles with the iodic solution. Preliminary results demonstrate significantly improved reactivity at the microsecond scale simulating a detonation event, and at the millisecond scale showing enhanced blast effects. This project will directly impact the Long Range Precision Fires Army Modernization Priority.

18. **(ARL) Reversible Martensitic Transformations: A New Approach to Managing Thermal Transients (DIRA), $150K:**

The Army is accelerating delivery of High Energy Laser (HEL), Directed Energy (DE) prototypes to bolster the Army's air defense capabilities. Significant design restrictions for thermal management and control reduce volumetric latent heat storage, increase size and weight, reduce DE duty cycle, and prevent widespread DE integration across various DOD platforms. This project aims to develop robust, metallic, solid-state energy storage materials that can serve as both the structural and the functional elements of thermal management systems. This project will improve DE pulse duration and/or duty cycle by two-orders-of-magnitude, and reduce system size and weight by 300%; thereby enabling more-continuous operation, and ushering in new design and integration possibilities for DE systems.

19. **(ARL) Alternative, Unexplored UV Materials (DIRA), 100K:**

Ultraviolet (UV) devices based on Yb+ trapped ions that are excited by near UV (NUV) lasers are needed for Army applications, such as position, navigation and timing, and optical communications operating in the solar-blind spectral. This project is for the exploration and development of alternative UV-responsive semiconductor materials that may be easier to dope than current state-of-the-art AlGaN. For the first time, we have developed the MBE growth of Strontium Telluride, and have shown it has an optical response in the 300-400 nm range.

20. **(ARL) Are We Ready to Build the First Quantum Repeater? (DIRA), $100K:**

One of the long term scientific goals of the last couple decades has been to create a "quantum repeater" that can distribute quantum entanglement over long distances. Such an entangled network is predicted to revolutionize ultra-secure communications, sub shot-noise sensor networks, and distributed quantum computing. ARL is approaching the level of performance in individual components that such a system could be realizable in the near future, thus a detailed study of ARL's platform capabilities is the focus of the subject project.

21. **(ARL) Machine Learning for Quantum Control and Design (DIRA), $50K:**

The subject project researches the design and control of quantum devices to achieve desired states and functionality, which may lead to new quantum sensors and integrated photonic circuits. The development of software for using machine learning (ML) to optimize quantum control and design is being pursued. Currently, quantum control requires analytical derivatives computed by hand, and quantum design requires intuitive understanding of how to parametrically explore the design space.

22. **(ARL) Near-Field Terahertz for Nano-Scale Spectroscopy of Low-Dimensional Materials (DIRA), $50K:**

Time-domain THz spectroscopy is a powerful measurement technique sensitive to electric fields (transport), free carriers, and phonons. However, measurements are diffraction limited due to the ~300-µm wavelength of THz, complicating measurement of low-dimensional features (i.e., surfaces, lateral transport, etc.). This project is working to develop slit-based, subwavelength apertures for THz nano-scale microscopy of low-dimensional materials to gain an understanding of basic physical processes, and inform future device designs over a wide range of applications.

23. **(ARL) User-Tailored Robot Motion Planning for Remote Navigation Tasks (DIRA), $50K:**

The current state of the art field robots in the military domain are those that are directly operated by a Soldier via a controller to gather information from an environment or execute various tasks. This burdensome method requires the operator to devote most of their attention to the robot while having little awareness of their immediate surroundings, a problem often addressed by tasking a second Soldier to serve essentially as a spotter. Directing a robot using spoken language reduces operator burden compared to the current method, however this approach introduces the problem of the robot incorrectly interpreting a command and executing unexpected behaviors. Additionally, it has been well documented in robotics and related areas that users interact with technology using widely varying styles based on personal history, which manifests in how commands are issued and expectations for how precisely they are to be executed. This project addresses user preferences for robot motion planning using machine learning and reinforcement learning approaches, with the goal of creating autonomous robot navigation algorithms that can be tailored to individual users, so robot behaviors will precisely match the expectations of the operator.

24. **(ARL) Fellows' Stipends to Support the Research Described Above, $575K.**

25. **(ARL) Research Collaboration with Rice University, $3000K:**

Rice University and the Army have established a five-year, $30 million cooperative agreement for research to enable advanced materials and next-generation networks. The subject effort is aimed at unprecedented intelligence, surveillance, and reconnaissance specifically focused on next-generation wireless networks and radio frequency (RF) electronics.

26. **(ARL) APG Materials, $2,000K:**

As mandated by DA and ASA-ALT, Army S&T needs to tighten OPSEC controls in the protection technology area. In response, a new program was created at a higher level of classification. Execution of the subject 6.2 effort requires investment in ARL infrastructure to meet ICD/ICS 705 v1.4 standards. Therefore, $2M of FY19 U.S.C. 2363 funds were invested to meet the described requirement. The goal is to mitigate the risk of compromising national security and re-establish technological superiority. The referenced capability will enable ARL to innovate novel protection concepts for the Next Generation Combat Vehicle (NGCV) in a secure space while minimizing the knowledge of adversaries.

27. **(ARL) Converge Essential Research Program (ERP), $1,356K:**

ARL utilized the referenced funds to pursue cutting edge research that will enable the recapturing of ground combat overmatch through technological superiority. The overall objective is to connect advanced technologies with autonomous behaviors for robust, multi-layer survivability and overwhelming lethality**.**

28. **(ARL) Grassroots Innovation Tank (GRIT), $500K:**

A truly "grass-roots" initiative to drive Army innovation, which is run and self-governed by rank and file S&Es at ARL.

a. **Pure Nanodiamond, $90K:**
The subject project explores a new class of materials made by conversion of carbon allotropes, advances understanding of plasma science and technology, and explores possible nanomaterials. The project's goal is to develop the methodology to produce energetic nanodiamonds (ND) possessing the desired diamond core/graphitic shell structure and energetic performance via atmospheric and non-thermal plasmas.

b. **Tag, You're It!, $90K**:
The referenced project researches technology to detect naturally occurring tags. Each person and surface is colonized by a unique combination of microbes, which can potentially be used as tags. This research is investigating using the described microbial tags for tagging, tracking, and locating (TTL). The potential impact will be the ability to mask Soldier operations and monitor adversaries. Currently, tags require application to the target, which is logistically cumbersome.

c. **Electrochemical Armor, $85K:**
This research seeks to develop a new multifunctional metal-foam-based armor that can be used to both protect and store charge. The focus is on hierarchical metal foam. Multi-functionality is a smart way to optimize the tradeoff between function and encumbrance.

d. **Fire Whirl as a Destructive Force, $70K:**
This project investigates fire whirl generation for potential Army use as a destructive weapon. The potential benefits include: A covert, quiet, and compact weapon, which will disrupt, degrade, and destroy enemy anti-access and area denial systems. The referenced technology will enable a unique destructive system without using energetic material.

e. **High-Speed X-ray Experimentation, $60K:**
The subject project conducts high-speed X-ray (HSX) experiments at Netherlands Organization for Applied Scientific Research. Targets will be 3D printed skull surrogates

coated with a rubbery skin simulate, filled with 10% ballistic gelatin, and wearing a size enhanced combat helmet (ECH). The project provides a challenging composite system to image multiple interfaces and register velocities. The HSX will be assessed for repeatability of quantitative material velocity measurements over time, and a determination will be made on the ability to image fracture initiation in the surrogate.

f. Pneumatic Networks for Camber Morphing, $60K:

The subject project continues the development of a novel actuator technology capable of camber morphing and stiffness modulation. Camber change delays airfoil stall, and increases lift, maneuver, range, and efficiency. Soft (elastomeric) robotic actuators reduce weight and increase RF transparency. The technology has far reaching applications wherever the diversion of a working fluid is required (e.g., munitions, aircraft, rotorcraft, watercraft, and submersibles).

g. 3D Printed Multifunctional Micro-Lattices, $45K:

This research will determine deposition parameters for conformal ALD coating of 3D carbon micro-lattices with piezoelectric PZT and anti-ferroelectric lead hafinate. This project characterizes microstructure and compositions of fabricated devices, and develops a methodology for filling/encapsulating coated micro-lattices with RT-liquid gallium alloy. The goal is to make new ultrahigh surface area, 3D energy storage and harvesting architectures with an order of magnitude increase in surface area of functional materials for greatly improved energy storage and harvesting capabilities.

29. **(ARL) Three Minute Thesis Awards, $525K:**

ARL awarded funding, $12.5K-50K/project, for eighteen highly compelling research projects to support enablement of the Army's critical technological needs. Technical leads for the proposed projects provided their presentations in the three minutes using one slide, which drove additional creativity, efficiency, and effectiveness.

30. **(AvMC) Advanced Gust Test Facility, $100K**

These funds provided turbulence gust fields to aid in the design and validation of advanced control laws for Advanced Unmanned Aircraft Systems (UAS). Army future UAS needed to be robust and capable of operating in anticipated flight environments. UAS will be capable of landing on moving vehicles and ships that generate strong turbulence behind their super-structures. The Army needed to understand and specify the required capabilities and develop advanced flight control systems to better operate in these environments to include the "Urban Canyons." New research facilities were needed to develop UAS for Army's future needs. This project developed the infrastructure to develop UAV flight control algorithms in a controlled unsteady wind environment.

31. **(AvMC) Hybrid Power System Develop and Test Tool set, $75K**

The CCDC AvMC Energy Lab is now currently researching, developing, designing, integrating, and performing engineering level testing (ELT) of hybrid power systems that are being used by or are being considered by U.S. Army Aviation and Missile PM's. The tool set includes necessary power modeling software, power analysis tools, work shop equipment, and power monitoring tools. This investment has been beneficial to CCDC AvMC by having a dedicated power lab to service power and energy related projects throughout Redstone Arsenal, and support our

customer needs from Program Executive Office (PEO) Aviation, PEO Missiles & Space (MS), PEO's Intelligence Electronic Warfare Sensors & Combat Support/Combat Service Support (IEWS & CS/CSS), Missile Defense Agency (MDA) as they transition to a Multi-Domain Battle (MDB) mindset and hybrid systems.

32. **(AvMC) Missile Electronics & Information/Signal Process Enablers for Army Modernization, $875K**

In support of Army Modernization, Long Range Precision Fires, it was imperative that CCDC AvMC perform the required applied research to provide the critical technologies needed in missile electronics and information/signal processing that allow significantly extending the range of precision missiles and munitions. Investments included a focus on development of feature extraction/classification and tracker algorithms, decreased component and overall electrics design weight, increased electronic computational throughput, and improved electronic thermal management. Deep and strategic strike capabilities were new mission areas for CCDC AvMC, and this investment in missile electronics & information/signal processing research was required for the future of Army lethality and precision engagements.

33. **(AvMC) Structural Battery (SB) Development, $160K**

Funding was used to support innovative basic applied research that was conducted at the CCDC AvMC Operational Energy Lab surrounding the development of structural batteries that can be integrated into aerial or Unmanned Aircraft Systems (UAS) airframes and Unmanned Ground Vehicle (UGV) systems. This effort coupled existing battery technology capability with a new application and approached to solving challenges surrounding UAS & UGV range and reliability gaps. The commercially available off the shelf (COTS) Lithium Ion or Nickel Manganese Cobalt (NMC) type battery was built into Rod shapes to prove structural load bearing capability. The intent was to build these Structure Batteries (SBs) to be lightweight, strong and of high Energy Density. This integration and development effort leaned the Directorate forward in the realm of autonomous system design and integration and has advanced battery technology with direct application to tactical systems.

34. **(AvMC) Structural Spaced Armor, $126K**

The investment funded in-house research to better quantify and improve the ballistic performance of a multifunctional structural system of spaced armor in which the components were load-carrying parts of the aircraft floor and outer skin. This system had significant potential to provide ballistic performance at weights significantly less than current state of the art systems. Weight savings were realized not just by higher performance, but also by the reduction of parasitic system weight. This investment has benefitted the Aviation Development Directorate (ADD) by enhancing and reducing risk in multiple ongoing and future technology development efforts, resulting in improved aircraft survivability and reduced aircraft weight. Additionally, conducting the work in-house resulted in developing the ADD workforce by leveraging newer employees, more fully using ADD capabilities such as the Ballistics Test Range for Aircraft Component Survivability (BTRACS), and yielding data fully owned by ADD.

35. **(AvMC) Structures and Materials Enablers for Army Modernization, $1,000K**

In support of Army Modernization, Long Range Precision Fires, it was imperative that CCDC AvMC perform the required applied research to provide the critical technologies needed in structures and materials technologies that allowed significantly extending the range of missiles and munitions. This investment included development of novel, low cost, high temperature

material solutions, developed prototype structures, generated modeling and simulation capabilities, and validated test data that can be provided to the community to include other Army research laboratories, industry, and academia. These funds provided funding to develop technical core competencies in this area of research to instantiate CCDC AvMC engineers as the experts with the skill set in advanced structures and materials required for future long range strike capabilities.

36. **(AvMC) Vacuum Chamber Rotor Test Rig, $200K**

This investment was for the fabrication of a stand-alone rotor test rig for testing a Mach-scaled rotor in vacuum chamber at Langley Research Center (LaRC). The rig has provided capability to accurately measure blade structural loads induced by cross sectional properties offsets and centrifugal force in the absence of all aerodynamic loading. Additionally provided significant time-saving for in-situ calibration of pressure sensors. The proposed test rig is capable of spinning a wide range of rotor blades (up to 15 ft. in diameter) in a vacuum, without the need for a complicated hub. This setup has utilized the blowdown sphere of the National Aeronautics and Space Administration (NASA) Langley Unitary Plan Wind Tunnel. This new capability has easily paid for itself by eliminating the destructive pull tests on one of every newly developed blade set. Without this funding, there would be significant added costs in future rotor tests of the order of $50K/blade set.

37. **(AvMC) Clutched Engine & E-motor/Gen for Hybrid UGV/UAS systems, $145K**

This funding was used to support innovative basic applied research conducted at the CCDC AvMC Operational Energy Lab in relation to the development of a clutched drive shaft/s that can couple and decouple the existing gas engine power plant with an electric motor/generator power plant. The E-motor/Gen is used to charge and is later then powered by a new innovatively applied structural battery design (unique in form and factor). This effort verified that the addition of an electric motor/generator, in conjunction with new structural battery design form, can provide increased range and reliability to existing UAS aircraft. This capability provided to UAS or UGV systems supports the Multi-domain Battlefield and S&T focus areas such as Future Vertical Lift (FVL), Autonomy and Robotics, etc. This capability also benefitted the Improved Turbine Engines Program (ITEP) as they investigate Hybrid power for aerial systems. This approach has supported the Army's "Demand Reduction" initiative and both the Aviation and the Maneuverability Systems Centers of Excellence.

38. **(AvMC) MSI University Outreach, $120K**

This is an enterprise wide effort supporting CCDC AvMC research efforts and expands our ability to reach diverse research university to address Missile S&T, sustainment, and Cyber related research tasks. This investment provided expertise in propulsion and other missile technology areas utilizing historically black colleges and universities (HBCU) or other Alabama-based university programs where collaborative research has gained improvements in the Missile S&T systems area, to include developing enabled technology for weapons propulsion components and providing data to allow for potential reduced cost shelf-life projections for propellants/rocket motors, and solutions for cyber controls perspectives.

39. **(AvMC) CCDC AvMC Missile Basic Research, $480K**

10 USC 2363 funding was sought to support basic research projects at CCDC AvMC (M). As with in-house laboratory independent research (ILIR) funding, the requested 2363 funds were distributed competitively, based on proposals submitted by CCDC AvMC (M) investigators and

reviewed by a panel of technical peers. The funding was used for the salaries of CCDC AvMC (M) investigators, but unlike ILIR, it also was used to pay for equipment, supplies, software, travel, and research associates (co-ops, students, post-doctoral researchers, visiting research scientists) located in and working directly with CCDC AvMC (M) investigators. Basic research is a core competency of AvMC. The innovations that come from discoveries and innovations in basic research have a profound impact over a broad sweep of applications and platforms, often in surprising and unexpected ways. This is the highest risk, highest payoff research the Army invests in, and while the transition pathway from basic research to fielded technology is often the most circuitous, it is also the most transformative. Examples include the invention of the laser, the invention of the fast Fourier transform, and the integrated circuit, all of which have a pervasive presence in military platforms, all of which were made possible by Army investments in basic research.

40. **(AvMC) Rotorcraft Aeromechanics Basic Research, $500K**

This project funded rotorcraft aeromechanics basic research wind tunnel experiments in the Army 7x10 wind tunnel at Moffett Field, CA. This work included the development of experimental databases for validation on computational models, investigations of fundamental aerodynamic phenomena, and development and validation of advanced experimental measurement technologies. This work was critical to achieving ADD mission objectives in support of Army Aviation development and acquisition. The 7x10ft wind tunnel was a critical tool for the development of advanced experimental databases for rotorcraft. As an Army-operated facility, the 7x10 allows ADD to exercise a high level of control on configuration, condition, and operation of the facility, which was critical to obtaining the required level of experimental fidelity and confidence in the data produced. Obtaining high fidelity experimental aeromechanics wind tunnel data was critical to the ADD mission to develop high fidelity computational models for rotorcraft.

41. **(C5ISR) Predictive Analysis/System Health Monitoring, $200K**

Initiated a research study related to the application of system health monitoring sensors and predictive analytics within communications and electronics (C&E) equipment. Effort included baselining current technologies and best practices, identifying opportunities for application of such capabilities within the Army's C&E equipment, and the development of a roadmap for Army investments to realize the benefits of applying these technologies and best practices. The end state enabled replacement of key C&E components prior to failure, but not un-necessarily, thereby avoiding cost and increasing readiness.

42. **(C5ISR) Cloud-Based Machine Learning for EW, $650K**

This effort continued and extended the FY18 innovative research to explore use of cloud-based machine learning (ML) for spectrum situation awareness (SA) and classification for electronic protection. Using ML in secure commercial cloud-based computing environment this effort continued to develop ML classification algorithms for spectrum SA and for electronic protection using unclassified radio frequency (RF) signature data. The effort continued generation of appropriately labeled RF data in C5ISR Center, Intelligence & Information Warfare Directorate (I2WD) laboratories at various classification levels. The effort leveraged a recent Independent Laboratory Innovative Research effort - Deep Learning with Known Confidence and the data labeling framework being develop by OUSDI Project Maven. The payoff of this effort included establishing a skill-base in artificial intelligence and machine learning, a skill base in leveraging attractive commercial cloud-based computing environments and development of innovative ML-based EW techniques that can eventually transition to military RF systems. This effort afforded C5ISR Center the opportunity to develop expertise, technical approaches and policies in using

cloud-based machine learning for electronic warfare purposes. Cloud-based machine learning is being adopted rapidly in the commercial environment. This effort helps DoD and the Army to develop expertise and processes to adopt this technology for EW applications. This effort supports Long Range Precision Fires and Network/C3I Army modernization priority.

43. **(C5ISR) Intelligence / Operations Convergence, $800K**

This initiative demonstrated the ability to co-host both mission command and intelligence services on the SitaWare environment. The effort developed a set of Application Program Interfaces (API) extensions to the data framework that allowed for Intelligence Services that support fusion and exploitation analytics to include sensor (e.g. Full Motion Video, MOVINT, SIGINT, etc.) and geo-spatial capabilities. This effort demonstrated how data and services from both operations and intelligence can be unified under a common information management foundation. Funding was also used to acquire additional hardware and software licenses. This effort supported current Program of Records (POR) from both Mission Command and DCGS-A to continue to push towards a converged common architecture. This convergence provided the tactical decision maker the ability to perform next generation exploitation techniques that require machine learning and deep learning methods that support real-time planning and execution. This effort supports the Network/C3I Army Modernization Priority.

44. **(CBC) Biological Engineering for Advanced Materials Solutions (BEAMS), $546K**

BEAMS was a program that CCDC CBC started three years ago and FY19 was its third and final year. With an overall goal to develop the synthetic biology capability at CCDC CBC through workforce development, infrastructure additions and research projects, BEAMS was able to begin transitioning projects and ideas. In FY19, BEAMS:

- Supported one post-doc who is investigating the biosynthesis of porphyrin molecules for light harvesting applications. These molecules have been shown in a paper written in FY19 to be able to photocatalytically oxidize mustard. The post doc is also supporting the SB4D program to develop hydrogel polymers to protect the components of cell free reactions.
- Developed new programs in the area of synthetic biology for materials including working with collaborators on developing new hybrid chemical/synbio databases to determine retrosynthetic pathways to reach otherwise difficult to reach molecules. One such molecule that has been investigated is disperse red 9, a red dye used in smokes, which has become increasingly difficult to source from Chinese sources.
- Purchased a large scale Lyophilizer to enhance Biotech's scale-up capabilities.
- CCDC CBC is now part of a DARPA program for the scale-up and testing of bio-templated carbon materials for the adsorption of toxic chemicals, storage of oxygen, and obscuration. The goal is to transition this work to materials developments in the area of protection at DTRA in FY21.
- Developed a future plan on the scale-up of biotechnology at CCDC CBC as a resource for the Joint Services, including AFRL, ARL, and NRL, and industrial partners including Zymergen.
- Provided chemical/materials expertise to the synthetic biology community as a whole including travel to various workshops on development of energetic precursors, materials and biosecurity.

45. **(CBC) Warfighter Innovation Leveraging Expertise and Experimentation (WILE-E), $521K**

CCDC CBC has established an innovation project based upon the concept of Design Thinking. The intent of the project is to discover agile and novel technical approaches to satisfying user

operational needs. A multi-disciplinary team from across CCDC CBC has been put together to focus on mitigating the "operational risk" associated with a CBR contamination event. Starting from a “clean” sheet the WILE-E team received briefings by:

- Numerous SMEs representing decontamination, detection, and protection aspects of contamination mitigation
- Several Warfighter’s providing the maneuver, Army 101, operational, and logistical perspectives. (20th Support Command, CBRN School, 10 day visit from USFK CBRN soldiers, etc.)
- Experts on chemical warfare agent chemistry
- Representatives detailing the gradual loss of over-match capability in many domains leading up to the AFC Modernization doctrine
- Intelligence officers describing adversary threat scenarios and lessons learned by recent world events as they related to MDO

The WILE-E Team conducted several "IDEATION EVENTS" which brought together cross-disciplinary expertise from CCDC CBC to work with Warfighters in the room. The entire "team" (WILE-E, scientists, engineers, logisticians, technicians, etc.) worked directly with Warfighters who OWN THE PROBLEM to ideate and brainstorm together. These exercises yielded several “lightbulb” moments which were unlikely to have been discovered had innovation been approached in a different manner. WILE-E is currently conducting analysis of the multiple conceptual approaches and identifying candidate supporting technologies. WILE-E is currently projecting a draft report by the end of 2QFY20.

46. **(CBC) Innovative Development of Employee Advanced Solutions (IDEAS), $509K**

IDEAS is a competitive internal CBC-wide program that gives the opportunity for CCDC CBC employees to pitch their ideas to develop initial data or prototypes for their concept and for the Center to make low-cost, higher-risk investments. The objective of this initiative is to provide a platform for innovative ideas that are intended to either address technology gaps from mission customers, or to create a transition to the Warfighter. Once the final selections were made, there was eight months to perform the work, write the final report and present findings and future plans. The CBC Innovation Team and CBC leadership selected a group of diverse and objective individuals to review each submission for its potential to advance the Center’s CBRNE mission and expertise and transitions to the Warfighter. The individual projects for FY19 are detailed below:

(CBC) IDEAS: InkJet Printed LED Circuits, $86K

A current S&T thrust is the minimization of the physiological and logistical burden by the modernization of our protective capabilities. The InkJet LED Circuit Project is a strategy to reduce this burden by incorporating low power circuitry into swatches capable of powering an array of LEDs for the photocatalysis of sulfur mustard (HD). These results represent a paradigm shift compared to conventional activated carbon and translates to a breathable yet reactive fabric, reducing the burden to the Warfighter. However, for this technology to be leveraged towards combat readiness status requires the use of an array of LEDs embedded into a textile and connected to a circuit capable of simultaneously turning on or off all LEDs and this project has successfully demonstrated this concept.

(CBC) IDEAS: Test Method Development for CWAs on Featured Surfaces using Multi-Point Pin Technology (MPPT), $79K

The objective of this effort is to develop a laboratory-scale test apparatus that will address a current gap in permeation testing of personal protective equipment (PPE) -the evaluation thick seams, folds, and closures against Chemical Warfare Agents (CWAs). Current PPE testing struggles with uneven featured surfaces and no capability currently exists to accurately characterize these features at the lab scale. Previous testing on featured surfaces have shown problematic because the weight cannot apply uniform pressure across an uneven surface, causing a potential vapor gap between the sample and the sampling media which allows for unaccounted for agent permeation. This gap was addressed by developing a laboratory-scale test apparatus that conforms to a surface to ensure complete contact. Adding this capability will aid in decision making during early suit development to protect the Warfighter.

(CBC) IDEAS: A Biologically-derived Transformer- "More than meets the eye…", $77K

In this effort, we will produce a first-of-its-kind, highly efficient, biologically-grown electronic transformer by using living bacterial cultures to grow a laminated transformer core consisting of alternating layers of magnetic nanoparticle-containing bacteria and nanocellulose. The magnetic layers of the transformer core will consist of thin layers of the magnetotatic bacteria (MTB) M. gryphiswaldense that contain chains of magnetic nanoparticles (mNPs) which have demonstrated superior magnetic qualities. Engineered living structural and mechanical materials may provide innovative materials to the Warfighter, possessing unique capabilities such as the ability to self-repair, self-organize, or sense and respond to their surroundings. With success, this effort would be the first to utilize living organic materials as components of electronics that in the future will be designed to meet the unique requirements and challenges of the defense environment

(CBC) IDEAS: Exploiting Designed Biological Recognition Elements for On-Target Detection, $68K

This project aims to use designed biological recognition elements in cell-free lysates to demonstrate a potential antibody-free platform for field portable biodetection. The current state of the art for unpowered biological assays is the lateral-flow immunoassay (LFI). While they are sensitive and specific, they are usually appropriate for testing against one threat per assay. Cell-free lysate-based detection platforms are currently being extensively explored by Office of the Secretary of Defense programs and have shown promise as field portable tools. Cell-free systems harness an organism's transcription and translational machinery without the use of a living cell, but sensing mechanisms that target molecules of interest to the DoD are lacking. It is becoming increasingly common to design proteins to bind targets using computational approaches complemented with modern high-throughput screening. The design rules, software, and techniques for this have matured and are in use beyond the initial developers. This project will utilize previously designed digoxin- and fentanyl-binding proteins as "inputs" to a cell-free sensor. This system is of particular interest as it is, in principle, highly generalizable and could be applied to any designed binding proteins.

(CBC) IDEAS: The Pocket Detection Pouch: One sample, multiple answers, $65K

In field-forward situations, quick sample collection and detection of CBRNE hazards is essential. The Pocket Detection Pouch (PDP), is a new collection-detection form factor that provides rapid, yet accurate, sample-to-results of multiple CBRNE targets simultaneously - in less than 20 minutes. The device requires minimal sample processing and can be customized to detect traditional and nontraditional threats such as chemicals, biologicals, toxins and/or explosives of interest at the same time and from a single sample. In this effort we will deliver a multiplexed prototype device capable of simultaneously testing for the presence of synthetic opioids and

chemical agent by using lateral flow immunoassays (LFIs), chemical detection paper-based assays (i.e. M8 and pH). The PDP is unprecedented in its design as an inexpensive, pocket-sized, flat, self-contained, and extremely simple-to-use collection-detection platform. The PDP platform concept requires minimal sample processing, no external power source, no cold chain logistics, no specialized equipment, and no proprietary equipment or software.

(CBC) IDEAS: Reproducible Construction of Unibody IMS Drift Cells with Additive Manufacturing, $56K

The goal of this project is to develop a 3D printable unibody ion mobility spectrometry (IMS) drift cell of precise length to eliminate defects from traditional manufacturing techniques. Deployed IMS systems detect threats by calculating an ion's reduced mobility (K0) value. Laboratory grade IMS drift cells stack the electrodes and insulators, however, currently fielded devices consist of electrodes only separated by air. This decreases the precision in electrode placement, allowing for variations in the angles or positions of electrodes when hand manufactured or in rugged use. This causes unaccounted for unit-to-unit variation in drift cell length as well as a non-uniform electric field within each unit. The objective of this project is to utilize CCDC CBC's MakerSpace to 3D print a single unified body drift cell with uniform electrodes and reproducible performance.

(CBC) IDEAS: Mobile Live Fire Protection Factor Testing, $50K

While the Army currently possesses the most accurate Protection Factor Chamber to conduct operationally relevant testing of respirators, there is no accurate way to evaluate the effects of weapon fire on the ability of the mask to provide continuous chemical and biological protection to the wearer as well as to evaluate the mechanical integrity of the mask after continuous firing. Several studies have been attempted in the past using M41 Protection Assessment Test Systems (PATS), but the data generated is unreliable due to the lack of control of the testing environment and resulting fidelity of the sampling equipment. A portable, open front test shelter was created so that soldiers may fire small arms weapons in order to evaluate the effects of weapon fire on the Protection Factor value of the worn respirator. Test participants will be able to fire their weapons inside of a uniform aerosol concentration while Protection Factor data is collected in real-time. This data may then be used by Engineers and Researchers to improve the form, fit, and function of the respirator as well as evaluate the physiological effects of firing a weapon while wearing a respirator which will translate to a superior product for the Warfighter.

(CBC) IDEAS: Proof of Concept for 3D Printing for Novel Energetic Devices, $28K

By printing detonation conductive ink (DCI) onto nitrocellulose paper, specific micro-explosive wave patterns can be generated to produce multipoint ignition sources in a minimum of space. This project includes the demonstration of a 3D printing capability for producing microexplosive devices capable of eliminating single point failures in miniaturized fuzes. These micro-fuzes can be applied to the entire energetic family of devices to include smoke producing devices and to support chemical and biological dissemination studies. These micro-fuzes would increase the amount of payload yield for a single device, thus increasing a soldier's battlefield survivability and lethality as well as aerosol yields in test devices. These microfuzes can completely eliminate single point initiation failures in energetic items.

47. **(CBC) Grand Challenge 3.0, $400K**

CCDC CBC's Innovation Team had an offsite this year to determine the next big capability investment for the Center that will follow BEAMS which represented the area of synthetic biology. Three target areas were identified; Radiological/Nuclear Defense, Artificial Intelligence/Machine Learning in CBRNE Defense and Scale-up Engineering of Materials. Three groups have been working to identify opportunities and investment areas in those three topics for recommendation to CCDC CBC leadership. This initial funding included the exploration of those three topic areas and after the leadership brief, planned for late 1QFY20, will being planning for workforce development, infrastructure and research projects.

48. **(CBC) Leading the User Market to Employ New Solutions (LUMENS), $290K**

This program consists of initiatives in the area of chemical demilitarization and elimination with the goal being to develop and market validated operational capabilities that CCDC CBC's Chemical Biological Applications Risk Reductions (CBARR) team has the skill set to perform. The three overarching functions for maintaining this portfolio are to assess the needs of the user market, transition RDT&E ideas to operational solutions and expand into emerging markets. Gaps and trends in current threats and capabilities will be assessed to answer the question "What operational capabilities are we missing?" Each portfolio project is scoped and proposed to capture intended approach and outcomes. Some projects will be straight forward 'operationalizing' of existing practices or equipment (draft and validate standard operating procedures, develop hazard analyses, etc.). Some may require testing be performed and documented as a decision point in the process. Details for each LUMENS project are below:

(CBC) LUMENS: Operationalize Thermal Decontamination Capability for Restoration of Decedent Effects, $150K

The purpose of this effort is to evaluate the efficacy of the chemical hot air decontamination (CHAD) technology to effectively decontaminate C-CDE items to the GPL after contamination with mustard (HD) and sarin (GB). This effort responds to the recommended solution in JUONS-0559 Department of the Army (DoA) EXORD 151-17 (22 October 2018) for the safe management and return of selected chemically-contaminated decedent effects. Decedent effects include all personal items the individual possessed bodily at the time of death.

(CBC) LUMENS: Evaluate ClO2 for Decontamination of Fentanyl Compounds, $140K

The purpose of this effort is to conduct R&D work to assess critical aspects of synthetic opioid decontamination using chlorine dioxide (ClO2). Due to the highly potent nature of synthetic opioids, such as fentanyl and its derivatives, remediation of contaminated sites poses formidable challenges. The primary goal is to provide data that demonstrates the efficacy, speed, and economic efficiency of ClO2 technology.

49. **(CBC) Makerspace, $133K**

This program provides CCDC CBC personnel access to additive manufacturing machines to support mission related projects and educate the CBC workforce about additive manufacturing. Through the MakerSpace, users are able to experiment with additive manufacturing technologies, equipment, and software to determine how it could aid their mission and support their workflows. The program makes additive manufacturing easier to access across CBC and provides a backbone for new innovations. It supports the Department of the Army in maintaining an accessible organic capability in additive manufacturing. MakerSpace reduces the need for labs to purchase their own additive manufacturing capabilities, thus increasing the quality of the products and creating a collaborative space for innovation. This capability will continue to support urgent mission

requirements while aiding the integration of additive manufacturing into lifecycle support activities that can improve Army readiness. This program also included SolidWorks 3D modeling training.

50. **(CBC) Seedling Program, $90K**

CCDC CBC's Seedling Program is an internally competitive program, similar to IDEAS, but focused solely on basic research. These low-cost, high-risk projects are often used as precursors for projects selected for CCDC CBC's In-House Laboratory Independent Research (ILIR) Program. Details for the FY19 Seedling projects are below:

(CBC) Seedling Program: Photonic PCR for Ultrafast Biological Identification, $50K

In the field, high confidence biological identification has been limited by the biochemical activity of the enzymes used in polymerase chain reaction (PCR) which requires repeated cycles of heating and cooling to amplify the unique DNA sequence of a targeted biological agent. Currently, there are a few unique methods of rapid PCR cycling, none of which are usable in the field due to inaccessible specialized equipment. This effort used light emitting diodes for a low-cost and lightweight photothermal rapid heating of gold nanoparticles to yield detection of DNA targets. The use of this proposed method will be able to identify target analytes in biological samples in under six minutes.

(CBC) Seedling Program: MWD Protection Test Capability Development, $25K.

This effort was undertaken to ensure that the center was being proactive and well postured to support the development of future military working dog (MWD) protective equipment systems as well as the associated test methodologies unique to this problem set. Thus far, this effort has resulted in a market survey of canine protective equipment; both commercial and military. We have also met with DoD MWD handlers to understand their typical mission sets and equipment needs. We have become aware of a number of potential MWD respiratory protection efforts on the horizon. Recognizing that there is no set system level test methodology available to assess these systems, we have modified our portable protection factor test methodology to accommodate this testing shortfall. We will next be working to take our portable protection factor test system to MWD handlers to determine which exercises MWDs can perform for use in standardized test protocols.

(CBC) Seedling Program: Aerosol Patent Prototype, $15K.

To fill a gap in the current state of technology which does not allow for efficient and reliable aerosol generation with liquid flow rates in the micro liter per minute to micro liter per hour range, CCDC CBC developed a liquid aerosolization device capable of functioning under ultra-low liquid flow rates. Funding was provided to build three additional prototypes for testing and use. All three prototypes have been built and are being tested. After testing, one prototype will be sent to interested customers for their evaluation. Patent licensing discussions will follow.

51. **(CBC) Advanced CB Suit, $50K**

A plan of action for the development of an advanced CB and ballistic protective suit concept was developed with participation from investigators across CCDC CBC. Near (1-3 yr), mid (3-10 yr) and far-term (>10 yr) phases were documented for iterative insertions of technologies. The initial FY19 focus was on the near-term integration of CCDC CBC developed technologies into suit material. The research team is waiting on sample material impregnated with multi-functional

materials with established resistance to chemical permeation. Once received, patterning for fabrication of a table-top demonstrator with commence. End goal is to reduce physiological burden and enhance soldier lethality.

52. **(CBC) Sensor Vehicle Prototype, $50K**

CCDC CBC developed a platform for sensor integration that has been utilized in many demonstrations and exercises to support programs at DTRA and the JPEO-CBRND. This project produced another sensor vehicle prototype in order to conduct internal spiral development activities. This asset is necessary to properly conduct current and future payload/platform development and to ensure integration and interfacing requirements are addressed. This asses it critical to the transition and demonstration of the Array Configurable of Remote Network Sensors (ACORNS) program. ACORNS was also initially funded by the CCDC CBC IDEAS program.

53. **(CBC) Chemical Agent Detector-Kit Colorimetric Reader (CADCoR) Program, $19K**

The CADCoR Program is a joint US/ROK collaborative project agreement to design an improved chemical detector with Japan. This was the last year of this effort and consisted of labor and travel to coordinate the final report with MSCoE and Japan.

54. **(ERDC) Fluid Structure Interaction (FSI) Integrated Modeling Toolkit - Extending and Improving 3D and 2D-Vertical Simulations (FY16-19), $500K**

Develop an integrated, validated, and efficient physical and computational modeling toolkit for the ERDC and Defense needs associated with fluid-structure interaction (FSI) (e.g., flow around vehicles and other media). The FSI simulation tools will be optimized for the Department of Defense (DOD) High Performance Computing Modernization Program (HPCMP) hardware and networks and capable of unprecedented fidelity for dynamic, 3D (and 2D-vertical) simulation. The improvements to physical modeling facilities will be modular and accompanied by formalized standard operating procedures to promote efficient physical model planning, execution, and data dissemination that is consistent across testing sites. This provides resilience in the allocation of resources. The standard operating procedures will ensure that physical modeling data sets are accurate, reproducible (through independent physical and computational experiments), and applicable to engineering analyses and computational validation. Such analytical capabilities enable reimbursable work supporting Defense acquisitions, planning, and operations. The core tools will provide fast and accurate, physics-based solutions for FSI problems across DOD, such as the evaluation and design of reliable vehicles, vessels, and infrastructure for riverine and near-shore military operations, reduced acquisition cost through computational prototyping and testing, and high-fidelity operational guidance in complex near-shore and riverine operational environments. This was the fourth year of a four-year project.

55. **(ERDC) Model Order Reduction for Engineering Using High Performance Computing (MORE HPC) (FY17-20), $1,190K**

This project will develop the necessary infrastructure for ERDC-wide model order reduction activity; will establish tools and processes for creating reduced order models (ROMs) for existing and future applications; develop ROMs for several, critical application areas; and build ROMs on top of a shared infrastructure to apply and integrate technology with other ERDC models benefiting our projects and mission areas. It will provide needed linkage between high fidelity, physics-based numerical models and customer-required response times and delivery platforms. MORE-HPC will make it possible to use fundamental, physics-based modeling to drive

engineering and scientific analyses reducing Army acquisition timelines and design costs This was the third year of a proposed four-year project.

56. **(ERDC) Novel Computational Environments for Rapid Decision Making (FY17-20), $910K**

This project will develop an overall decision analytics strategy and establish an initial framework and capability in deep learning and machine learning for conducting large-scale decision analytics. This effort includes analysis of deep-learning methods on high performance computing (HPC) architecture and scalability analysis of machine-learning methods hosted on HPC architectures. This research serves as the foundation for utilizing decision analytics to solve large and complex problems across the Army. This was the third year of a four-year project.

57. **(ERDC) Unlocking the Physics of Near-Surface Soil Mechanics (FY18-20), $290K**

Many Army research programs have a specific focus on near-surface environments, defined as the upper meter of the subsurface. Specifically, multiple investigations require a full understanding of the near-surface soil properties and subsequent behavior, but prevailing classical theory is unable to replicate real world field observations. The impact to fielded technologies can be significant, with non-trivial effects to the warfighter. Other than the pioneering work executed in the Military Engineering Basic Research programs (FY15-17), very little is understood about the complex soil mechanics of the near-surface environment, and numerical modeling with current physical understandings is inadequate. To this extent, aims to develop the constitutive physics, which can be validated through laboratory experimentation and surrogate numerical modeling, to explain the complexities of near-surface soil behavior. This behavior is fundamental to a broad range of military mission spaces,
intelligence operations and strategic research efforts, e.g., source characterization; wave propagation; tunnel sensing; ground-coupled surveillance sensors; unattended ground sensors; penetration depth calculations for sensor delivery vehicles; and airfields, mobility operations and dust control for small unmanned aerial and ground vehicles. This was the second year of a three-year project.

58. **(ERDC) Bio- and SynBio-enabled pathways for material synthesis and indigenous material manipulation to increase military utility (FY18-20), $342K**

The overall objective of this work is to develop robust biological methods to manipulate the chemical composition, crystallinity, and morphology of minerals including indigenous materials to optimize the performance of structural materials. The work will provide new knowledge and means to engineer biological systems in ways that improve their military utility by producing high performance materials with increased speed. Another outcome of this work will be an understanding of the use of biological systems to manipulate indigenous materials to support various mid- and long-term military applications. This was the second year of a three-year project.

59. **(ERDC) Growing the Dark Web: Metal Chelating Fungal Melanin as an Electrically Conductive Biowire (FY19-20), $150K**

This demonstration could change the thinking about fungal mycelium that are known to carry chemical signals through vast arrays in forests. Perhaps in the future they can be used instead to carry electrical signals and serve as a large subterranean sensor net. In the scientific community, the methods by which micro and some macro organisms utilize small electrical signals to communicate and how they respond to them as well is a field that is still fairly understudied. This research could provide insights in how currents can move through organisms when propagated

and provide further knowledge on how these currents can be manipulated in other organisms, tissues, or other biological material. The greatest significance perhaps though is demonstrating the feasibility of biological molecules for micro and nanoelectronics. This basic research endeavor it could facilitate the production of biological wires that are grown, virtually undetectable, biodegradable, and that allow for the communication of low voltage subterranean devices such as a pressure sensor array for early intrusion detection. This was the first year of a two-year project.

60. **(ERDC) Quantitative Threat Detection Using Artificial Intelligence (FY19-21), $361K**

This research targets the identification of threats using Artificial Intelligence (AI) techniques using both physical data (the geospatial environment) and cognitive data (the learned environment). Over time, such entities establish a plan of action that, while indistinct over individual components, becomes a structure conducive to dangerous behavior. The 50-hour Army training course, 'Advanced Situational Awareness,' teaches Soldiers to discover threats in the human and environmental terrain. This research will aim to accomplish something similar through technical means, using analysis methods such as Neural Networks to learn what threat networks may look like in highly dimensional Army intelligence, the physical environment, social media, and demographics. The basic research will investigate the AI methods to reason over the graphs, while the applied research will be tailored to an Army application. This was the first year of a three-year project.

61. **(ERDC) Instant Structural Materials Technology for Military Applications (FY19-20), $498K**

This effort will develop ERDC capabilities for production and testing of instant structural material (ISM) technology that will support multiple military applications. The core concept requires packaging proven polyurethane materials in flexible envelopes for rapid expansion of structural geometries suitable for a variety of applications. Varying the core material, envelope, or geometry can make the concept useful for applications ranging from expedient crater repair in support of force projection by air or land, enabling gap crossing operations in support of combat maneuver or lines of communication, or as bullet barrier for force protection. The research effort would provide an opportunity for developing in-house capability to fabricate the flexible envelope and evaluating different materials for it, developing new/improved foam materials that meet specific application requirements, and designing optimum system configurations required for each military application. The culmination of these efforts will be a technology demonstration. Successful development of this concept would provide novel, lightweight, and rapidly deployable solutions for force projection, protection, and maneuver support. This was the first year of a two-year project.

62. **(ERDC) Accelerating the Tactical Decision Process with High-Performance Computing (HPC) on the Edge (FY19-21), $480K**

The traditional approach to collecting, transmitting, analyzing, and distributing data on the battlefield is adversely impacted by network and logistical constraints on the tactical edge. This project will use a new approach for making decisions on the battlefield by moving the analytical capabilities closer to data sources as opposed to transmitting the data. This change will transform decision making on the battlefield by eliminating data transport delays. Real-time situational awareness is achieved by locating computational assets at the tactical edge and transform algorithms and methods to exploit that relocation. This new approach could revolutionize battlefield operations by making better decisions faster. This was the first year of a three-year project.

63. **(ERDC) Augmented Reality Laboratory (FY19), $300K**

The project will add a driving simulator capability and Google type viewing lenses to allow an operator to drive or walk through actual terrain, incorporate this technology with existing Army Geospatial Enterprise (AGE) Node capabilities. It will establish space for augmented reality tools, and application concepts of operations, including an open area for simulations. This capability will significantly improve mission planning and Rehearsal of Concept drills. The intent is to have a dedicated space to showcase new capabilities into already existing AGE Node technology for demonstrations and briefings.

64. **(ERDC) 150kV Flash X-ray System (FXR) for the Fragmentation Simulation Facility (FY19), $378K**

A 150 kV flash x-ray will enhance research of projectiles impacting and penetrating protective materials. The FXR is the only way to see into materials to assess the projectile during the penetration process. This facility will improve Army research into both new warheads and new protective systems.

65. **(ERDC) Agilent Triple Quadrupole Liquid Chromatograph / Mass Spectrometer (FY19), $536K**

This equipment will allow ERDC to provide solutions to the DOD for the detection, treatment, removal, and remediation of perfluorinated compounds in soils and water as well as on surfaces. The water at or around 126 military installations contains potentially harmful levels of perfluorinated compounds, which have been linked to cancers and developmental delays.

66. **(ERDC) Modernization of Construction Techniques for Coastal and Hydraulic Fixed and Loose Bed Physical Modeling (FY19-21), $200K**

The objective is to modernize the current 75-year-old construction process for coastal and hydraulic fixed and loose bed physical models through the application and development of three-dimensional printing capabilities. These modern printing technologies, including carbon fiber infused polymers and concrete, can be applied to construct model bathymetry and hydraulic structures in a modem and efficient manner. The Current ERDC model construction methods rely on skilled handwork requiring highly experienced craftspeople. Thus, once constructed, if ever deconstructed, models cannot be accurately replicated to the original. With the attrition via retirement of the ERDC craftspeople, the required personnel to construct physical models will no longer be available by 2021. Using three-dimensional printing provides a means to decrease laboratory footprint, increase production, decrease cost, and provide a means of reproduction. It would also increase the ERDC model construction ability where multiple agencies across the Army could access. Additionally, it would increase the capability and reliability of ERDC-developed concrete printing technology for a broader range of applications. This was the first year of a three-year project.

67. **(ERDC) Environmental Forensics for Reverse Point Sourcing and Attribution (FY19-20), $250K**

This projects aims to improve situational awareness to identify adverse activities by using biogeochemical signatures to back-trace particle sources using atmospheric transport models, geomorphic landform datasets, and snow/ice deposition materials. Functional changes in microbial communities due to anthropogenic activities at the source location can be preserved and

detected at the depositional site as an indication of remote, clandestine efforts. An immediate payoff of this research will be the near real-time corroboration of threat hazards in access-denied areas as well as their stability on surfaces such as snow and ice, terrain, water, and other surfaces. The proposed effort will advance Long Range Precision Fires regarding target acquisition, Future Vertical Lift to identify areas of brownout potential, and Soldier Lethality with respect to hazardous air quality and pathogen exposure risk assessment. This was the first year of a two-year project.

68. **(ERDC) Microphone Secondary Calibration System (FY19), $148K**

Purchase of an in-house National Institute of Standards and Technology-traceable microphone secondary calibrator system. At present, the requirement for routine calibration is satisfied through the U.S. Army Test, Measurement, and Diagnostic Equipment (TMDE) process facilitated by the USACE Logistics Activity. This process requires shipping of all microphones to one of several TMDE laboratories on a yearly basis, which limits the capability of ERDC acousticians to complete their mission until the microphones are returned. In addition, shipping presents risks of damage, loss, or mechanical disturbance of the calibrated value. Recently, concerns of quality control have also arisen with TMDE reports. Purchasing this system allows TMDE-equivalent calibration quality to be obtained in-house without the need for shipping and logistics support. In addition, high-quality calibration could be performed on demand, instead of waiting several months for the calibrated microphones to return as is done presently. This would extend ERDC's ability to provide high-quality noise assessment and monitoring solutions for installations across the Army.

69. **(ERDC) Creation of a Data Lake (FY19), $500K**

This project creates a persistent petabyte scale data storage environment to meet the requirements for data analytics, artificial intelligence, machine learning, and the digital engineering community. These storage environments are referred to as Data Lakes. Data Lakes provide a repository of data stored in its natural/raw format. This investment provides the foundation components for a data lake that allows the Army's data scientists and digital engineers to have a single location to store data that requires computer intensive resources, and would be extensible, allowing for future storage capacity growth.

70. **(ERDC) Spectral and Terrestrial Analytics Reconnaissance (STAR) Group Test Node for Rapid Tactical Geospatial Visualization: a Deployable Enhanced deep Learning Tactical computing Analyses (DELTA) Unit (FY19), $400K**

Acquisition of an integrated system (DELTA) that would allow research and development of methodologies for rapid data processing, fusion, and generation of tiered products both in the laboratory and at the point of collection. The system is comprised of a fixed laboratory component and a deployable component for in-field processing. The ultimate goal is to enable rapid delivery of analytic products to the Warfighter. The Geospatial Research Laboratory (GRL) is co-located with the Army Geospatial Center (AGC). Although AGC possesses a state-of-the-art modeling and simulation (M&S) capability, leveraging and integrating the GRL Geographic Information Systems/Geospatial Intelligence (GIS/GEOINT) expertise is a challenge as these datasets have become so large. There is an additional obstacle in understanding how to automate integration of the GIS/GEOINT and M&S metadata to achieve rapid visualization of geospatial data. Acquisition of an integrated data processing and visualization capability will allow GRL scientists and engineers to rapidly process geospatial big data in an automated fashion using machine learning and deep learning algorithms. This will greatly enhance the development of the

Network and Synthetic Training Environments (STE), which directly addresses critical challenges identified by the Network and STE Cross Functional Teams (CFTs).

71. **(ERDC) Robotic Technology Kernel Integration on Pathfinder Robotic Autonomous Systems in support of Assured Position, Navigation, and Timing (FY19), $270K**

PATHFINDER represents a multi-resolution geospatial approach to Assured Position, Navigation, and Timing (A-PNT) that combines hardware and software solutions in the air-to-ground guidance of robotic autonomous systems (RAS) navigating across complex and dynamic terrain in the absence of GPS. The PATHFINDER concept is being developed through collaborations within CCDC-Ground Vehicle Systems Center (GVSC -formally TARDEC) Robotics Wingman Group and C5ISR Center's Night Vision and Electronic Sensors Directorate (NVESD) - Ground Combat Systems (GCS) Directorate. This project integrates these systems for field testing and technology assessment into the current suite of augmented localization technologies. To complete the test-bed and expand experiments guiding A-PNT solutions, PATHFINDER will leverage funding to integrate the CCDC (TARDEC) robotic technology kernel into a second test vehicle. This will effectively bring a multi-resolution solution set as part of enhanced mobility and maneuver in GPS-denied environments by means of: 1) wheel encoding and gyro navigation (inertial navigation system), 2) lidar simultaneous localization and mapping, using frequency-domain continuous wave Doppler data, and 3) 3D base map updates and automated ground control point-GCP (waypoint) extraction via Falcon 2 pod. The goal is that maneuver position-navigation (POS-NAV) accuracy of robotic autonomous control of the test vehicle will improve linearly as the above resolutions are realized with the best position and navigation trajectories achieved in open terrain via 3D visualization data afforded by the Falcon 2.

72. **(GVSC) Soldier Experimental Gaming and Analysis, $173.6K**

Data collection and analysis routines were developed for Virtual Experimentation by Soldiers in a video game format, emphasizing UAV tracking and mapping paths driven by vehicles.

73. **(GVSC) Soft Kill Armor, $165.0K**

Technology exists that can jam an oncoming vehicle's engine management system causing the vehicle to stall. This project evaluated if a similar system can be embedded in vehicle armor for protection against "smart" threats.

74. **(GVSC) Additive Manufacturing of Metals - Rapid Residual Stress Analysis, $105.0K**

Additive Manufacturing has enormous potential but is hampered by residual stresses in the final part that can lead to premature failure. This project is measuring in-situ stresses induced during manufacture to help eliminate or reduce stress.

75. **(GVSC) Direct Terrain Profile to Drive Time History Generation, $70.0K**

A faster test method was developed to allow for laboratory testing on the durability of military vehicles as opposed to the far more laborious methods currently in use.

76. **(GVSC) Repair by Welding of Armor Grade Steels and the Metallurgical Effects of the Repaired Area, $65.4K**

Based on a need for improved welds, this project is investigating weld wires used by the Navy for submarines. Ballistics tests are being carried out on welded Rolled Homogeneous Armor (RHA) to evaluate the efficacy of various weld wires.

77. **(GVSC) Demonstration of Solid Optical Power Limiter for Day Camera or LIDAR Protection, $45.0K**

Investigators identified a solid optical limiter for protection against lasers that will simplify integration into camera sensors. An article on the results appeared in Journal of DOD Research and Engineering.

78. **(GVSC) Stryker Silent-Watch Energy Ramp with Embedded Li-Ion Structural Batteries, $42.3K**

This project is adapting a Stryker rear door to hold 60 prototype lithium-ion batteries to meet the Stryker's 4-hour silent watch requirement, which is currently not possible with available battery options.

79. (GVSC) Project Robo-Talk 9, **$38.8K**

This project is investigating a system that employs speech recognition and natural language processing so that the Warfighter can voice commands to an unmanned vehicle using natural language just as they would speak to another person.

80. **(GVSC) Wrist-based Operator Control Unit (WOCU), $31.9K**

This project is developing a wearable Operator Control Unit for controlling robots that will reduce cognitive load and the learning curve for the operator.

81. **(SC) Soldier Innovation Fund, $25K**

Fund novel ideas and explorations that offer the potential to enable disruptive or breakthrough approaches to deliver significant overmatch or performance advantages for Soldiers. This year focused on Soldier Innovation Fund's program conception, development, and implementation through a call for technical proposals from scientists and engineers with endorsement from within the proposing Directorate. Project selection and execution will begin in FY20.

82. **(SC) Bootstrap Program, $244K**

Bootstrap is a program that continues to afford anyone in the organization the opportunity to propose an idea (new equipment, process change, improvement to productivity, and then it is the workforce itself, through an anonymous voting process that decides which ideas offer the highest potential to impact the organization and the mission. Bootstrap uses a "crowdsourcing" model where personnel submit and "pitch" proposals describing their ideas. Internal marketing and poster sessions directly enable workforce awareness and connection to the mission.

83. **(SC) REI Initiatives, $1017K**

Research Equipment and Instrumentation continues supporting the acquisition of research equipment and instrumentation for the significant advancement of CCDC SC capabilities.

Research Equipment and Instrumentation contributes to the creation of new innovative cutting-edge research opportunities to develop transformative knowledge and concepts through the procurement of state-of-the-art laboratory and research equipment. The initiative reaches beyond standard equipment purchases; it is centered on new instrumentation specifically identified through the inherent knowledge of the workforce. Selected equipment and instrumentation is anticipated to enable the achievement of scientific advancements in priority Combat Capabilities Development Command Soldier Center mission areas to support Army Modernization and create an entirely new essential capability for the center.

84. **(SC) Enabling Technologies for Synthetic Training, Simulation and Training Technology Center $100K**

Investment to investigate simulated battlespaces using constructive wargaming technologies. Leverages neural network training environments existing work at ICT in order to investigate "what would a more optimal battle plan be?" questions over an existing battle plan. The anticipated final use is the training of COA decisions - augmented with machine-learning constructive simulations rather than the state-of-practice scripted agents within constructive simulations. This generally means that the level of COA decision training would be able to be pushed down from battalion-on-battalion level to squad-on-squad level. FY19 progress is "performer selected, funding awarded", with kick-off of project in FY20Q1. This funding serves as seed funding at the technical level for the Wargaming CWP effort.

85. **(SMDC) TC Research Council, $13K**

The TC Research Council continued to provide oversight on the organization's in-house research, technical transition opportunities, and technical personnel positions. The council met quarterly in FY19 and approved projects on the TC's Directed Research Program as well as approving Small Business Innovation Research topics and Rapid Innovation Fund requirements.

86. **(SMDC) TC Directed Research Program, $441K**

The TC Directed Research Program continued as an internal program to promote technical development of government engineers within the core technical competency areas of the TC. Emphasis was placed on projects that maintain core competencies, expand cutting edge technologies, and explore new areas in the basic science of their perspective areas and fuel discovery that will lead to more successful proposals within assigned areas. A Directed Research Program Project Review was held with the TC Research Council early in the first quarter and seven projects were selected by late first quarter. The projects began at the start of the second quarter and lasted eight months. Mid-term and final presentations were delivered to the TC Research Council in the second and fourth quarter of the year. FY19 projects included: Image Compression over Software Defined Radio; Thermal Management Solutions for Unique Military Applications; 3-D Printed Axial-Injection; End-Burning Hybrid Rocket Motor Regression Rate Study; Real-Time Wavefront Distortion Prediction Using Neural Networks; Atmospheric Phase Projection System; and On-Orbit Refueling of Small Satellites.

87. **(SMDC) Quantum Entanglement Data Teleportation (QEDT) Research for Space Communications, $585K**

Current quantum entanglement communication scenarios make use of very low brightness sources with limited numbers of entangled photons. This effort is taking current commercial-off-

the-shelf (COTS) devices for Quantum Entanglement (QE) communications and looking for higher brightness replacement components.

B. ***Technology Transitions.*** In FY19, the Army funded 35 technology transition projects, with an annual investment of $17,640 K:

1. **(AC) Field Expedient Capabilities (FEC), $500K**

Field Expedient Capabilities (FEC) Program Mission is to provide Combatant Command (COCOM), Special Forces specific operators, with regionalized build manuals to produce capabilities with indigenous resources (Naked Man Concept) and generate techniques to address United States Army Special Operations Command (USASOC) Operational Gaps. During FY19, FEC focused on the following:

- Portable Power Supply (PPS) which provided the ability to operate universal power tools (drills, grinders, saws, lighting, etc.), as well as the ability to weld various metals. The PPS is based upon the modification of a vehicle alternator.
- Development of low cost, low power mesh networked sensor packages, which resulted in two variants. The two variants were a hand tossed version, named "Breadcrumbs", and one that is a slightly larger but still portable by man. Both of these systems address the Operational Gaps in the topical area of surveillance operation.
- Development of interchangeable heads for cost effective Cartesian coordinate and, in the future, six axis robots allowing for a full capability suite of milling, welding, water jet cutting, plasma cutting, laser cutting and 3D printing.
- Precision, Cost Effective 3D printing techniques with high print resolution of tradition and non-traditional materials. Efforts have been demonstrated to operational units, who have expressed significant interests in this set of capabilities, as this ability can fill several operational gaps in the COCOM operational areas. Unmanned Aerial Vehicles (UAVs): 3D printed UAVs with modular capabilities to support: reconnaissance, surveillance and counter UAV missions.

2. **(AvMC) Artificial Intelligence Airworthiness Strategy, $300K**

The technologies of Artificial Intelligence are already being employed in aviation systems, and will continue to increase in complexity and pervasive application. The subjective, statistical, and non-deterministic output of some AI systems prevents existing airworthiness process from accommodating flight of the new technologies. Existing systems are beginning to incorporate elements of AI without labeling them as such, and current programs are working to qualify system elements in the absence of complete engineering cognizance. While the existing workforce has already gained a level of expertise to adapt, accelerated advances are expected in the area of AI with a 5-10 year horizon. Therefore, it will become possible that we fail to address critical aspects of system/subsystem/software qualification. This investment benefitted CCDC AvMC by ensuring that the organization as a whole instituted a consistent, effective response to the need for airworthiness of AI systems. This proposal supported consolidation of Directorate knowledge in order to evaluate path forward to achieving technical expertise that supports the airworthiness response, including training and policy.

3. **(AvMC) Airworthiness Cybersecurity Vulnerability Assessment, $100K**

Airworthiness is the primary mission of the US Army Airworthiness Authority. Cyber security has become an increasingly important topic within the defense community, as demonstrated by the mandatory evaluation of cyber vulnerabilities of all major Department of Defense (DoD) weapons systems by FY 2016 NDAA 1647. Within the Aviation Community, the term "Airworthiness Cybersecurity" has been created and is supported by organizations such as RTCA (DO-326A), Naval Air Systems Command (NAVAIR as demonstrated by their CYBERSAFE program), as well as the United States Air Force (USAF). To remain secure in our cyber capabilities, the Army Aviation community needs to invest in a new process for investigating the attributes of security and engineering integration, and how that integration affects airworthiness. This investment has enabled the US Army's Airworthiness Authority to identify potential threat vectors and access points within their inventory of high-priority systems (Embedded GPS Inertial (EGI), Aviation Missile Planning System (AMPS), Degraded Visual Environments (DVE), Flight Computers, Flight Controls, Weapons, etc.), partner with the appropriate Program Managers to develop and conduct vulnerability assessments, and if applicable, demonstrate those assessments in a lab environment. The funding from this investment has allowed for the conduction of Airworthiness Cyber Risk Assessments by the US Army Aviation Engineering Directorate. The outcome of the Airworthiness Cyber Risk Assessments has been used to inform our Airworthiness Cybersecurity Requirements, as well as direction provided to PEO Aviation and the Warfighter.

4. (AvMC) Development of Aviation Data Science Technologies, $750K

This investment was used to fund a collaborative CCDC AvMC in-house project ($750,000 total per year, $250,000 per year each at Aviation Engineering Directorate (AED), Aviation Development Directorate (ADD) and Engineering Directorate (ED-RAM) that brings together Army resources to demonstrate that advancements in data science can enable readiness improvements for the current aviation fleet, FVL, and Future Unmanned Aircraft Systems (FUAS). Specifically this effort has advanced data science techniques such as machine learning and other “Big Data” technologies through the use of existing operational aviation data and the Army’s new High Performance Computing hardware acquired by the US Army Corps of Engineers to examine how data analytics can increase operational availability and health state awareness through multivariate and time series data analysis. This investment targeted technologies such as deep learning, natural language processing, data programming, massively parallel batch processing of data, and reinforcement learning to unlock the potential of the vast amounts of sensor data being collected through condition based maintenance (CBM) implementation. This proposed effort has provided CCDC AvMC engineers with the capability to analyze the entire history of aircraft fleet data, including flight test, engineering, maintenance, and usage records, to quickly identify relevant information, and then develop that information into a view of live data - a "data product" - that can be deployed directly to other organizations within CCDC AvMC, aviation program managers, or AMCOM logistics. This capability has radically redefined the expectations of program managers relative to aviation data analysis by greatly reducing the time required to respond to soldier requests from the field and provide engineering recommendations.

5. (AvMC) Manufacturing Technology Maturation & Transition Plan for Future Rotorcraft, $375K

These 2363 funds were used to accelerate the development, transition and use of innovative, cross-cutting technologies through development and delivery of a manufacturing technology maturation and transition plan for implementation opportunities within future rotorcraft variants. The plan included identification of state of the art technologies and processes, to include those developed within CCDC AvMC, other defense laboratories and industry, with specific advancement milestones and time lines to support future rotorcraft development. The program also looked to leverage existing and funded CCDC AvMC Aviation S&T, Manufacturing Technology and Manufacturing USA (the National Network for Manufacturing Innovation (NNMI)) efforts. Goals of this program included accelerating the maturation and transition of technologies and processes, developed within CCDC AvMC, other defense laboratories and industry, to improve the performance, sustainability and affordability of both legacy and future rotorcraft variants. Execution of this effort has equipped both CCDC AvMC Aviation S&T subject matter experts (SMEs) and PEO Aviation (PEO AVN) customers with an understanding of manufacturing technology gaps, risks and the investment requirements to 1) reduce the sustainment costs of legacy systems and 2) meet/improve the affordability metrics of future designs at the appropriate time horizon.

6. (AvMC) Manufacturing Technology Maturation & Transition Plan for Missile System Technologies, $375K

This investment was used to accelerate the development, transition and use of innovative, cross-cutting technologies through development and delivery of a manufacturing technology maturation and transition plan for implementation opportunities on missile system technologies. The plan included identification of state of the art technologies and processes, to include those developed within CCDC AvMC, other defense laboratories and industry, with specific advancement milestones and time lines to support future missile development. The program looked to leverage existing and funded CCDC AvMC Aviation S&T, Manufacturing Technology and Manufacturing USA NNMI efforts. The End Product of this Investment was a Manufacturing Technology maturation and transition plan encompassing Industry, PEO Missiles and Space, and CCDC AvMC. The plan was to be a roadmap to provide pervasive benefits to the Army's Missile systems improving performance/affordability and reducing cost/risk to Army Modernization Priorities including 1) Long Range Precision Fires, 2) Network/C3I, 3) Air & Missile Defense, and 4) Soldier Lethality. Execution of this effort equipped both CCDC AvMC Missile S&T subject matter experts (SMEs) and PEO Aviation (PEO MS) customers with an understanding of manufacturing technology gaps, risks and the investment requirements to 1) reduce the sustainment costs of legacy systems and 2) meet/improve the affordability metrics of future designs at the appropriate time horizon.

7. (AvMC) Sustainment Simulation Software Upgrade, $377K

The CCDC AvMC Logistics Engineering Laboratory (LogLab) has developed a sustainment simulation capability for both aviation and missile utilizing a government owned software tool called System of Systems Analysis Toolset (SoSAT). PEO Aviation, PEO Missiles & Space, and multiple PMs, are utilizing this capability to conduct analysis and provide input for major acquisition documents. In addition, this capability applied to evaluate emerging CCDC AvMC technologies early in the R&D phase. We have also had initial contact with deploying units with a

need for the capability to provide input to strategic plans in support of multiple military operational deployments. This funding has enhanced the Graphical User Interfaces (GUI) for input and output to allow portability of this capability. Upgrading the capabilities of the SoSAT tool has provided CCDC AvMC with the ability to quickly develop and deploy sustainment simulation tools to conduct situational analysis and what-if scenarios for technology upgrades to legacy platforms and implementation of future weapons system such as FVL, Multi-Mission Launcher (MML), and Integrated Air and Missile Defense (IAMD).

8. **(AvMC) Test Capability Improvements for LBASM, other programs, $1,400K**

This investment addition of two digital mirror device Mid-wave infrared scene projectors for the support of Land-Based Anti-Ship Missile (LBASM) program and future Mid-wave infrared sensor applications. Two units were purchased for lab testing in an open and closed loop simulation environment. A matched set was purchased for full up seeker testing in a hardware-in-the-loop (HWIL) laboratory environment. Units were utilized to test all LBASM lab and flight hardware as well as assist in algorithm development in earlier stages of the program. The projectors were capable of being utilized by future mid-wave seeker/sensor efforts with minimal effort. This investment has greatly reduced the risk to algorithm development and all up round integration. Significant simulation runs have been made using actual flight hardware as opposed to bypassing the actual sensor. This has allowed programs to progress through the following sequence: 1.) All digital simulation - 2.) Processor in the loop - 3.) Hardware in the loop. This system would be simply replacing all digital components with the real systems as the program progresses in maturity leading to a more natural progression to flight hardware. This was also a significant cost savings in doing a larger portion of the testing in the lab environment as opposed to a (HWIL) environment which is considerably more expensive.

9. **(AvMC) Multi-Core Processor, $1,080K**

The commercial industry is and has shifted away from manufacturing single core processors towards multi-core processors (MCPs). Due to the inherent non-deterministic nature of MCP architectures and instruction controllers, use of MCPs in safety critical, flight critical, and mission critical applications across all US Army weapon systems possess significant risks. Current safety critical and mission critical applications disable all but one core of the processor. However, this does not take advantage of the full computing power provided by MCPs. This investment has benefitted CCDC AvMC by developing a vital in-house MCP laboratory capability which will be used to analyze and evaluate MCP architectures and multi-threaded software applications. An MCP laboratory has been used to develop safety and airworthiness qualification requirements and analytical and test evaluation methods, computing benchmark metrics, criteria, standards, and guidance necessary for identification, characterization, and mitigation of potential interferences and non-deterministic behavior associated with software applications hosted in an MCP architecture.

10. **(C5ISR) TSM Interference Cancellation (IC), $1,100K**

The IC effort continues and extends the FY19 innovative research to implement digital interference mitigation (IM) techniques to enable communications in the presence of enemy sources in congested and contested tactical environments. C5ISR Center partnered with

TrellisWare to develop the Tactical Periodic Interference Estimation (Tactical PIE) algorithm. In October 2018 Tactical PIE was partially implemented on a tactical radio, the TW-950 TSM Shadow™, in order to perform an initial evaluation of the anti-jam (AJ) capabilities of this IM algorithm. Although Tactical PIE is currently being tested and characterized on the TW-950 handheld radio, the Tactical PIE IM technique is applicable as an AJ capability across a wide range of tactical radios and high throughput waveforms. The purpose of this effort is to further development of the Tactical PIE IM from previously only supporting uni-directional (simplex) communications, to now supporting two-way (half-duplex) communications and to optimize the Tactical PIE IM algorithm implementation both for increased performance and for full bi-directional voice and IP operation with the TSM™ 1.2 MHz waveform. Additionally, at the end of the contract TrellisWare will demonstrate the enhanced capabilities of Tactical PIE in the presence interference. The payoff for this effort includes Tactical PIE IM technology being at TRL-6 and fully implemented with the TSM waveform. The TSM waveform is being fielded as part of the Integrated Tactical Network (ITN) as early as FY20, and the inclusion of Tactical PIE IM technology will enhance the performance of those TSM radios in contested environments for future Capability Sets. Additionally, having the Tactical PIE IM technology working with the TSM waveform will allow ease of transition of the technology to Program Manager Tactical Radios (PM TR). The Tactical PIE algorithm is intended to be radio and waveform agnostic offering the flexibility to be deployed in software defined radios of other vendors and also utilized in other waveforms. This effort reinforces C5ISR's long term investment of electromagnetic compatibility solutions and interference cancellation techniques to guarantee electromagnetic dominance in the battlefield. This effort supports the Network/C3I Army priority.

11. **(C5ISR) Universal Communication Gateway, $500K**

Enabled various, conventional P&E equipment to communicate with each other using standard communications protocols. Increased ability to realize "Connected" micro grids, hybrid power, etc. and further support investments aimed at optimizing Expeditionary Energy & Sustainment Systems (E2S2) operations, realizing equipment diagnostics, etc.

12. **(C5ISR) Protected Communications for MUM-T (PCM), $864K**

Currently working this PCM effort. The goal of this effort is to enhance current COTS communications system for the wireless tether to the Robotic Combat Vehicle (RCV) that provides desired range, throughput, and latency while enabling anti-jam, low probability of intercept, and low probability of detection (AJ/LPI/LPD) for operations in congested and contested environments. It will enable assured operation of the RCV from the Optional Manned Fighting Vehicle (OMFV) in contested threat environments as well as heavy foliaged and urban terrains. The goal of this effort is to transition prototype to Program Manager (PM) Tactical Radio (TR) for evaluation/ demonstration/experimentation in future Integrated Tactical Network (ITN) Capability Sets. This effort supports the Army Network Modernization Priority.

13. **(ERDC) Total Watershed Decision Support (TWDS) (FY16-20), $644K**

This project is developing a modular modeling and decision-support framework that encompasses the total watershed, including physical processes through impacts. The effort will deliver a geospatial platform to characterize biogeophysical, social, and environmental products supporting

Army engineer operations, intelligence, mission command, disaster response, and remediation. This is the fourth of a five-year project.

14. **(ERDC) Army Geospatial Enterprise (AGE) Node, $700K**

This project continues software development and integration of research projects into the Army Geospatial Enterprise (AGE) AGE Node. The AGE, developed and implemented through the Common Operating Environment, results in a more efficient, interoperable, consistent, relevant, and responsive implementation of geospatial capabilities. The AGE Node integrates multiple computing environments through linkage of representative Programs of Record (PoR) (e.g., Nett Warrior (NW), Joint Battle Command Platform (JBC-P), Distributed Common Ground System Army (DCGS-A) and Command Post of the Future (CPOF)). The overall goal is for collecting, managing, sharing, exploiting, and transforming geospatial products and information across and within Computing Environments. The AGE Node will facilitate researcher and research project understanding, to include the development, integration, and transition of research capabilities to PoRs, enabling a more efficient, interoperable, consistent, relevant and responsive Army Geospatial Enterprise realized across these PoRs.

15. **(ERDC) Technology Transfer Program, $1,187K**

Develops ERDC policies and procedures to receive, evaluate, and fund technology. Direct and Oversee execution of technology transfer and infusion activities. Develop ERDC guidance and provide intellectual property protection support to transition products. Develop and Lead ERDC enterprise document management system (DMS) for workflow processes and centralized repository. The purpose of this program is to make ERDC better at transferring technology to the Army.

16. **(ERDC) ERDC University, $458K**

ERDC University is a program that provides technology transition between ERDC and USACE Divisions/Districts in order to grow a collaborative environment. It also provides a six-month developmental opportunity to USACE Engineers and Scientists while working on real-world solutions.

17. **(ERDC) Mechanisms for Patents, $200K**

This program provides mechanisms for researchers to file invention disclosures, obtain patents, licenses, and software copyrights for technology transfer in coordination with ERDC Office of Counsel. This program helps protect Army Intellectual Property.

18. **(ERDC) Transition Stratagem Development, $15K**

Engages ERDC personnel in the development of both external technology transfer strategies, initiatives and programs, and infusion of external technologies for the advancement and expansion of the original purpose of the proposed technologies.

19. **(ERDC) Partnership Intermediary Agreement, $500K**

Partnership Intermediary Agreement (PIA) development to engage ERDC researchers collaboration with industry and commercialization of products and technologies, aimed at providing the Army the most up to date and cost effective technology solutions.

20. **(ERDC) E-PAS Development, $499K**

Purpose of E-PAS is to create a centralized database and document management for ERDC's processes. This phase of E-PAS development will include creating data forms, workflow process, routing, approval, and storage of addition ERDC processes. This effort provides benefit through the development and improvement of the technology transfer program by allowing for the first time an enterprise system for accountability of projects, technologies, and products through life-cycle development. These efforts improve the ability to deliver products on time and within budget and thereby accomplish missions for the Army.

21. **(ERDC) ERDC Technology Transfer and Infusion/Knowledge Management (DiscoverERDC), $360K**

This effort provides benefit through the improvement and expansion of the technology portfolio to include knowledge sharing and collaboration for the advancement of technologies for new purposes and expansion to new mission areas. These efforts improve the ability to communicate with partners and customers, deliver products, and accomplish missions for the Army. The objectives are 1. Develop an annual communications campaign plan; 2. Improve Discover ERDC; 3. Create and maintain Discover ERDC content; 4. Support USACE Campaign Goal 4a; and 5. Research innovative opportunities for improving Knowledge Management.

22. **(ERDC) Arctic Domain Stakeholder Engagement and Collaborations (FY16-20), $396K**

This project identifies DOD Arctic and cold region domain knowledge gaps; shapes new and emerging requirements via direct interaction with the Combatant Commands (CCMDs); develops relationship among the Services and other federal agencies to capture business opportunities and build a sustainable Arctic domain program with horizontal integration of efforts across ERDC. This project also addresses DOD and other federal agencies' Arctic and other cold region needs. The objective of this effort is continued refinement and execution of an ERDC Strategic Roadmap for the Arctic, enabling the ERDC enterprise to become a crucial solutions provider for austere cold regions support. This is the fourth of a five-year project.

23. **(ERDC) An Integrated Dashboard for Technology Transfer and Marketing of ERDC Chemical Risk Assessment and Management Products and Capabilities, $500K**

This project aims to further transition of technologies by developing a web-based resource, or a dashboard, that aggregates and facilitates access to ERDC technologies, products, and expertise for (1) chemical fate and transport, (2) determining chemical exposure, (3) assessing chemical hazards/effects, (4) risk assessment, and (5) management of chemical risks. The dashboard will provide a coherent and easily accessed framework to transfer technologies developed at ERDC; the dashboard will make capabilities that are currently available discoverable and provide information on when to use them and how to access them. The dashboard will support decision making in the Army by providing rapid access to solutions that can minimize and mitigate adverse impacts of chemical or other material hazards during material production, military operations and training, and post-operation clean up.

24. **(ERDC) Army Geospatial Node Transition Demonstration (FY19-20), $32K**

This project will demonstrate and operationalize ERDC research using the AGE Node in support of the Army Common Operating Environment (COE). ERDC hosted a two-day workshop at the Army Geospatial Center (AGC) with staff rotating through multiple venues to interact with current and prototype Army command and control systems, learn fundamental information of

Army units, fundamentals of the Joint Capabilities Integration and Development System (JCIDS), introduction to key program executive offices (PEO) and programs of record (POR), and providing necessary insights for successful technology transition.

25. **(ERDC) Terrain and Signature Physics Integration Center (FY19-20), $291K**

The primary objective of the Terrain and Signature Physics Integration Center (TSPIC) is to consolidate, upgrade, and integrate ERDC modeling capabilities related to signature physics and environmental impacts on sensor performance. This set of integrated software capabilities enables ERDC to take the initiative in addressing Army modernization plans, and to rapidly adapt to other new customer and transition opportunities with a critical mass of "ready to go" modeling capabilities. This consolidation of ERDC and Army signature physics and sensor performance technologies is achieved using the latest software tools for version control, code review, and collaboration. The TSPIC improves coordination and outreach for signature physics research across ERDC, and deepens collaborations with other Army organizations such as the Army Research Lab, Armament Research, Development and Engineering Center, Night Vision and Electronic Sensors Directorate, and NATO partners.

26. **(ERDC) Mobile Low Logistics Hygiene Systems for BCT Support (FY19-20), $441K**

This project seeks to increase Soldier lethality, reduce exposure to attack, and extend operational reach by developing a logistically efficient mobile field hygiene system that drastically reduces the amount of water that needs to be transported by a mobile brigade combat team (BCT) during Multi-Domain Battle against near-peer adversaries. In the first year, the team will built a Palletized-Load-System (PLS) compatible hygiene unit that includes pop-out water-efficient shower stalls, an onboard water recycling system, and water heat recovery technology. In the second year, the team will build a second unit with water efficient latrines and onboard treatment technology. By reducing water demand and wastewater generation, such a system could greatly reduce the need for 5000-gallon water trucks and increase time between resupply.

27. **(ERDC) Enterprise Solution for Deployed Force Infrastructure Assessment and Site Selection (FY19-21), $467K**

ERDC research, tools, and capabilities for engineer site selection and reconnaissance will transition into the Engineer Site Identification for the Tactical Environment (ENSITE) enterprise platform, which provides Instrument Set, Reconnaissance, and Survey (ENFIRE) a single touch point. When ENSITE transitions to the ENFIRE platform, customers can transition into a POR and can be accessed by ENFIRE's user communities that include Field Engineer Support Teams (FESTs), Request for Information (RFI) contingency reachback groups, and Geospatial Planning Cells (GPCs). Subject matter expertise will be provided to the Army Aviation and Joint service LOTS communities in an intuitive and integrated platform via ENSITE as the Geospatial Common Operating Platform for ENFIRE. More efficient and accurate infrastructure assessment and site selection will assist in the reduction of material demand, reduce risk to personnel, and preserve transportation and logistics flows.

28. **(ERDC) Advanced Graphene Enabled Technologies for PFAS Treatment and Enhanced Concrete (FY19-20), $450K**

The objective is to transition ERDC's significant and pioneering research in graphene through adaptation of graphene-based composites to address critical technology and capability gaps faced by the U.S. Army. Graphene based composites are one of the most active research areas of the past four years and they are emerging as one of the most effective multifunctional materials

currently known. This work will focus efforts in two new main thrust areas across multiple business areas; 1) use of graphene/polymer composites to develop a "trap and treat" structure for the treatment of organic contaminants in water, with a particular focus on highly problematic perfluorinated alkylated substances, 2) incorporate graphene materials into concrete and asphalt to provide increased resiliency in existing hardened surfaces and building materials for Army assets and force protection.

29. **(GVSC) Tradespace Toolset, $125.0K**

The Advanced Requirements Integration and Exploration Systems (ARIES) is a decision support tool which provided stakeholders with the analytic capability to explore tradeoffs and gain insights to support the requirements integration process. The funding for this effort brought ARIES out of a prototype toolset and into a production ready trade space tool for GVSC use. This effort involved refining and testing optimization algorithms and developing the user interface.

30. **(GVSC) Baselining WindChill Techloop, $25.0K**

This project enabled transition from the 9.0 to 10.2 Windchill configuration. GVSC users experienced interface changes and system challenges in the past. The new Windchill release allowed for a better transition and minimized potential impacts. The software baseline provided the ability to properly and effectively test the new software to minimize the potential impact to the user in the form of data corruption, interface and overall performance.

31. **(SC) Engineering Innovation Center, $500K**

Engineering Innovation Center funds small quick ideas or provide expertise and materials to accelerate developments of existing projects while initiating a capability with design, engineering, prototyping and testing expertise to explore new designs and ideas and accelerate integration of technology into physical systems that can be put in warfighters hands for assessment.

32. **(SC) Soldier/Squad Integrated Protection Demonstration, $379K**

FY2019 was a planning year to determine how to measure Soldier/Squad Lethality while at the same time piloting a process with specific Combat Capabilities Development Command Soldier Center technologies to get meaningful data to both inform the specific technologies, and provide a baseline to move forward from. The continued intent of this program is demonstrating technology enabled capability concepts that emphasize standoff (distance) and time as the 1st line of defense for soldiers and squads. The technologies included in this demonstration will allot the capability of being demonstrated in an operational environment in their as is state or with minor modifications.

33. **(SC) Demonstration and transition of technologies in support of the Army's modernization priorities, Simulation and Training Technology Center $1.075M**

Investment which accelerate the maturity, demonstration and transition of technology to the warfighter in support of the Army modernization priorities. Investments include efforts that accelerate the transition of technologies or knowledge products to inform and enable the development of the Synthetic Training Environment. Transitions are documented via Transition Agreements and coordinated with the Synthetic Training Environment Cross Functional Team and the Program Executive Office for Simulation, Training, and Instrumentation.

34. **(SMDC) QEDT Demonstration for Space Communications, $500K**

This effort is leading to space qualified components for small satellite quantum communications. The components are COTS devices not designed for low size, weight, and power (SWaP) space applications. In execution of the effort in FY19, TC capabilities for testing spacecraft components in-house (shake, jerk, thermal, vacuum) are being established that will enable future missions to be executed more quickly and cost effectively. The components are being implemented and tested for integration into a flight experiment to demonstrate QEDT and Quantum Key Distribution over the next few years in multiple space flight missions (STP-H7 & H9 and maybe even free flyers as rides are available) in a small satellite SWaP. The end result components will be prototypes for future satellite crosslink, uplink, and downlink capabilities for high data throughput on a quantum physics encrypted channel. The effort impacts the QuEST Lab by creating leave behind capabilities and expertise within the government. The impacts to the warfighter will be higher data rates and secure channels for communications.

35. **(SMDC) Linebacker System Modifications and Re-evaluation, $272K**

The following modifications were accomplished on the Linebacker system in FY19: Commercial software defined radio implementation (to reduce costs to duplicate), an increased engagement distance through hardware improvements, more portable/flexible waveform techniques via algorithm implementation in GNU Radio, and an improved mechanical design. A set of baseline waveform techniques and an experimental payload with real-time instrumentation were developed to characterize the Navigation Warfare (NAVWAR) effectiveness of the Linebacker waveforms. Laboratory experiments and a field assessment at the Position, Navigation and Timing Assessment Exercise (PNTAX) were conducted that fully characterized the effectiveness of the system against commercial Unmanned Aircraft Systems threats for potential transition partners. Data collected at the field assessment (raw signals, processed metric information, and engineering notebooks) were able to successfully validate the laboratory capabilities to assess NAVWAR systems. Linebacker modifications and testing in FY19 resulted in the development of infrastructure to characterize NAVWAR systems, which will support rapidly providing increased NAVWAR capability to the future warfighter and would not have otherwise been feasible without 10 U.S.C. § 2363 funding.

C. ***Workforce Development Programs:*** In FY19, the Army funded 64 workforce development projects, with an annual investment of $23,772 K.

1. **(AC) Armament Graduate School (AGS), $4,082K**

The Armament Graduate School (AGS) was established at Picatinny Arsenal, NJ to develop CCDC AC scientific and engineering knowledge and skills in weapons, ammunition, and fire control, through in-house education, with the aim to enhance future warfighter capabilities. The AGS is pursuing Federal authorization and Middle States Commission on Higher Education (MSCHE) accreditation while already reducing the time it takes to train fully-proficient armament engineers to the highest level, at reduced cost. To date, 20 students have completed the Masters portion of the curriculum; 7 students are conducting dissertation research and 1 student has completed his AGS-funded dissertation research to earn a PhD.

During FY19 the AGS funded basic research, with immediate and clear Army applications, by both students and faculty, and supported the engineering knowledge infrastructure by enhancing

access to peer-reviewed journals for AGS and the CCDC AC community. Research support is necessary to meet criteria for accreditation, and furthers the overall CCDC AC mission. All of the funded research advanced fundamental understanding of engineers and scientists, and contributed to the body of knowledge associated with armaments development. Funding was allocated to the following research projects.

- An extended finite element method
- Atomic and multiscale modeling of tungsten
- Creation of saliency maps for feature extraction
- First-principles investigation of the kinetics of energetic materials
- Human electrophysiology for soldier-armament integration for autonomous systems
- Mechanistic studies of soluble redox
- Quantifying the performance of wind-sensing strategies in direct-fire ballistics
- Simulations of interactions of particles undergoing melting and solidification phenomena in high-speed, high-temperature fluid flow
- Synthesis of energetic organic light-cured diluents

2. **(AC) Science, Technology, Engineering, and Mathematics (STEM) Program, $1,422K**

The science, technology, engineering and mathematics program (STEM), supports education for elementary, high school, and college students. The STEM office encourages these students to become part of the future workforce needed in our Department of Defense Laboratories via direct hiring or participation in scholars programs. The STEM Program contributes to a technologically proficient society by allowing the CCDC AC workforce to connect with our local educators and better prepare students for a technical careers at CCDC AC. In FY19, the STEM Program extended its reach to 67 classroom visits, 5 field trips, 8 library visits, 2 workshops and 19 local activities. STEM sponsors 97 FIRST (For Inspiration and Recognition of Science and Technology) teams around the area, supporting 53 FIRST Robotics teams (High School), 27 FIRST Tech Challenge teams (Middle School) and 19 FIRST Lego League teams (Elementary Schools). The STEM office also established, refined and launched its third year of the STEM Scholars program. In the program, 40 highly skilled and driven students worked with our scientists and engineers over the summer on mission critical projects paving the way for their potential future employment here at CCDC AC. Furthermore, partnering with the New Jersey Research and Development council, as well STEVENS and Rutgers University, 10 local students participated in a week long externship at CCDC AC. Three of these students were hired for the summer under the STEM Scholars program. The STEM Program has become our gateway into the local community for access to topnotch human capital to help meet warfighter needs, as well as a means to retain highly qualified engineers and scientists by providing them with opportunities to reignite their enthusiasm for their chosen field as they share it with the students and perform hands-on activities.

3. **(AC) Lean Six Sigma (LSS), $998K**

Lean Six Sigma Competency Office (LSSCO) trained 45 CCDC AC employees on Continuous Process Improvement, which resulted with a significant $29.8M cost avoidance/savings. LSSCO directly supported various types of projects in an effort to make them more effective and efficient. Some projects included the Modeling and Simulation Senior Advisory Group (SAG) Funding Process, the CCDC AC Strategic Roadmap for Autonomous and Semi-Autonomous Armaments Systems with integrated Artificial Intelligence, the CCDC AC Baldrige effort, and the DoD Ordnance Technology Consortium (DOTC).

LSSCO significantly impacted several programs such as high explosive cast crack defects on the 155mm M1122 training projectile with Trinitrotoluene (TNT) at Crane Army Ammunition Activity (CAAA), and asphalt related defects on the 155mm M1122 training projectile with Insensitive Munition Explosive (IMX) at McAlester Army Ammunition Plant (MCAAP). As a result of the investigation, the asphalt defect rate was reduced from ~30% to less than 1%. LSSCO also investigated the Cal 50 pressure decay leak tester at Lake City Army Ammunition Plant (LCAAP). The IPT team successfully replaced unsafe, old, and outdated Cal 50 leak tester with a safer, automated pressure decay leak tester that meets the Occupational Safety and Health Administration (OSHA) standards.

4. **(AC) CCDC AC Greening Program, $152K**

The CCDC AC Greening Program per RDECOM OPORD 10-037, provides better technology solutions, in a shorter time through increased knowledge and collaboration with our Warfighters. The program is 5-phases which on-boards employees to CCDC AC's mission, vision and values, and begins the process of dedicating our employees to our nation and Warfighter customers. In the words of the DoD Workforce Gold Medal Examination Team: "This program accelerates the on-boarding of our employees by 10 years". Additionally, the program educates and trains our S&E workforce and Warfighter customers on each other's skills, capabilities, environmental considerations, and current/future technology feedback/weaknesses during direct Warfighter engagements in the Warfighters environment; while at times providing near-time technology solutions. Completion of the 5-phased program results in physically-fit, trained and operational ready S&Es capable of deploying as fully qualified members of a Science and Technology Assistance Team in support of Combatant Command contingency operations.

5. **(AC) OSD Sustainment Fellowship, $152K**

Dr. Bernard Reger completed an assignment as an Office of the Secretary of Defense (OSD) Sustainment Fellow in the Office of the Deputy Assistant Secretary of Defense for Materiel Readiness (ODASD(MR)) covering all of the reorganized function areas under the purview of the Assistant Secretary of Defense for Sustainment (ASD(S)). He represented the ODASD(MR) in the Defense Innovation Board's Software Acquisition and Practices (SWAP) Study Team Working Group, which is now responsible for the Software Acquisition Pathway Policy. This policy is set to change the way the Department of Defense (DoD) acquires software for years to come, and help restructure, redefine, and retrain the software engineering workforce as defined by our personnel systems and the Defense Acquisition University. Dr. Reger also self-initiated an effort to automate the analysis of weapon system materiel readiness and availability, and enable its effective presentation to the Under Secretary of Defense for Acquisition and Sustainment, a direct tie to the 2018 National Defense Strategy's first line of effort. Dr. Reger's participation in the OSD Sustainment Fellowship program served to raise awareness of the US Army CCDC AC among the DoD sustainment community. His actions supported the three lines of effort from the 2018 National Defense Strategy: 1) Build a More Lethal Force - analyze materiel readiness and weapon system availability to determine areas of concern, 2) Strengthen Alliances and Attract New Partners - build stronger ties between the CCDC AC and the DoD sustainment community, and 3) Reform the Department for Greater Performance and Affordability - help support and develop new emerging software acquisition policy to streamline and accelerate the delivery of new cyber physical capabilities to the warfighter.

6. **(AC) Systems Engineering Directorate (SED) Training, $128K**

The Systems Engineering Directorate improved and/or held the following training courses to improve systems engineering competency across the command: Systems Engineering at Armament Center, Dynamic Object-Oriented Requirements System (DOORS), Key Parameter Development & Management (KPD&M) Phases I & II, two classes of Configuration Management Basics, four classes of TDP Readiness Assessment & Mitigation, and Technical Data Package Certification.

7. **(AC) Armaments Initiative for Special Warfare (AISW), $109K**

The Armaments Initiative for Specialized Warfare (AISW) continues to develop workshops and research new content to stay ahead of threats and operational requirements. In FY19, AISW efforts included the support of advanced breaching for the US Army Engineer School, Fort Leonard Wood. Working with Armaments Center (AC) engineers and the Combined Explosives Hazards Center (CEHC), the AISW has helped to develop learning content focused on improving Army Engineer School Instructors knowledge base in breaching. Subject matter covered within the new curriculum pulls from core CCDC AC competency and subject matter experts in explosives and warheads, and helped to develop novel solutions for more complex engineering problems facing the instructors and Army engineers. AISW is also continuing support to the combatant commands, to include European Command (EUCOM) and Central Command (CENTCOM) to offer solutions in advanced manufacturing, energetics, warheads, and emerging AC technology. This growing relationship is helping to expand operational understanding of threats in that region and aligning AC research to mitigate those threats.

8. **(AC) Smithsonian Environmental Research Center (SERC) Fellowship, $84K**

(AC) Two employees participated in Smithsonian Environmental Research Center Fellowship. The first employee conducted research on the nature of rework that led to a published peer-reviewed conference paper that was briefed at the 2019 Conference on Systems Engineering Research (CSER). This person also conducted research on areas of rework that resulted in a literature review white paper on Set-Based Design (SBD). Based on the literature review, a draft high level process map was developed for enhancing Key Parameter Development and Management (KPD&M). Furthermore, the employee completed the following courses for PhD: Research Methodologies, Engineering Cost Economics, and Research Credits. The second employee completed research to support four published papers in FY19, two papers to be published in 2020, and is scheduled for dissertation proposal in March 2020.

9. **(ARL) Distinguished Fellowships and Postdoc Program, $1,507K:**

The ARL Distinguished Fellowship program is designed to attract the best nationally recognized new Ph.D. scientists and engineers to ARL. The goal of the ARL Distinguished Fellowship program is to attract young researchers who display extraordinary ability in scientific research, and show clear promise of becoming outstanding leaders. The program provides the opportunity for recipients to pursue independent research of their own choosing that supports the mission of ARL. Participants benefit by having the opportunity to work alongside some of the Nation's best scientists and engineers. ARL benefits by the expected transfer of new science and technology that enhances the capabilities of the U.S. Army and the Warfighter in times of both peace and war.

10. **(ARL) Leadership Training, $800K:**

ARL continues to develop and execute structured programs to support the training of current and future leaders in the organization. This includes development for the executive leadership team and all layers of organization management. The training program also extends to those scientists, engineers, and administrative personnel who aspire to technical or managerial leadership.

11. **(ARL) Strategic Communications and Extended Site Outreach, $314K:**

    ARL funded several programs to promote strategic communications and outreach to extended sites. This included funding for student tours, a symposium, and students conducting basic research into Transformational Scene Understanding and Object Recognition Technology through Booz Allen Hamilton.

12. **(AvMC) T-6 Aircraft Qualification Training, $266K**

    This investment provided modern aircraft qualification training for ADD pilots. Funds covered training and TDY expenses for pilots attending T-6, UH-60M, and CH-47F aircraft qualification courses. Before, no Aviation Applied Technology Directorate (AATD) pilots were qualified in the T-6 aircraft. A minimum of three pilots required qualification training this past year with two lined up for the following year in order to meet organizational flight test mission requirements. Now qualified, the ability to train and operate the T-6 aircraft has better enabled ADD to support multiply-occurring test projects which enhances testing efficiencies to mature and transition critical aviation technologies.

13. **(AvMC) Flight Test Engineer Training, $45K**

    Funds covered training and TDY expenses for attending courses in advanced flight control theory and tools, unmanned aircraft testing, and system architecture testing. Continued training for our Flight Test Engineers was needed to maintain their relevant technical skillset in the evolving flight test discipline. Focused testing in the increasingly complex and rapidly expanding areas of control law development and UAS testing required an aggressive approach to stay relevant and capable.

14. **(AvMC) HBCU Outreach – ADD, $100K**

    Continued funding for HBCU initiatives with Norfolk State University and Hampton University in the areas mission system integration on air vehicles for electronics and electrical engineers. Sustained outreach effort was a facilitating achievement of CCDC AvMC diversity goals.

15. **(AvMC) Missile Fundamentals, $600K**

    The CCDC AvMC required expertise to design, develop and execute conceptual weapon system programs. To provide CCDC AvMC with the personnel to accomplish this mission, it was necessary to recruit and train individuals to provide the critical skills, knowledge and aptitudes to successfully perform their duties which included a system level understanding of missile systems. Individuals with that missile system engineering skill set were critical to the Missile Science and Technology community especially in the execution of major 6.3 missile system programs. This program provided training and insight into the total missile system engineering process, providing a high level overview of a total missile system providing a functional understanding of missile subsystems and simulation tools utilized for performance analysis. This program was a joint Weapons Development and Integration Directorate (WDI), Systems Simulation, Software and Integration Directorate (S3I), and Engineering Directorate (ED) effort.

16. **(AvMC) Additive Manufacturing Training Equipment, $20K**

The ManTech branch of the MST division has offered AM overview training for 4 consecutive years now, providing hundreds of CCDC AvMC employees a basic understanding of what additive manufacturing is, the different processes, applications, and technology gaps. These 2363 funds benefited the organization in that the students can now take the knowledge back to the customers they support and have another tool in their toolbox to help solve customer problems. Also, now that they are exposed to additive manufacturing during the course of their jobs, they are aware of the technology and have some understanding of what is a reasonable application and what is not given the current state of technology. In the past we have had to rely on contractor provided printers, which did not always perform well and needed to be shipped and set up prior to training. Now having our own printers to use during training has saved significantly on the cost of the class as well as allowing organic sponsored training and Science, Technology, Engineering and Mathematics (STEM) activities.

17. **(AvMC) Advanced Degree Training, $500K**

The advanced degree training investment (Masters, PhD) for CCDC AvMC workforce disciplines (e.g., Aerospace Engineering, Computer/Electrical/Software Engineering, Computer Science, Math/Physics/Computational Fluid Dynamics). Four year funding was planned to cover two classes (years 1-2, years 3-4) of 25 Masters students each, and one class (years 1-4) for 8 PhD students based on recent CCDC AvMC surveys on interest with applicable academic and administrative support (books, fees, academic support). The start of funding coincided with Winter/Spring Semester. Activity supported the ability of CCDC AvMC to recruit and retain workforce thru investment in science and engineering disciplines and ensure sustainability and advancement of domain expertise for CCDC AvMC core mission and functions.

18. **(AvMC) CCDC AvMC Director Workforce Development, $50K**

These 2363 funds were used to establish developmental opportunities for employees to compete in a designated area defined by the Center Director in a program or function determined to be of importance to the mission and direction of the Center. These developmental opportunities supported the core functions of the Center and will serve as an investment in our future workforce and in our science and engineering disciplines.

19. **(AvMC) Daedalus, $373K**

This was an enterprise wide effort supporting CCDC AvMC, Workforce development and innovative technology development. Funds were provided to host two Daedalus teams in FY19 for approximately 5 months each. Daedalus teams analyzed far reaching and complex missile system problems that stretched the current state of the art. The teams provided feasibility analysis for potential Science & Technology programs as well as courses of action analysis for technology insertion. Daedalus teams consisted of entry and midcareer engineers and scientists. The teams built the bench by providing members with an opportunity to enhance creativity and critical thinking skills while producing relevant products for the Army.

20. **(AvMC) Data Modeling Capability Development, $194K**

This investment increased capability within CCDC AvMC (specifically ADD and S3ID) to develop data models that are conformant to the Future Airborne Capability Environment (FACE) Technical Standard and apply Model Based Systems Engineering (MBSE) principles to acquisition and execution processes of future S&T initiatives. This proposal funded Data Model subject matter experts to provide training to CCDC AvMC (ADD, S3I) personnel to conduct two (2) classes a year that made up a detailed specialized data model curriculum. The proposal included labor funding for government personnel to continue technical skill development activities pre- and post- data model training classes. The proposal cost included seat licenses for relevant software development packages. Data modeling in the robust manner required within the FACE Technical Standard is currently understood by an extremely limited set of technical personnel. In order to more widely propagate this capability, training and hands-on learning was required. Having this capability within ADD was crucial as it has helped to ensure the programs' software was inter-operable and not locked in to a particular vendor.

21. **(C5ISR) New Hire Talent Management, $1,734K**

This funding was used to recruit, acquire and retain new talent and provided training and developmental assignments across C5ISR Center and Program Executive Office communities. The experience gained from these training opportunities helped our employees become well rounded Engineers and Cyber professionals and will offset the potential loss of technical and engineering Subject Matter Experts (SME) gap we foresee due to aging workforce/projected retirements of our most seasoned and talented SMEs. This effort served as a principal tool in C5ISR's talent management strategy and enabled C5ISR Center to meet pressing US Army requirements for C5ISR technologies enhancing Soldier survivability.

22. **(C5ISR) COHORT, $400K**

This funding was used for employees to attend the C5ISR COHORT program which provides approximately a 14-month period. The four graduate-level courses offered are Design and Managing the Development Enterprise; Systems Thinking; Design for System Reliability, Maintainability and Supportability; and Systems Supportability and Logistics.

23. **(C5ISR) Business Development Training Session for Engineering Workforce, $21K**

Engineers learned how to promote C5ISR Center's organization and increase C5ISR Center's customer base. C5ISR Center's engineers developed an understanding of their integral role and partnership of developing, setting, and achieving the organization mission statement.

24. **(C5ISR) Technical Engineering Training, $450K**

This training supported the continued training of C5ISR Center's workforce to ensure their knowledge, skills and abilities remain at the leading edge of C5ISR technologies. Funding was leveraged for the education and facilities necessary to expand the knowledge base of its personnel. This training served as a principal tool in C5ISR Center's talent management strategy and will enable C5ISR Center to meet pressing US Army requirements for C5ISR technologies enhancing Soldier survivability.

25. **(C5ISR) Leadership Training. $285K**

Provided funding for leadership courses for our emerging leaders. This effort ensured our brightest, most talented employees will be ready to step into critical leadership positions as our current leaders retire due to aging workforce. Senior Leadership Cohort, Leading from the Front Line, as well as other OPM leadership courses were attended just to name a few. These leadership courses are an instrumental part of C5ISR Center's talent management strategy and ensures we have our workforce ready and fully capable to lead.

26. **(CBC) Center-wide Training Opportunities Program Management, $203K**

This program is for the overall oversight and implementation of all training programs across CCDC CBC. This includes coordination with employees and supervisors, finding new training opportunities and ensuring CBC has gained value from the trainings. The opportunities managed by this program include Leading from the Frontline, Emerging Leaders, APG Senior Cohort, Strategically Leading Organizations, Leader within Me, the Academic Degree Program, Student Internship Program and any developmental assignments.

27. **(CBC) Developmental Assignments (STEM/DARPA), $150K**

These funds are for two developmental assignments for CCDC CBC employees. The STEM assignment is with the CCDC CBC G-1 to assist in the development of teaching plans for "hands-on" experiments/activities to meet the needs of teachers in Harford County and Cecil County Public Schools as part of ongoing STEM Outreach activities and to support engagement with HBCU/MI institutions. The DARPA assignment is part of the DARPA Fellows program where a CCDC CBC scientist is participating in DARPA programs for three months. Both assignments are temporary and are meant as broadening experiences for the employees to take back to their full time positions.

28. **(CBC) Emerging Leaders, $123K**

This program includes assessments of leadership strengths and areas of improvement, classroom-based instruction, and activities intended to build the competencies of communication, accountability, problem solving, resiliency, decisiveness, leveraging diversity, conflict management, and team building. Employees benefit from the "Four Lenses" personality instrument which allows them to better understand their own strengths and weakness as well as how to recognize the strengths and weaknesses of colleagues. Employees will also complete a leadership assessment called OPM 360, which will help them learn about themselves and the APG workforce, preparing them to fill senior leadership positions. Employees will complete an emotional intelligence workplace assessment and explore behaviors and skills necessary for developing emotional and social intelligence in leadership.

29. **(CBC) Process Improvement Initiatives and Training, $86K**

CCDC CBC, in cooperation with CCDC DAC and ATEC, participated in Lean Six Sigma (LSS) Green Belt and Black Belt training. CBC's LSS Master Black Belt candidate co-taught the four-week training event. Four employees from CBC were among the fifteen people to attend Black Belt training. CCDC CBC's trainees applied their skills to projects that included engineering support to DLA, CBC administrative processes, and contracting.

30. **(CBC) Ordnance Removal and Remediation Course, $80K**

Ordnance Removal and Remediation courses include the first and only civilian UXO Technician I course certified by the Department of Defense Explosive Safety Board. This course provides participants with comprehensive, hands-on training in the safe detection, location, identification, and disposal of unexploded ordnance using the techniques and emerging technologies of today's UXO remediation industry. This project provides training for 8 personnel and supports CCDC CBC's mission for chemical material elimination and remediation.

31. **(CBC) Postdoctoral Resident Research Associateship Program, $60K**

The intent of this program is to significantly increase the involvement of creative and highly trained scientists and engineers from academia and industry in scientific and technical areas of interest and relevance to the Army. These scientists work side-by-side with CCDC CBC employees on some of the most complex chemical and biological defense issues of concern to the warfighter. In FY19, six Postdoctoral Fellows participated in the program in a varied range of specialties.

32. **(CBC) Academic Degree Training, $54K**

The ADT program is a competitive program that provides members of the CCDC CBC workforce with an opportunity to enhance their knowledge and skills through funding Bachelors, Masters, and PhD-level academic training courses with the stated objective of obtaining an academic degree. The program is restricted to nationally accredited colleges and universities, and courses must be directly related to the performance of the individual's official duties or organizational strategic goals. Employees must have a minimum of three years of permanent, full time employment as a DA civilian and have met any acquisition position certification requirements to be eligible. Employees must sign a Continued Service Agreement (CSA), which is three times the length of the training program. Final approval rests with the Assistant Secretary of Army (Manpower and Reserve Affairs (ASA (M&RA)).

33. **(CBC) Engineering Directorate Workforce Development Training, $49K**

The CCDC CBC Engineering Directorate funded employees to attend systems engineering, acquisition, and manufacturing training courses to support requirements for their position and to improve product quality. These courses included entry level systems engineering courses at Johns Hopkins covering basic understanding of systems engineering and its applications and a manufacturing technology course covering how to review manufacturing bill of materials, validation of revision compliance, and understanding product requirements.

34. **(CBC) APG Senior Cohort, $40K**

This senior leadership program, designed around OPM Executive Core Qualifications, develops and sustains a cohesive cadre of high impact leaders within the APG community. The program is a year-long leadership and community development experience. It consists of nine sessions (each 3 days) facilitated by leading experts in their field. Participants receive executive one-on- one coaching throughout the program, allowing them to focus on their personal growth and professional development. Participants also mentor an employee junior in grade as well as complete a myriad of assessment tools to aid in identifying developmental areas for future refinement, such as the OPM 360, DiSC Behavioral Styles, Conflict Dynamics Profile, a Senior Executive Assessment Center and the Ethical Type Indicator.

35. **(CBC) Leading from the Frontline, $28K**

This five day course provides the competencies required to meet the performance management and leadership responsibilities of those in a supervisory role. Topics covered include conflict management, developing others, interpersonal skills, leveraging diversity, oral communication, performance management, and team building. Program participants experience a variety of learning activities including case study analysis, two assessments, small group discussions, small and large group activities, role-plays and supportive lecture, and hands-on application opportunities.

36. **(CBC) Aberdeen Proving Ground Greening Course, $25K**

The course is designed to give civilians a taste of life as a Soldier by letting them experience tasks and training that Soldiers participate in. This programs fosters the relationships between the Soldier and Army Civilian Corps and provides the Civilian Corps a better understanding of the needs of a Soldier. Through this experience scientists and engineers are better able to provide technologies that better address a Soldier's needs.

37. **(CBC) Coffee with Colleagues, $25K**

This program provides an opportunity for CCDC CBC engineers and researchers to brief current scientific or project work (through poster sessions) and learn what is going on throughout the organization. It also offers the opportunity for discussion on where we are now, where we need to be in the future, and how do we get there.

38. **(CBC) Strategically Leading Organizations, $11K**

This course is designed to identify, explore, and practice the crucial leadership skills needed to lead organizations to success. Employees learn skills for influencing people and organizations across boundaries, recognizing barriers towards organizational change, creating and promoting a culture of innovation and creativity, and strategic thinking and decision-making in a volatile, uncertain, complex, and ambiguous world.

39. **(CBC) Scientists in the Foxhole – Dugway Proving Ground, UT, $10K**

The intent of this program is to enable scientists and engineers to have real-world immersive experiences with warfighting activities associated with actual operational CBRNE mission sets. Participants have opportunities to understand the needs of the Warfighter and the types of missions performed to protect themselves from Chemical and Biological threats and stimulate ideas or technology innovations to enhance CBRNE defense capability needs. This program was a coordinated effort between the Defense Threat Reduction Agency Research and Development Directorate for Chemical and Biological Defense, the 20th CBRNE Command, and the Service Laboratories.

40. **(CBC) Leader within Me, $10K**

This course was designed for employees in developmental positions to create an understanding of the importance of using one's strengths at work. The participants take the Gallup 2.0 Strengths Finders and MHS Influence Style Indicator assessments, identify and explore specific personal talents that makes them unique, and learn how to build upon their talents to develop strengths. Participants learn strategies, models, and behaviors that will help them develop and hone their influence skills.

41. (ERDC) **Long-Term Training for Advanced Degrees, $1,597K**

It is the policy of the ERDC to provide all employees the opportunity to develop further their careers while enhancing performance in their current jobs. This training is critical to ensuring that ERDC maintains the technical knowledge, management, and skills necessary to provide research, development, operational expertise, and scientific leadership in our mission areas. This investment supports pursuit of doctorate degrees for approximately twenty persons (classes of academic years 18/19 and 19/20).

42. **(ERDC) ERDC Leadership Development Programs , $374K**

The ERDC Leadership Development Program (LDP) is a critical workforce development program that contributes to the goal of recruiting and retaining personnel with scientific and engineering expertise. The LDP has been very successful in building and refining leadership skills in our current and future ERDC leaders, including numerous ERDC Team Leaders, Branch Chiefs, Program Managers, Technical Directors, and Division Chiefs. The program successfully develops results-oriented, agile leaders with broad perspectives who will lead the organization into the future.

43. **(ERDC) ERDC Mentoring Program, $32K**

The ERDC Mentoring Program, a corporate process for improving knowledge transfer at the ERDC by enhancing mentoring opportunities and interactions, is designed for all federal ERDC employees in any career field and grade level, including engineers and scientists, technicians and administrative employees. This voluntary program is intended to improve retention of current employees and recruitment of new employees; and to help all employees better understand the ERDC culture, improve professional and people skills, and gain greater insight and awareness of career focus and opportunities. Matches the workforce with appropriate mentorship increasing career satisfaction by providing tools for success.

44. **(ERDC) Emerging Leader Group, $228K**

The ERDC ELG Program is a corporate process for developing future leaders for the ERDC, by providing training opportunities, interactions with other emerging leaders, developmental assignments, and mentoring opportunities for mid-level employees with Corps senior leaders. As a workforce development activity, it has been very successful in building and refining leadership skills in our current and future leaders at the ERDC such as the current ERDC Associate Director, Directors of the Environmental Laboratory (EL) and the Coastal and Hydraulics Laboratory (CHL), as well as numerous ERDC Technical Directors, Division Chiefs, and Branch Chiefs. This highly successful program is needed to ensure a pool of highly qualified candidates trained and available for future leadership roles in the ERDC.

45. **(ERDC) Innovation Alley Program, $82K**

The Innovation Alley project provides quality, low-cost solutions for problem statements relative to employee engagement. This includes researcher-to-researcher communication program, ERDC ambassador program, career development program, employee development and integration programs, teach to fish – increasing business sophistication, and a new innovation competition.

46. **(ERDC) Career Program 16 (Engineers and Scientists Non-Construction) Activities $40K**

This effort supported activities for project management and professional development. This program is critical to workforce development in that it assists in providing training opportunities and career progression to recruit personnel and enhance retention while also promoting growth in areas of basic and applied research and critical scientific and engineering knowledge. ERDC has over 800 CP16 careerists.

47. **(ERDC) Acquisition Training for the Non Acquisition Professional, $13K**

This effort was designed to develop and conduct follow-on acquisition training for ERDC non-acquisition professionals. Tactically, the course is focused on increasing core competencies of research engineers and scientists by: 1) evaluating innovative, sustainable concepts for acquisition knowledge transfer and 2) providing detailed "how to" instruction on preparing procurement action request packages. The strategic purpose of the project was to positively impact workforce recruitment and retention by improving researcher job satisfaction.

48. **(ERDC) First Line Supervisor Training, Development and Support (FY19-20), $18K**

This project will enhance the ERDC community relationships, collaborative program development, and execution oversight through a deliberate process of sharing knowledge, capturing best practices and lessons learned resulting in ERDC's first enterprise-developed First Line Supervisor Manual. The effort will improve cross-laboratory collaboration and improvements to inherent continuity of practice across the enterprise, increasing the pool of First Line Supervisor candidates across the enterprise. The unique challenges of research and development in a reimbursable setting are not well considered in standard Army supervisor training, this effort would address that gap.

49. **(ERDC) ERDC Recruiting and Future Workforce Development Center, $30K**

The new Recruiting and Future Workforce Development Center will be home to science, technology, engineering, and math (STEM) activities, along with continuing education for the current workforce through classrooms and training centers. The STEM outreach center will increase public awareness of ERDC through the large sphere of influence our partners have in the community. This program will cultivate the future STEM talent pool through supporting and enhancing undergraduate and graduate students served by DOD-sponsored STEM programs.

50. **(ERDC) ERDC Workshop, $26K**

This workshop provided a collaborative environment for ERDC engineers and scientists to learn more about the work and research being accomplished throughout all ERDC Laboratories. The workshop focused on cross business area opportunities and promoted the one ERDC culture.

51. **(ERDC) Leadership Development Workshops Using Case-Ex® Videos for the Environmental Lab: Focus on Military Program Research Team Leads (FY19), $250K**

The Praevius Group will conduct tasks related to leadership development workshops for strengthening the Environmental Lab's military technical or scientist team leads. The Contractor will conduct and facilitate workshops that provide researchers insight into how the military and warfighter use innovative technology for enhanced technology transition. The objectives of the

workshops are: 1) show constraints of R&D in the military; 2) how R&D advances the military and the warfighter; 3) train researchers on military needs.

53. **(GVSC) Academic Training, $1,002.0K**

GVSC is committed to employee development and being the center of excellence for DoD ground vehicle systems modernization and sustainment solutions. One of the key strategies to maintaining the edge on the appropriate knowledge and technology is through advanced academic training. In the past few years, GVSC has been able to increase the number of PhDs and Master's Degrees that our associates hold. That has translated to increased technological advancements as well as increased notoriety in the Science and Technology community, both within the DoD and industry. This ultimately improves our chances of taking on new programs, receiving grants and other funding, and attracting more talent to GVSC. In Fiscal Year 2019, GVSC was able to provide funding for 15 associates to take multiple courses at the undergraduate level, 50 associates to take multiple academic courses at the graduate level, and 25 associates to take multiple courses at the PhD level.

54. **(GVSC) Technical Training, $917.9K**

Technical training funds are used to train the GVSC workforce. This is critical to filling gaps and developing needed skills to GVSC's Primary Mission areas. It is also critical to maintain the high level of technical knowledge and professional skill in the workforce. There is both a strategic and mandatory necessity to fund and provide ample training to the workforce. GVSC was able to provide over 160 technical training courses to multiple associates. These training courses provided associates with knowledge and skills in various areas including: Cyber Security, Hybrid & Electric Vehicle Systems, Software, Mobility, Powertrain, Robotics, Materials, Leadership, Quality and other mission essential technical areas. These training courses provided GVSC associates the knowledge to fill critical skill gap areas while gaining knowledge and expertise critical to the GVSC mission.

55. **(GVSC) CSI and Materials Accreditation Training - Weld Specifications, $490.0K**

This project is a collaborative effort between the Center for System Integration and the Materials Directorate to qualify GVSC to MIL-STD-3040, Arc Welding of Armor Grade Steel. This project consists of fabricating and welding mechanical test plates as well as creating H-Plate fixtures in order to weld various H-Plate thicknesses of 1/4", 1/2", and 1" of High Hard and Rolled Homogenous Armor (RHA) material. After the H-Plates are welded, ballistic shot testing will be conducted. In addition, Procedure Qualification Records (PQRs) are to be created of the welding procedures. GVSC is qualifying to the new MIL-STD in order to understand what it takes to be certified to the new standards because current and future defense contracts are required to weld to the new MIL-STD-3040.

56. **(GVSC) Senior Service College and Long Term Training Labor, $201.7K**

Senior Service College Fellowship (SSCF) develops civilian acquisition leaders in preparation for roles as product and project managers, program executive officers, and other key acquisition positions. SSCF also helps prepare participants for positions in the Senior Executive Service (SES). The program is intense but does provide the time to think and reflect-normally not available in the government workplace. GVSC was able to provide funding for one associate to attend Senior Service College.

Fellows who successfully complete the fellowship will be equipped to:

- Apply the knowledge and leadership tools gained to assume positions with higher levels of responsibility within the government;
- Lead and strategically guide at the highest levels in the Department of Defense (DoD);
- Mentor individuals within their commands and areas of responsibilities; and operate at the most senior levels within the government.

Long Term Training funding is used to fill critical current & future skill gaps, especially Science, Technology, Engineering and Math gap areas within the organization, which are otherwise difficult to obtain through recruitment. GVSC's focus is on technical skill gap areas that are essential for future success and achievement of the primary mission areas of GVSC. Long-Term Academic Training is awarded on a competitive basis within the high priority areas of the GVSC mission. In Fiscal Year 2019, GVSC was able to provide funding for 2 associates to complete research at the PhD level in Ground Vehicle Robotics.

57. **(GVSC) Recruit and retain engineers and scientists - Labor, $111.6K**

Recruit and retain engineers and scientists by providing funding for training and development of Army career civilians. Training provided was on the job training. Personnel onboard had their first 3 months' salary paid from out of 2363 funds. After the first 3 months, employees were transferred to RDTE or reimbursable funding, but had the skills necessary to perform work on those projects.

58. **(GVSC) Artificial intelligence Competency development, $46.7K**

GVSC pursued the development of an Artificial Intelligence (AI) competency (Machine Learning, etc) to facilitate the introduction of enhanced capabilities to current and future efforts as well as building the required skill base to sustain software utilizing this technology in the future. Through an initial demonstration project, GVSC engaged local engineers with background and interest in AI technologies to build up foundational knowledge which will form a spring board for larger leaps, facilitate more informed strategic direction development, and identify additional areas where the technologies can be applied.

59. **(SC) Recruitment & Retention, $17K**

"Benchmark Core" tool offered by PayScale. Allows access to the largest salary database in the world, to help avoid data gaps that we experience today when setting pay for outside candidates. Additionally allows the ability to price and benchmark positions based on job descriptions, titles, and compensable factors and price to the market. It enables the creation of many labor markets as needed based on city, industry, company size, revenue, sector, etc. As the workforce transitions to the Personnel Demonstration Project (PDP), it is increasing confidence in pay setting decisions and establish the precedent for culture and morale by relying on fact-based decisions related to compensation. It will also provide market reports for each job in real time. This is a much needed compensation tool that will improve the capacity to recruit and retain personnel with necessary scientific and engineering expertise and maintain fidelity in compensation under a pay banding system.

60. **(SC) Recruitment & Retention, $70K**

Army Futures Command (AFC) is deploying Human Resource Enterprise across AFC and other organizations in support of key Army initiatives. This consolidation of Human Resource data will streamline processes, save money, reduce labor, time, and allows analysis in support of decision

making. Funding is required to support the Human Resource Enterprise application including infrastructure, maintenance, troubleshooting, help desk support, and system care and feeding. C5ISR HQs will provide overall project management including implementation of technical solutions, information assurance, certifications, and IRB approval. In addition to HR Enterprise baseline features and capabilities that are required for the Center's G1 and senior leaders to be able to not only manage their workforce, but also automate current manual workflows, streamline business processes and provide data for analytical decision making.

61. **(SC) Quarterly Modeling and Simulation & Training (MS&T) Speaker Series, Simulation and Training Technology Center $125K**

The 2363 funded initiative resulted in exceptional collaboration, understanding, integration, and incubation of Synthetic Training Environment topics. The ability to bring in speakers listed below with an in person attendance averaging 50 to 65 participants from industry, academia and government civilians. The funds also allow it being broadcasted via UCF social media outlets, Team Orlando Distribution (Army, Navy Air Force, Marines, ADL-Colab, CFT-STE, and UCF).

62. **(SMDC) Technical Mentorship Program, $21K**

Under our technical mentorship program for FY19 we continued focus on regular one-on-one and small group mentoring sessions between senior engineers and scientists and our junior level workforce. The program also looked at methods to utilize academia and industry Subject Matter Experts (SMEs) in addition to approaches to quickly acquire technical competence across the TC mission areas leveraging a combination of in-house development and teaming with academia and industry partners. The program continues to assist with talent development and knowledge sharing and better position the TC for succession planning and growth.

63. **(SMDC) Concepts Analysis Laboratory (CAL), $1,658K**

The CAL is a state-of-the-art lab environment for interns (DOD Science, Mathematics, and Research for Transformation (SMART), Department of the Army, and Local) and newly hired S&Es to be trained and gain hands-on experience by performing research and development directly in support of TC programs. Labor funding was provided for the newly hired interns and senior engineers mentoring the interns and SMART students. Information Technology (IT) and Information Assurance (IA) support and new computer hardware and software were funded to provide the stand-alone network to enable use of non-standard state-of-the-art scientific hardware and software. Calibration and maintenance support for lab equipment use by the interns were also funded. The CAL was critical to the TC in recruiting and developing highly qualified young scientists and engineers to support the Army mission by conducting RDT&E of tactical responsive space and directed energy technologies.

64. **(SMDC) Project Horizon, $659K**

Project Horizon served as an innovation cell within the TC to generate technical capabilities focusing across a few areas in FY19. In support of the Aerophysics Research Facility, Project Horizon focused on increasing competency in research and operations of light gas guns. The project included attendance at the Hypervelocity Impact Symposium and the Aeroballistic Range Association meeting. These meetings provided information on cutting edge research in light gas gun operation and research which allowed for identification of research applications and enhancements for the light gas guns as well as networking with the hypervelocity test community.

In addition, the Project Horizon team presented on the light gas guns to potential customers and discussed facility improvements that would better meet the need of the customer community. This increase in competency and interaction with the test and customer communities aided development of a test and instrumentation plan for returning the TC light gas guns to operational status. In support of the RTS, Project Horizon completed the first year of studying the effectiveness of several new corrosion mitigation techniques with current methods. Different material treatments were applied to small test structures designed to mimic the materials and fabrication of the ARPA Long-Range Tracking and Instrumentation Radar and the Target Resolution and Discrimination Experiment radar structures and were placed near the radar assets in Kwajalein. Over the next year, corrosion formation and treatment durability will be observed and correlated with recorded environmental data. Finally, Project Horizon began exploring new model development for the small satellite hardware in the loop capability in support of our space-related S&T projects.

65. **(SMDC) Technical Continuing Education (TCE) Program, $22K**

The TCE program provided members of the TC workforce with an opportunity to enhance their knowledge and skills through funding advanced technical training courses. The program focused on selecting courses that are directly related to the performance of the individual's official duties or organizational strategic goals. Courses taken included orbital mechanics, computation of physics, radar fundamentals, advance computer architecture, spatial array processing, Kalman filter design, among others. The program assisted in TC technical talent development and employee retention.

D. ***Laboratory Revitalization, Recapitalization, and Minor Military Construction Improvements.*** In FY19, the Army funded 69 laboratory infrastructure improvement projects, with an annual investment of $79,073 K.

1. **(AC) Equipment $5,403K**

Funding for replacement or upgrade of critical lab equipment. The equipment purchases include but aren't limited to:

- High Performance Computing equipment and Hardware-In-The-Loop (HITL) simulator that can simulate end-to-end engagements of the threat fly-out and aircraft, and can assess the effectiveness of current and developmental expendable decoy design candidates against fielded and advanced guided missile systems. This simulator will allow the accelerated development of new countermeasures by helping to determine decoy performance requirements and testing effectiveness. This equipment will immediately support the future vertical lift development program as well as other new countermeasures for existing aircraft
- Secure Video Teleconferencing (SVTC) equipment which allows CCDC AC to hold classified meetings and VTCs on-site saving travel cost and travel time.
- High Speed Cameras in support of Armaments Experimentation Division (AED). Embedded technology and performance characteristics of the new cameras are far superior to current stock and will provide clearer high speed videos that allow for better assessments of asset performance. This new equipment will provide the latest capability in high speed photographic evaluation and properly support the AED's mission

2. **(AC) Project Planning, Preparation and Support, $4,827K**

Funding supported the project planning and preparation for the site selection, Planning Charrettes, design and project management of multiple construction and/or renovation projects. These projects include an addition to Bldg 18 which will create multiple labs for the Fire Control Systems & Technology directorate and will also create additional engineering space, repairing cracks in the foundation of Bldg 44's elevator which is used for testing, Bldg 31 vehicle exhaust system which will be used to exhaust all fumes from vehicles that need to remain running inside the high bay for vehicle integration work, Bldg 1301 installation of frangible wall and blast hood which is required for new test equipment for energetic operations, new standard earth covered magazines which replace old 100-year old above ground magazines, fume hoods in building 217 which are for new test equipment for energetic operations in the Explosive Research Development Loading Facility, and electrical load analysis and design for multiple lab renovations and/or modernization.

3. **(AC) B92 Experimental Verification and Validation Assessment Lab (EVAAL) Equipment, $800K**

   Completes a new virtual and augmented EVAAL reality test bed lab to track objects (humans and systems) in the environment and be able to feed that information into the virtual environment.

4. **(AC) Tower Hoist Upgrade Continuation, $608K**

   Completion of the Precision Armaments Laboratory (PAL) tower redesign and rebuild of the hoist safety system and control software, and installation of equipment that will overcome technological obsolesce.

5. **(AC) B3024 Safety Improvements, $600K**

   The building 3024 safety improvement project addresses numerous safety issues for CCDC AC's explosive development facility. One of the safety concerns addressed was replacing and installing new conductive floors. The floors required to be grounded/milled and recoated with conductive material. This project also replaced a 24" inch diameter exhaust vent pipe which was deteriorating. The pipe extended from Chamber 142 through a camera room to the top of the building, which allowed the detonation products to enter the camera room.

6. **(AC) B3028 Lab Refurbishment/Fume Blast Hoods, $389K**

   Incorporation of safety enhancements and modernization of 19 individual laboratory rooms which are used for explosives synthesis, formulation and analytical operations.

7. **(AC) Fragment Containment Test Stand (FCTS), $200K**

   Project provides funding to complete a project initially funded thru FY16 Section 219 to construct an FCTS designed to contain potential hazardous fragments from leaving the structure by fully encapsulating the detonation area. This structure will be capable of supporting large projectile detonations (e.g. M795, M107), with a net explosive weight of up to 25 lbs.

8. **(AC) Benet Firing Lab/Range Decommission, $100K**

   Project is to properly dispose of excess test assets, range back stop containment items and test equipment.

9. **(AC) B908 Neutron Generator Shielding & Safety Interlocks, $75K**

   Project provides safety shielding and interlocks for the operation of a neutron generator. Funding for this project includes construction of a concrete wall, mechanical piping and plumbing for the chiller, electrical work, interlocks, asbestos floor removal, leveling the floor and replacing with laminate flooring.

10. **(ARL) A2I2 Network Infrastructure, $5,110K:**

    The subject project addresses the need for a robust infrastructure to support the Artificial Intelligence and Machine Learning research, which feeds the Network/C3I Modernization Priority, as well as the Next Generation Combat Vehicle (NGCV) Modernization Priority. Research relating to Artificial Intelligence and Machine Learning spans the entire ARL Enterprise, including Cyber Defense, Autonomous Networking, Intelligent Analytics, and Autonomous Platforms. With the formation of the ARL A2I2 focused on Autonomous Maneuver for the Army, including NGCV, the described project addressed infrastructure needs in support of A2I2. The referenced project worked to integrate assets, streamline capabilities, and accelerate technology deliverables.

11. **(ARL) Modular High Performance Computing Capability, $5,000K:**

    Constructed a site to establish Modular High Performance Computing (HPC) capabilities at Aberdeen Proving Ground (APG). ARL has the described facility as part of the DoD Supercomputing Resource Center (DSRC), which provides the DoD with HPC capabilities. This facility provides robust classified and unclassified computing environments, as well as the capability to provide real-time processing and data storage solutions in direct support of the DoD Research, Development, Test and Evaluation community. This modular HPC capability will augment current HPC facilities with a series of 10-40 modular and/or containerized units to be located near other ARL HPC resources.

12. **(ARL) SLAD Infrastructure Projects, $3,947K:**

    Funds provided the following: Installation of a walkway; installation of security upgrades to building 1648; installation of three window air conditioner units in building 1624; and installation of steel stairs in LC-47. Also, funds were sent to New Mexico State University for research and development services, and equipment purchases.

13. **(ARL) Intelligent Systems Integration Experimental Facility, $1,430K:**

    Completed infrastructure for research data connectivity on-site, and for connectivity to enable distributed operations at GQ, APG, ALC, and ARL's extended sites. The referenced infrastructure will enable ARL to take advantage of the existing structures for collaborative planning and AARs in the office areas; and to conduct integration, troubleshooting, and repair in the garage and high-bay areas. This project establishes physical infrastructure on the existing pad

in the form of an urban structure complex constructed of modified shipping containers and traditional construction materials. The purpose of including this type of structure is based on the need to facilitate reconfiguration for scenario variety.

14. **(ARL) EF14 Indoor Experimental Facilities C and D, $2,400K:**

    Completed the EF14 Indoor Experimental Facilities C and D, which will provide a safe, secure, user friendly, and environmentally controlled facility with enhanced capability for Armor technology development. The intent is to house several different highly sensitive diagnostic devices, such as the Multi-Energy Flash Computed Tomography (MEFCT). The MEFCT will provide greater detail to enhance our understanding of projectile/target interactions, which will lead to improved materials and better protection for the future Army.

15. **(ARL) EF9 Modernization, $3,000:**

    The subject project completes the facility design phase by the U.S. Army Corps of Engineers, which addressed needed improvements to the building structure to prevent migration of radioactive contaminants into areas used by the general public, and provided a three-tier transition area between "clean" and contaminated areas. The project also raised the floor to ensure that flooding will not damage critical diagnostic instrumentation and equipment. EF9 is the only U.S. Army R&D facility capable of conducting high-fidelity terminal ballistic experiments using large-caliber ammunition, made of depleted uranium (radioactive material), against modern armor technologies that include explosive reactive applique and complex base armor configurations. The facility can operate in all-weather conditions, except electrical storms, and provides a means to quickly rearrange diagnostic instrumentation for the utmost flexibility. Furthermore, the facility can be laid out to conduct component level lethal mechanism evaluations for both cannon-launched projectiles and static detonation warhead configurations that are under consideration.

16. **(ARL) Upgrade of Building 601, Visitor Center and Conference Space (Phase 2), $413K:**

    The subject project supports the ARL/Maryland Army National Guard (MANG) collaboration in B601, and included cosmetic upgrades, furniture, and electronic security measures, as well as the design for establishing operations (visitors and collaboration) at the Adelphi Laboratory Center (ALC) MDAG Readiness Center.

17. **(ARL) Assessment for Alignment of Facilities to Essential Research Programs, $490K:**

    Completed an assessment across ARL’s sites of facilities and their inherent ability to support research that is aligned with ARL's ERPs. The analysis also identified capability gaps, as well as when, where, and how to bridge them. Deliverables from the assessment will be incorporated into the Laboratory Master Plan (LMP), which will feed into CCDC’s and DASA’s overarching S&T strategy; and will inform UFR submissions per Section 2806.

18. **(ARL) Clean-Room Backup System Refurbishment, $200K:**

    Refurbished uninterruptable power supply (UPS) for the Clean-Room. Completed needed repairs, upgraded controls, and replaced parts to bring the system up to current standards.

19. **(AvMC) Building 3707 North Expansion, $784K**

The S3I mission in Bldg. 3707 has expanded to support R&D simulation programs such as PFAL and Aircraft Survivability Equipment (ASE) Common IR Countermeasures (CIRCM). These programs required expanding classified space to the existing building for the development of high-fidelity simulations, performance analysis, data extraction of flight test hardware, and development of electronics. Expansion of the existing building was the most economical solution given existing staffing and programs were already in progress. These funds provided CCDC AvMC with additional classified space for engineering labs for simulation analysis, electronics development/testing, and data extraction from flight hardware.

20. **(AvMC) Advanced Fabrication Building, $3,500K**

The existing infrastructure was WWII or immediate post WWII era buildings that were at the end of their useful life and have continued to require high levels of maintenance and upkeep. Several times each year repairs were required to the existing sheet metal shop (Building 3509) to fix the leaking roof, heating system, and/or air conditioning system and similar repairs to the separate office space. To maintain accuracy of the computer numerically controlled (CNC) fabrication machinery within the building, a constant temperature is required (68 degrees F plus or minus 2 degrees). In order to meet current and future mission objectives, a new facility (approximately 10,000 sq./ft.) was needed to accommodate upgrades and improvements of machinery and available technology such as additive manufacturing equipment, cleaning and de-burring machinery, laser marking equipment, etc. A larger building accommodates an improved manufacturing layout. Because of the existing small workspace, storage of in-process and finished work was a problem, and current assembly size capability was restricted. A larger facility now allows development of a local composite capability and storage for the required equipment.

21. **(AvMC) CCDC AvMC Energy Laboratory (AEL), $56K**

This investment stands-up the CCDC AvMC Energy Laboratory initiated by ED senior management and organizationally placed with the Reliability Availability Maintainability (RAM) Division which is currently housed in Bldg. 3460, a warehouse industrial storage/operations facility. This investment included cubicles, paint, carpet, computer drops, admin/engineering printer/plotters, shelving, industrial tables, power drops, tools, electronic tools, tool chests, soldering station, etc. Proper housing and facilitation eased the SME burden and facilitated Project Management Office (PMO) customer support. The working energy lab provides a space for this critical function.

22. **(AvMC) CCDC AvMC/Engineering Directorate/Quality Engineering/Quality Information Systems personnel move to Bldg. 5687, $175K**

This funding was used to procure 15 Workstations and lab furnishings to be installed and placed in service at Bldg. 5687. The funding acquired hardware, delivery/installation, related materials, and related services. The funds were provided for work stations for the employees as well as tables, chairs, and other required furnishings to stand up two Army field network labs. The QIS branch was moving into a newly renovated building and had to leave their existing workstations at the former facilities. The new workstations provide the personnel with workstations conducive to the type of work the branch preforms. The QIS branch develops statistical analysis applications for Army aviation field maintenance soldiers.

23. **(AvMC) Defense Research Engineering Network Connections for ADD Eustis, $75K**

These funds were used to expand DREN connections to hangar and Bldg. 401/403/409 area to enable direct connections to Redstone Arsenal (RSA) DREN network resources. This has enabled cost/resource efficient sharing of computer software licenses and efficient transfer of data between all ADD elements. Eustis operated within the Army Network Enterprise Center (NEC) network with very limited DREN connectivity. Providing DREN connectivity has enabled access and pooling of costly special application software between CCDC AvMC elements to reduce total life cycle cost and improved information exchange efficiency.

24. **(AvMC) Model Based Systems Engineering (MBSE)/Center of Model Based Acquisition and Technology (CoMBAT) Lab Facility Establishment, $50K**

    MBSE was rapidly becoming an essential tool for Army acquisition programs to define requirements and functional architectures. The CoMBAT lab and MBSE function used to reside in the ED as a core SE mission. Borrowed workspace (@Bldg. 6267) was maxed out and left no room for growth or classified lab space as required by present customer base. Adequate work space and software tools were necessary to sustain current efforts and grow CCDC AvMC Government expertise and competence to minimize reliance upon contractors in the future. New work space has allowed the MBSE/CoMBAT team to expand and grow Government in-house skill and expertise in using software tools to assist program managers, users, etc., in defining requirements and functional architectures as well as perform requirements traceability and identify impacts of changes to the system.

25. **(AvMC) Network Switch Replacement – EOL, $2,200K**

    This was a request by CCDC AvMC G6 office. Replacing the obsolete, unsupported network infrastructure hardware items (Switches, Servers, Firewalls, Routers, Gateways, etc.) that were end of life and were jeopardizing IA security posture were necessary. This has allowed the organization to continue to access network services to include RULI connections, File Shares, Email, Internet, etc.

26. **(AvMC) Relocation of RDMR-WDP-M Operations from Redstone Road to TA-10, $2,000K**

    Relocation of WDP-M Ammunition and Explosives (A&E) operations from 7120 / 7155 / 7171 complex on Redstone Road to buildings 7347, 7346, 7357, and ECMS 7302 and 7304 in TA-10. This investment included repairs, renovations, and upgrades to the subject buildings required to accommodate the specialized A&E equipment that was needed for the WDP-M mission. The majority of these updates were required to meet regulatory compliance for A&E Operations. A space utilization request was made for these facilities in September 2014 and August 2015. The relocation of A&E operations away from Redstone Road reduced the risk to public roadways from explosive operations and thus enhanced operational stability for WDP-M mission and for long term planning.

27. **(AvMC) S3I Campus Antenna Platforms, $275K**

    This project was to design and construct antenna Platforms at the S3I Campus. The CCDC AvMC Safety office coordinated with United States Army Garrison (USAG)-Redstone to restrict all access to the roofs. The organization has approximately 115 antennas that connect back into the labs for software testing and validation. These 2363 funds have allowed the organizations projects to continue their operation with the connectivity required to access Global Positioning System (GPS), satellite and mission related communication with space assets.

28. **(AvMC) Standalone Fixed Telemetry Capability Integration, $1,100K**

By adding permanent telemetry (TM) receiving capability at Felker Army Airfield, this has allowed increased TM reliability, greater TM distances and allows access to real time data from flight test engineer workstations. This has required permanent TM receiving antenna on the flight line and receivers and processing equipment in dedicated room/space at the airfield. It has also allowed for flexibility when the TM trailer needed to be used at remote locations and when multiple TM effort require simultaneous support. Having this stationary TM station at the airfield has allowed for capturing TM at greater distances. It also allows for flight test engineers (FTE's) to access the data real time from their office workstations.

29. (AvMC) **Datalinks Laboratory Modernization, $200K**

The Combat Capabilities Development Command Aviation & Missile Center (CCDC AvMC) Weapons Development and Integration (WDI) Image Processing (IP) Data Links Group (DLG) was in urgent need of laboratory space to support classified and unclassified projects. The current DLG lab facilities located in building 5400 room D135 were inadequate to support the current programs. The DLG had invested a significant dollar amount in various high precision scientific test equipment to support their projects. Due to lack of space, some equipment had to be moved into the main corridor in D135 to perform experiments. This had consequently resulted in warnings received by the Safety Office. The DLG had thus far attempted to make most efficient use of the currently assigned lab space, but given the assigned projects and the associated equipment, the requirement for additional/augmented lab space had become imminent. This investment benefitted the organization by optimizing the layout of the space, correcting electrical and HVAC issues that enabled the team to support multiple efforts and tests simultaneously. This has translated directly to cost savings and projects being completed on schedule.

30. **(C5ISR) Radio Frequency Communications (RFC) Laboratory 403/405 Upgrades, $1,198K**

By leveraging the 2363 authority over the past three fiscal years, C5ISR Center Space and Terrestrial Communications Directorate executed preliminary design, final design, and construction contract award for a $1,965K (1,198K in FY 19) complete laboratory renovation. This effort provides flexibility and efficient use of lab space to maximize support to ongoing and future missions. Additionally, the flexibility provided by the renovations streamlines laboratory operations and provides the ability to showcase the laboratory and its capabilities to current and future customers. The space was reworked and equipment upgraded to support high priority R&D as well as continued customer efforts. The funds allowed, flow, egress, and cross team collaboration. Additionally, this effort provided flexibility for functional areas to expand and reduce with project demands. By creating flexible lab spaces RFC is poised to fully support the Non-traditional Waveforms, Every Receiver a Sensor, Next Generation High-Frequency, Spectrum Obfuscation, and other R&D mission programs.

31. **(C5ISR) Modernization of Sensor Development and Maturation Laboratories, $1,500K**

C5ISR Center, Night Vision & Electronic Sensors Directorate (NVESD) modernized its aged sensor and sensor system development and maturation facilities to synchronize with emerging Army requirements. This modernization required a significant amount of capitalization for laboratories and infrastructure to ensure technological resonance with stakeholder and transition partner requirements were achieved. This funding helped acquire novel fabrication tools which run the gamut of products delivered by NVESD (i.e. focal plane arrays to heavy machinery needed for humanitarian demining missions). These efforts directly enabled C5ISR Center's ability to support the Army Chief of the Staff's modernization priorities.

32. **(C5ISR) Modernization of Automatic Target Recognition Laboratories, $1,400K**

This effort modernized and enhanced facilities and infrastructure intended to mature and demonstrate automatic target recognition algorithms enabled by EO/IR sensors. Specifically, this effort matured and modernized an aging restructure needed to demonstrate algorithms required for a variety of missions to include detection and tracking of personnel and military vehicles with infrared sensors and weapon/no weapon determination in cluttered environments. This effort allowed C5ISR Center to categorize and manage a repository of industry, academia and government algorithms with applicability to EO/IR and other modalities. This effort ensured the US Army will have the facilities necessary to ensure the adequate testing of game changing sensing capabilities and enhancing Soldier survivability and US overmatch in situational understanding in all situations.

33. **(C5ISR) Mobile Radar Test Bed, $650K**

Capitalized on existing hardware to refurbish a mobile radar collection test bed. This effort provided C5ISR Center, I2WD with a flexible and modular capability to mount a variety of antennas within a self-contained collection and processing vehicle. Currently TARDEC is funding I2WD to oversee the development & integration of a ground moving target radar for the squad-centric mounted maneuver concept prototype development & demonstration. The mobility of this system will allow both on-the-move testing as well as the capability to vary clutter environments (Urban, foliage, etc.…). Additionally the ability to mount different antennas onboard the platform provided an excellent test bed for ongoing high priority missions such as Counter–Unmanned Aircraft System, Active Protection System, force protection and ground Intelligence, Surveillance, Reconnaissance missions identified by I2WD customers. This effort is in line with the Chief of Staff of the Army's 4+2 initiative for the Next Generation Combat Vehicle.

34. **(C5ISR) Network Conversion, $1,261K**

All of C5ISR Center, except for I2WD was on the NAE Domain. I2WD resided on the MI Domain. I2WD being on the MI Domain had introduced multiple issues in maintaining consistency and streamlining communications across the Center without investing money, time, and/or labor developing and/or architecting solutions to accommodate this difference. Even doing this, it was not always possible to rollout a Center wide application, solution, and/or establish standard guidelines that would provide efficiencies, cost savings, and standard communication. Moving I2WD from the MI Domain supported by INSCOM to the NAE Domain supported by NETCOM and APG RNEC did the following: 1) Put all of C5ISR Center on the same Domain; 2) Allowed for C5ISR Center, I2WD to take advantage of RNEC C4IM services thus reducing the need for a full team of shadow IT support on NIPR and SIPR; 3) Allowed for C5ISR Center, I2WD to upgrade their infrastructure to the NETCOM standard and then turn over responsibility for cost, maintenance, upgrades, and responsibility to the APG RNEC thus divesting themselves of a large financial responsibility; 4) Gave I2WD full access to C5ISR Center's collaboration tools, communication platforms, business support applications, help desk, and more and funds are no longer needed for sole I2WD support as they used to be on the MI Domain.

35. **(C5ISR) CNICS IA/Accreditation Equipment, $758K**

Funds implemented permanent C5ISR Campus laboratories Defense Research and Engineering Network (DREN) and Interconnected Closed Restricted Network (CRN) Software Defined Network and Access (SDN / SDA) through Cisco Digital Network Architecture (DNA). The implementation of the software defined architecture network greatly improved network security, monitoring, and supportability through centralized management and enabled faster configuration at reduced manpower. Cyber Security / Information Assurance improvements were enabled through centralized management reducing the number of independent configurations required for individual network appliances such as routers and switches. The SDA network eliminated network stovepipes and "flatten" the network which will enhance our Cyber Security posture through better ability to identify, trace, mitigate, and contain threats.

36. **(CBC) Restoration and Modernization of E3330, $1,196K**

These funds were used to support the ongoing MILCON R&M project for CCDC CBC's building E3330, a major laboratory and administrative building at CCDC CBC which was originally built in 1941 with an addition added in 1954. That R&M project is now above the cut line for MILCON in FY20. Planning and full design efforts will continue over the next year to facilitate the execution of the MILCON planning and restoring one of CCDC CBC's major and historic buildings to a modern laboratory facility. Specific actions used by these funds were for the Corps of Engineers planning and design labor to award an architect-engineer (A-E) contract to develop a request for proposal (RFP) for a design-build contract.

37. **(CBC) CBC Engineering Directorate Building E3549, $1,087K**

Building E3549 is a multi-purpose laboratory facility that houses 200 CCDC CBC personnel and is now over 30 years old. The interior of the building has not been modified/upgraded since the original construction. Funds will be used to modernize and refurbish infrastructure (electrical, HVAC, plumbing, etc.) and laboratory workspace in one quadrant of the building (C100 area) to ensure continued functionality and safety. This effort will start in 2QFY20 with planned completion in 4QFY20.

38. **(CBC) Infrastructure Laboratory Equipment Upgrades, $539K**

Funding was used to bring outdated laboratory equipment (Benchtop GC-TOFMS, GCMS Triple Quad System, GC/MS, Thermal Desorption System) in alignment with current standards to ensure CCDC CBC continues to provide state-of-the-art research capabilities.

39. **(CBC) E5804 Red Phosphorous (RP) Facility Deluge System, $350K**

Due to the age of the facility, the deluge spray system has become outdated and required an update in order to conduct RP research. Research in this area cannot be completed safely without the update to this system.

40. **(CBC) Biometrics Access Control Security Upgrade for the Chemical Transfer Facility, $250K**

Conduct upgrade to the access control systems within the chemical transfer facility. Replace the surety locks and keys with biometric iris scanners and Prox readers for CACs. Johnson Controls Federal Systems provides labor, supervision, materials and equipment per the following: JCI provides and installs one On-Guard stand-alone access control system to replace the existing access control system. The proposal includes installing 17 biometric readers and sever sfor

connection to their headend system for integration. 23 additional prox/pin readers installed along with new replacement electric locks.

41. **(CBC) CCDC CBC Chemical Filter Supply Management, $250K**

    CCDC CBC must maintain supply of carbon filters to include 16 inch cell, M48 radial and M98 trays to ensure continuous operation of the Center's surety laboratories. Infrastructure modernization of CCDC CBC's building E2204 is necessary to provide proper security, safety and environmental controls to meet manufacture storage requirements.

42. **(CBC) E5100 Roof Design, $150K**

    Due to the current roof design and age of E5100, there have been continual leaks that have never been adequately addressed and continually affect research capabilities. The past patch and repair process has not been sufficient to address the issues. This new roof design is the first stage of a multiple stage process to adequately repair the roof and restore the building to an efficient research facility.

43. **(CBC) E5951 Aerosol Chamber Modifications for Low Toxicity & Simulant Characterization, $125K**

    This upgraded facility decreases the time and cost of non-surety research by adding the ability to perform low toxicity/simulant compound characterization measurements in a non-surety chamber. This facility increases our ability to perform surety research by removing the need to perform non-surety work in a surety facility.

44. **(CBC) G-Field Soil, $110K**

    In 2016, CCDC CBC assumed operational control of the G-Field Test Area. G-Field is being prepared for the testing of various chemical/biological demilitarization and treatment systems to include the Castalia Demilitarization System. Prior to construction, CCDC CBC will develop a sampling and analysis plan and perform environmental (soil) sampling of the G-Field Test Area to evaluate the area for contamination that occurred as part of the JLENS program activities. This sampling will assist in future attribute of contamination in the event in the event a spill or release occurs at the site during test operations.

45. **(CBC) Modernization of E3330 Room 179 to support Environmental Monitoring Laboratory (EML) operations, $100K**

    Modernization was needed to ensure the lab would support EML mission of analysis of samples from mission related work at CCDC CBC. Equipment purchased to allow for ergonomic and operational efficient systems to be installed. It is expected to allow the EML to support customers and CCDC CBC while also removing some operations from the basement of the E3330, which has moisture issues.

46. **(CBC) CBC Engineering Directorate Building E4301, $38K**

    Funding was used to increase the worker safety in E4301. E4301 houses our Advanced Design and Manufacturing and Product Development functions and the fire safety provisions were outdated. These systems were modernized and now provide the best safety available for our workers. The alarms were outdated and modern alarm networks that are now available were installed.

47. **(CBC) E3150 Animal Care Area Repairs, $26K**

During a recent inspection, deficiencies were identified that needed to be completed to provide a safe environment for both animals and personnel. These funds were used to repair deficiencies that included patching and painting walls and floors within the facility.

48. **(CBC) CBC Engineering Directorate Building E3510, $5K**

Funding was used to modernize the alarm network for the chemical biological surety hood enclosures. The alarm system is critical to maintaining the safety of the operators and the occupants of the facility during surety operations. Modernized systems that are more reliable and more easily networked are now available. These more modern systems were purchase and installed with this funding.

49. (ERDC) **ERDC Recruiting and Future Workforce Development Center, $100K**

This funding was for the actual creation of the new Recruiting and Future Workforce Development Center.

50. (ERDC) **Upgrade of Outdated Programmable Logic Control System for the Triaxial Earthquake and Shock Simulator, $414K**

The CERL triaxial earthquake and shock simulator (TESS), also known as the Shake table, is a unique national asset that simulates earthquakes, blasts/shocks, and vibration environments for the testing of a wide variety of large specimens such as equipment and structural models. TESS's programmable logic control (PLC) system controls the hydraulic power supply, blowdown system, operational sensors (temperature, pressure, and oil level), and the emergency stop buttons. Over the past few years, several PLC units have failed, causing test delays and costly expedited repairs. These PLC units are no longer manufactured, replacement units are difficult to obtain, and the manufacturer no longer supports our obsolete equipment. This will replace the outdated, failing TESS PLC system with an upgraded system that uses current technology and will be supported by the manufacturer. Being a national asset, proactive maintenance and timely upgrades to the Shake table are key to realizing its full potential, while making it available to the Army, nation, and other customers.

51. (ERDC) **Unconventional Countermeasure Prototyping Laboratory, $440K**

Construction of a lab to evaluate prototype survivability enhancers in support of ERDC Unconventional Countermeasures R&D. This facility directly supports the Development of Unconventional Countermeasures for Enhanced Survivability 6.2-6.3 Program, as well as several reimbursable programs in the area of unconventional countermeasures.

52. (ERDC) **Wind Tunnel Porous Media Test Facility (FY19-20), $250K**

FY19 funds will be used to purchase of industrial scaffolding to elevate the wind tunnel channel inside our existing facility, remodel the existing laboratory space, and installation of power drops and climate control system piping. The second stage will occur in FY20, and will move the wind tunnel including all ancillary systems, sensors, and equipment from the Colorado School of Mines to the prepared facility at ERDC. This unique facility is crucial in understanding the environmental effects on sensor performance.

54. **(GVSC) Center for Systems Integration (CSI) Readiness Office Space Growth and Materials Lab, $5,486.5K**

Funding will be executed in FY20 to fund a portion of Center for Systems Integration (CSI) Readiness Office Space Growth as well as the Materials Lab.

The CSI business area has grown 10%-15% annually over the last few years. There is a need for additional desk space in order for CSI to continue to grow and meet the Army's need to address high priority readiness concerns for ground vehicles and to conduct prototyping activities for Army Modernization.

The Materials Lab project will expand the GVSC Materials laboratory capabilities, and will provide design and construction services (Design-Build) for expanding the current footprint within Building 200D, focusing on growing the competency in materials and additive manufacturing. New equipment will be purchased and new electrical infrastructure will be required to support the equipment needed to perform these functions. This project will increase lab capabilities in support of the Army's modernization and readiness.

55. **(GVSC) 228 NEW CONSTRUCTION, $5,055.0K**

The scope of work is to provide design and construction (design-build) for a new building (approx. 6600sf) north of Building 227. This project is to be built in accordance with Sensitive Compartmented Information Facilities (SCIF) regulations. The current regulation is the Intelligence Community Directive (ICD) Number 705, SCIF (effective 26 MAY 2010). This project was funded and approved through the Laboratory Revitalization Program and was vital to continue GVSC's mission as the previous office area was grandfathered under an old accreditation. GVSC can then repurpose the existing space in Building 200 for other areas needing to grow.

56. **(GVSC) PRIOR YEAR BILL, CONSTRUCTION CONTRACT W912JB-11-D-4013 BR04, $591.0K**

GVSC settled a Reasonable and Equitable Adjustment (REA) for this contract in which the Government paid the contractor for additional costs incurred during the period of performance. The scope of work for this project is to design and construct (Design-Build) a new Systems Integration Lab (SIL) for GVSC's Ground Vehicle Robotics group in Building 200C. The 5,800sf Lab can support three vehicles and over 24 bench labs focusing on robotics and autonomy. The lab has been in operation since FY18.

57. **(GVSC) PRIOR YEAR BILL, CONSTRUCTION CONTRACT W912JB-11-D-4013 BR03, $296.2K**

GVSC settled a Reasonable and Equitable Adjustment (REA) for this contract in which the Government paid the contractor for additional costs incurred during the period of performance. The scope of work for this project is to design and construct (Design-Build) new Systems Integration Labs (SILs) for GVSC's Ground Vehicle Survivability and Protection group. This project includes four SILs (laser lab, Vehicle Protection Integration Lab, Active Defeat Lab, and Cyber Lab), which have been in operation since FY19. The new 23,000sf SILs have greatly enabled GVSC to operate within the Agile Layered Protection and Cyber Engineering missions.

58. **(GVSC) CSI Press Brake Tooling, $194.6K**

This funding was used to purchase a set of English dies for the press brake. GVSC previously only had metric dies for the press brake that lead to quality issues with our formed parts due to not having the exact die size that was needed per the engineering designs that were getting manufactured. By having an English set of dies, the developed lengths of our cut flat stock will match the required developed length that is required in order to manufacture the formed parts within tolerance.

59. **(GVSC) GVSC AM Capability, $190.0K**

This funding provided additional capability to the GVSC-Materials Additive Manufacturing mission. This included purchasing of various pieces of equipment and supplies such as powder materials to support the use of the Direct Metal Deposition system for repair of parts/components. GVSC's efforts to develop repair procedures using additive manufacturing will support the Depots in repair of worn parts, vs scraping them. This capability supports the Army to reduce cost of parts by refurbishing existing parts vs. purchasing new parts. In addition, GVSC gained additional polymer 3D printing capability (Markforged X7). This printer was needed to increase the print volume of Polymer parts to align with current customer demands, and provided the much needed capability to print vehicle parts using polymer and composite materials resulting in parts that are higher strength, and high quality. Without this 3D printer capability, prototyping multiple military vehicle parts to provide solutions to the field would be significantly delayed.

60. **(GVSC) 200C OFFICE RENOVATIONS ADVANCE CONCEPTS, $163.7K**

The scope of work for this project is to provide design and construction (Design-Build) services to renovate the Advanced Concepts Office area to accommodate increased occupancy. This will involve modifying the existing mechanical, fire protection, and electrical systems, along with architectural requirements for construction of new hard wall offices, and new carpet. This renovation will add approximately 50% more workstations, which will house Cyber Engineering employees, since their SIL is adjacent to this office area. This is one example of how GVSC is able to accommodate workforce growth by maximizing additional footprint.

61. **(GVSC) GVPM, Monorail JIB Crane & PEVEL Bridge, $89.1K**

This contract is for the purchase of four (4) monorail cranes. These cranes are needed to carry out daily work activities within Power Energy Vehicle Environmental Laboratory (PEVEL). Specifically, these cranes will be used for the purpose of removing and installing in-line torque meters (200 lbs) to dynamometers and connecting drive shafts (1,500 lbs) to vehicle hubs. This equipment will not only improve the safety of test cell operators, but greatly reduce the time needed to setup a military vehicle for powertrain testing. This will increase the utilization of the lab allowing for more vehicles to be tested per year. Vehicle powertrain testing within PEVEL plays a significant role the modernization of the US Army's ground vehicles.

62. **(GVSC) MOBILE SIMULATORS HARDSTAND, $25.7K**

The scope of work for this project is to provide design and construction (Design-Build) services to install a new concrete pad to support several custom mobile simulators, procured by GVSC's Immersive Simulation group. Electrical and telecommunications infrastructure will be ran from

Building 215, northwest to the pad's location. The mobile simulators will enable large scale virtual experimentation to support up to a Company level (80-120 soldiers), which was requested by the NGCV CFT. The first Company sized experiment is planned for FY20 Q4. Since the simulators are mobile, they can also be transported to various sites for demonstrations or to the location of the participating soldiers, thus saving travel expenses.

63. **(SC) Modernize Administrative Space Bldg. 4, $2,876K**

Upgraded office space to include new ceilings, flooring, wall systems, paint, HVAC, electrical, and furniture. Completion of this project ultimately consolidates space for multiple Directorates (including associated secure spaces) in Bldg. 4 as well as increase the efficiency of the space. This improves the Combat Capabilities Development Command Soldier Center ability to conduct revolutionary customer focused research providing engineering solutions and product development that ultimately enables the Soldier and small units to dominate and succeed on the battlefield.

64. **(SC) Supporting Requirements and Small Projects, $200K**

A contract has been awarded to remove Combat Capabilities Development Command Soldier Center relocatable buildings, and will be complete by 2QFY20. This allows us to move forward with our facilities modernization efforts. This currently includes several smaller efforts such as updates to aging laboratories to support current core competencies, removal of Combat Capabilities Development Command Soldier Center relocatable buildings which are at end of life, and initiating design efforts related to upgrading the refrigeration system in the Doriot Climatic Chambers.

65. **(SC) Laboratory Renovation, Simulation and Training Technology Center Bldg. Multi-Purpose Room, Medical Demonstration Testbed, & GPU Cluster, $600K**

This effort upgraded currently outdated one dimensional meeting space and turned it into a multi-purpose room that can accommodate numerous mission tasks within the Simulation and Training Technology Center building. This project allows the Simulation and Training Technology Center to conduct larger meetings and not rely on outside organizations for support, as well as conduct in house classroom training and mission planning. The project included purchasing new tables, monitors, and chairs. Funding will support a medical testbed to execute in-house research and testing of haptic systems.

66. **(SMDC) Space & Directed Energy Technology Complex, $700K**

An updated Area Development Plan and Environmental Assessment for the Space and Directed Energy Technology Complex was completed. TC worked with USASMDC Deputy Chief of Staff, Engineer to begin designs of temporary locations for lab space until the permanent locations can be constructed and completed the requirements for a new RDT&E laboratory for the Technology Complex – Unspecified Minor Military Construction, Army project number 94062.

67. **(SMDC) Aerophysics Research Facility, $1,672K**

Operations and maintenance upgrades to the Aerophysics Research Facility included replacing the facilities aging septic system and connecting to the garrison sewage service, widening and paving the road to the facility, and installing a new water main. Development of the Safety Operating Procedure and the Light Gas Gun Operational Procedures were completed for the facility. Additionally, facility investments were made in new instrumentation for research of

phenomenology related to hypervelocity impact and hypervelocity flight in the earth's atmosphere.

68. **(SMDC) Payload Demonstration Lab (PDL), $1,578K**

The vision for the PDL is to establish a facility to plan and conduct on-orbit payload demonstrations in support of USASMDC small satellite programs. Accomplishments in FY19 include completion of the TC's portion of the Redstone Garrison Antenna Farm and the purchase of an Orbital Systems 3.7 meter antenna system.

This infrastructure, including the network hardware, has provided cost savings to the TC by enabling the Lonestar technology demonstration to be conducted in-house rather than contracting out each individual ground segment. The PDL represents a significant improvement to the TC's payload demonstration infrastructure that would not have otherwise been feasible without 10 U.S.C. § 2363 funding.

69. **(SMDC) PNT Resiliency Lab (PRL), $960K**

The vision for the Positioning, Navigation, and Timing (PNT) Resiliency Laboratory (PRL) is to establish a test facility within the TC to simulate, characterize, and develop innovative technologies that assure PNT resiliency to the warfighter. Accomplishments in FY19 include completion of laboratory facility configuration in Bldg. 5220 room 4013 including installation of lab power configuration, test equipment, and benches. The PRL facilitated cutting edge testing and proof of concepts which resulted in improvements and an increased development pace in the following projects: Joint Battle Command Platform, Lonestar, and Linebacker. Additionally, the PRL provided workforce development through cooperative projects worked with the CAL. The PRL represents a significant improvement to the TC's testing infrastructure, serving as a catalyst for in-house and Army programs, that would not have otherwise been feasible without 10 U.S.C. § 2363 funding.

70. **(SMDC) Modernization of Test Execution Support Equipment, $791K**

The TC's Test Execution Support Division provides threat-representative, low-cost, short-range ballistic missile targets for missile defense testing. The Telemetry (TM) and Operations Vans are used on all Zombie missile targets launches to record and playback TM for pre-mission integration and post-mission analysis. Most of the TM equipment is 10+ years old and doesn't meet IA requirements. The funding provided was used to purchase new TM receivers, wideband recorders, and upgrade the antenna control unit. This new equipment increases reliability of the system and is also critical to the current Authority to Operate and approved upcoming plan to enhance IA compatibility for future Risk Management Framework (RMF) audits. The Zombie suite of ballistic missile targets is used in flight tests to verify the performance of missile defense weapon systems. These flight tests demonstrate interceptor weapon capability and provide training for warfighters. Target TM recordings are used in post-mission analysis for weapon systems performance evaluation.

Appendix B: Navy Projects/Activities Investments in FY 2019

The Navy Appendix B is unavailable as it contains Controlled Unclassified Information. Request for this document shall be referred to Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation)

Appendix C: Air Force Projects/Activities Investments in FY 2019

U.S. AIR FORCE FISCAL YEAR 2019 ANNUAL REPORT

This report provides information on Air Force efforts funded under 10 U.S.C. Section 2363(a) authority in Fiscal Year 2019 (FY19). Section 219 of the Duncan Hunter National Defense Authorization Act for FY 2009, as amended by Section 2801 of the National Defense Authorization Act for FY 2010, and further amended by 10 U.S.C 2363(a), directs the Secretary of Defense, in consultation with the Secretaries of the military departments, to establish mechanisms for the director of a defense laboratory to utilize not less than 2% and not more than 4% of all funds available to the laboratory for four specific purposes:

Category 1: To fund innovative basic and applied research conducted at the defense laboratory, and support military missions

Category 2: To fund development programs supporting the transition of technologies developed by the defense laboratory into operational use

Category 3: To fund workforce development activities improving the capacity of the defense laboratory to recruit and retain personnel with needed scientific and engineering expertise

Category 4: To fund the revitalization and recapitalization of the laboratory pursuant to Section 2805(d) of title 10, United States Code

The funding provided under this authority is to be used at the discretion of the laboratory commander in consultation with the Science and Technology (S&T) Executive of the military department concerned.

In FY19, the Secretary of Defense, in consultation with the Secretaries of the military departments, formally titled the program as the DoD Funding Laboratory Enhancements across (X) Four Categories (FLEX-4) Program.

The Air Force is dependent on technological advances in response to emerging threats and to maintain a competitive advantage. We have a comprehensive and deliberative planning process to identify and fund research that is expected to have the greatest benefit to the Air Force and the warfighter. FLEX-4 authority provides the Commander, Air Force Research Laboratory (AFRL) (the “laboratory director” referenced in the legislation), in consultation with the AF S&T Executive, a degree of flexibility to rapidly exploit scientific breakthroughs or respond to emerging threats, to include developing a skilled workforce and necessary

infrastructure. This flexibility increases the rate of innovation and accelerates the development and fielding of needed military capabilities to address current and future problems.

Overall, the Air Force Research Laboratory allocated a total of $86.1M (3.25% PB) for FY19 FLEX-4 projects and initiatives. A budget breakout and summary of efforts in each category is described below. These activities reflect management decisions driven by needs to upgrade existing in-house laboratory capabilities. Category 2 work continues to be funded through other budgets to allow more FLEX-4 money to fund additional Category 4 improvements. Continuing to upgrade existing in-house laboratory capabilities, and innovative basic and applied research, the laboratory allocated the majority of resources to infrastructure and research projects, resulting in investments of $69.7 million or 81% of all investment dollars. More detailed summaries of individual projects are provided in the Air Force FLEX-4 Investments table attached.

FY17 Funding	FY18 Funding	FY19 Funding	Description of FY 2019 Investments (M=Million)
$74.6M	$83.2M	$86.1M	- **$32.5M** Basic and Applied Research programs - **$0.0M** Technology Transition* - **$16.3M** Workforce Development - **$37.2M** Infrastructure Revitalization
Comments			
*Tech Trans has been funded via other sources through FY16-FY19.			

Cat 1 - Commander Directed Research & Development (CDRD) Fund: A total of $32.5M was invested in Cat 1 projects. The majority of funding focused on new 1-3 year projects strategically aligned with high priority S&T areas. Approximately a quarter of the allocated Cat 1 funding was applied as venture funds to seedling initiatives that serve as a proving ground for new concepts in R&D. Combined ongoing and new R&D funding commands about 38% of the FY19 FLEX-4 budget, with near-term projections in the same window.

Cat 2 - Transition of Technologies into Operational Use: No Category 2 projects were funded with FLEX-4 in FY19. Technology transition responds to urgent needs from Combatant Commands, Acquisition Centers, and Major Commands, resulting in Rapid Reaction projects that develop and deliver prototype solutions within 12 months.

Cat 3 - Workforce Development: FLEX-4 funds were applied to projects that enhanced recruiting, increased current and future workforce skills - to include STEM outreach, and supported operational costs of AFRL Institutes. Institutes executed the majority of the Cat 3 budget at about 70%, with workforce development projects executing the remaining 30%. Cat 3 received about 19% of the FY19 FLEX-4 budget. Future years are projected to maintain similar levels with Institutes held at the same dollar cap.

Cat 4 - Laboratory Revitalization & Demonstration: Cat 4 funds continued to provide up to $6M in MILCON/minor MILCON projects with focus on state-of-the-art, research facility improvement projects that support strategic R&D objectives of AFRL S&T, and AF S&T 2030 Strategy. Facility projects absorbed another 43% of the FLEX-4 budget for FY19, with near-year projections expected at similar or rising levels.

Best Practices: The AFRL pursues aggressive reforms to ensure resources align with the highest priority activities. Many of these have resulted in best practices that focus allocations and prioritizations in line with improvements driven by the National Defense Strategy and AF S&T 2030 Strategy, such as:

The AFRL has institutionalized responsibilities, processes, procedures and policy across the AFRL within the FLEX-4 authority, which is codified and maintained through AFRL Instruction 61-102.

The Air Force also maintains a separate program element for FLEX-4 funds, 0602212F, where the funds are internally reprogrammed in the year of execution after receipt of the appropriation. This allows FLEX-4 projects to cross all technologies, and not require matching to multiple program elements by specific technology.

Expanding on the AFRL FLEX-4, Cat 1 CDRD process model under Research Advisory Council (RAC) oversight, AF S&T 2030 seedling projects are now included with matching funds and RAC oversight.

Attachment
Air Force FLEX-4 Investments
Appendix
Air Force Implementation of FLEX-4 Authorities

Attachment 1
AIR FORCE FLEX-4 INVESTMENTS

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$8,734	Entrepreneurial Research Funds (ERF)	The Entrepreneurial Research Funds (ERF) are managed by each of the Technical Directorate Chief Scientists for in-house research. The funds are innovative basic and applied research conducted in-house and supporting military missions. The money is distributed to each technical directorate to decide what projects to fund. The projects support cutting edge research across AFRL. The projects maintain scientific and technical vitality of AFRL, enhance the laboratory's ability to address future Department of Defense missions and foster creativity and stimulate exploration at the forefront of science and technology.
$1,360	Photonic Agility in Contested Environments	The Photonic Agility in Contested Environments project seeks to create transformational laser radar capabilities for non-traditional platforms in contested environments and across multiple domains. We are replacing large and heavy optical components with fast, agile, electro-optical components, including tunable flat lenses, laser beam steering devices, and dynamic filters and mirrors. We have achieved several breakthroughs in photonic materials design by employing machine learning techniques to discover uniquely patterned structures with desirable optical properties several thousand times faster than with conventional approaches. We use nanofabrication techniques to implement these designs in liquid crystals, electro-optical crystals, phase change materials, and various semiconductors. The Light Detection and Ranging (LiDAR) systems we are building from these photonic materials allow for enhanced capabilities within novel form factors, such as a near-conformal lens array to generate high-resolution imagery and see targets through foliage and concealment. These advances may help overcome operational constraints for adding LiDAR to future unmanned aerial vehicles, guided munitions, and space satellites towards holding critical mobile targets at risk and defeating integrated air defenses in highly contested environments.
$2,150	Enriched Understanding of Hypersonic Materials	The use of high-temperature materials, while enabling, are a major source of risk for hypersonic flight. The overarching objective of this project is to gain a complete understanding of materials interactions in hypersonic environments that will lead to more accurate models of material performance and input into life-cycle models for high-temperature materials in sustained hypersonic flight. This will be accomplished by (1) developing a robust suite of mobile diagnostic tools to thoroughly characterize thermochemical environments and probe material response in multiple high-temperature, high-heat-flux hypersonic ground test facilities in situ and (2) implementing and demonstrating that the tools provide an enriched understanding of the performance of materials in simulated hypersonic environments and the performance of materials in ground-based tests. During the first year, this project has completed the design of the 3-in-1 mobile sensor suite for measuring spatially- and temporally-resolved temperature and major species concentration. The construction of the sensor suite has started as well as development of the software for data analysis. In addition, we have identified the requirements of the experimental apparatus for high-temperature RF material characterization and plasma-material interactions. This new apparatus is capable of exposing hypersonic window and leading-edge materials to an environment comparable to a supersonic plasma flow and temperatures above 600°C. Diagnostics such as temperature and electron density are being refined and integrated into the measurement fixtures.

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$1,500	Micro-Comb Technologies for Timing, Sensing, EW and Quantum Applications	This project looks to develop optical integrated circuits to add capabilities in broadband signal processing, quantum communication, and precision timing. Signals of interest are increasing in bandwidth, density, and modulation complexity. To stay ahead of these advancements, two techniques – folding and channelizing the spectrum – are key to next-generation systems which will be able to identify these signals. Central to this technology is the ability to generate low-noise, RF frequency combs spanning 100s of GHz. While a daunting task for electronics, frequency combs generated in the optical domain are a promising avenue to meet this need. Recent developments of micro-comb technology have reduced system sizes from table-top to chip-scale. To date, micro-comb frequency spacing generally falls in the THz regime, a value that is too large for many relevant applications. A portion of this CRDF effort is focused on developing micro-comb technology to meet these current and future requirements. Working in tandem with industry and academia, this project is systematically exploring competing material platforms to develop micro-combs with RF comb-tooth spacing ranging from 10s to 100s of GHz. Ongoing investigations include novel, low-loss lithium niobate micro-ring resonators, electro-optically assisted micro-rings, and gain-switched optically-injected semiconductor lasers – all on integrated platforms. Quantum effects, such as superposition and entanglement, benefit numerous applications. In some cases, such as communication and networking, the innate randomness and strong correlations given by quantum mechanics guarantee security. Overall though, the key to advancement of the field is the ability to fabricate these devices in standard commercial foundries and exploit the entanglement afforded by integrated photonics. The integrated photonic devices themselves produce energy-time entangled photon pairs (a quantum microcomb) containing extremely large amounts of entanglement, useful for applications such as communications, networking, and information processing.

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$1,670	Nano and Micro-Structured Nonlinear Waveguides for Wavelength-Agile Lasers	Although high peak and average power fiber lasers have found many applications in DOD systems, their wavelength of operation is limited to a few specific wavelengths that are not necessarily eye-safe or optimal given the optical transmission of the atmosphere. Wavelength conversion techniques require transitioning from fiber components to free space components, thus increasing the opto-mechanical complexity and reducing opto-mehcanical robustness. We have been investigating nonlinear processes in micro-structured fiber waveguides, and to a smaller degree, in planar waveguides for low cost, size, weight, and power wavelength conversion techniques; the investigation includes both experimental and numerical approaches. The bulk of our wavelength conversion effort has focused on stimulated Raman scattering (SRS) and quasi-phase matched optical parametric amplification (QPM OPA) in gas-filled hollow-core photonic crystal fibers. SRS in Methane (CH_4) filled fiber has been studied experimentally and numerically for development of "eye-safe" high power lasers; experimental results yield near quantum-defect limited wavelength conversion. The aim is to investigate the scalability of this architecture to reach high peak & average power for applications such as target illuminators and beacon illuminators. On the second architecture studied, the QPM OPA, the team has set the near-term design around a Xenon filled fiber encased between periodic electrodes to produce 2.12um emission from a 1.06um pump laser. The periodic electric field produced by the periodic electrodes creates an effective second order nonlinearity and, with the appropriate poling period, can allow efficient wavelength conversion in the Xe filled fiber. The QPM OPA is attractive since, in principle, you can design the system to produce nearly any wavelength from the near IR to the mid-IR using the common 1.06um pump laser and there could be near zero heat dissipated in the nonlinear medium. Recent modeling has established the basic design parameters and performance for this wavelength conversion technique. On the numerical modeling front, the team has implemented a mini-cluster to support operation of the Generaled Unidirectional Pulse Propagation Equation for study of nonlinear optical phenomena (gUPPE). The gUPPE code has been benchmarked against the experimental Raman work with methane showing good agreement. Future investigation will exploit the computational capabilities to optimize the laser designs and experimental results will be used to iterate model parameters to verify accuracy and improve laser design.

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$1,540	Looking Where You Are Going…Superior Weapons with Articulating Heads	The goal of this effort, Missile Enhancement via Reconfigurable Interceptor Nose (MERLIN), is to introduce morphing missile technology with unprecedented weapon effectiveness and lethality. Specifically, we are researching the effectiveness, operational strategic use of a missile with an articulated head for more agile aerodynamic control, improved targeting, and directed fragmentation to defeat a greater set of targets over the state of the art fixed-body missile systems. To date, our team has developed 1) a modeling and simulation toolset that provides accurate trajectory and capability analysis of morphing homing missiles, 2) skeletally reinforced skin structures that accommodate bending of the missile body casing and 3) actuation mechanisms for articulation designed to withstand the required forces equivalent to the weight of a mid-sized sedan. Presently, MERLIN is working towards a comprehensive capability assessment of the articulation mechanism using simulated and experimental thermo-mechanical loading in a laboratory environment representative of real world operating conditions. MERLIN has also transitioned to an advanced technology demonstration where a benchtop full-scale missile articulated fore body is being controlled and evaluated through a full trajectory simulation. In pursuit of greater technology readiness, the MERLIN team is actively planning flight experiments of rocket powered articulated missile systems. Additionally, MERLIN has led to the creation of new research areas in morphing hypersonic weapons, for which a cross-service team (NRL/AFRL/ARL/MDA) was established and a proposal was sent to the Office of the Secretary of Defense. These efforts support US Air Superiority and the ability of the USAF to affordably and rapidly defeat long distance threats with the highest lethality.
$1,660	Extremely Thin Active Antennas for Space	The project develops the foundational technologies enabling the world's thinnest tensioned active antennas that bring large satellite capability to small satellite platforms. Achieving a 1-mm thick antenna requires integrating structural, electromagnetic and thermal design practices with the latest manufacturing approaches. The project crosses multi-directorates looking at space systems, deployable structures, thermal control, antennas, devices, materials, and manufacturing. Major tech achievements this year include: Transmit/receive modules selected and tested, Component thermal analysis completed. An orbital thermal analysis was completed enabling the development of a mission level Concept of Operations. Gallium Liquid Metal Alloy Hinges were tested in the space environment on the International Space Station with sample return expected this quarter for further analysis. Initiated program to use additive manufacturing techniques to revolutionize the Integrated Circuit design directly on the antenna structure to potentially reduce overall panel thickness by as much as 50%. Commercial off the shelf and additively manufactured DC/RF cross over bridges were investigated with goal of reducing numbers of substrate layers. A baseline structural concept developed an initial structural model created with preliminary results showing opportunities for further mass reductions while maintaining sufficient structural stiffness. A prototype batten and column structure was developed and tested validating structural models. Origami folding techniques for phased array antenna were investigated with a focus on non-linear mechanics for a multi-stable structural design. If successful, origami approach could significantly reduce overall structural mass and part count. Three papers were published this year directly related to work on CRDF. The project will help U.S. Space Force look for solutions to a threat that may extend into space—supports new space paradigm with cost and resilience driving the requirements.

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$1,645	Employing Interactive Visualization Analytics for Explainable Artificial Intelligence	This effort is developing an Explainable Artificial Intelligence (XAI) approach using deep topological ensemble modeling which (1) rivals state-of-the-art machine learning and artificial intelligence approaches for classification and prediction; (2) structures the data in a fully-interrogatable manner for maintaining decision explainability; (3) enables interactivity with machine driven solutions to enhance trust and embed human semantic understanding; and (4) generalizes across domains that include more than 20 different data use cases encompassed within the CRDF. Thus far the project has: • Demonstrated prototype-level XAI approaches across multiple computer vision tasks in geospatial satellite , hyperspectral, Light Detection and Ranging (LiDAR), wide-area motion, synthetic aperture radar, and high resolution radar imagery sets for object classification, post-disaster damage assessment, and tracking aerial assets in high noise video feeds. • Demonstrated machine learning approaches for radio frequency modulation prediction for signal intelligence decryption. • Developed XAI prototype demonstrations for identifying material defects in metal alloy additive manufacturing processes, examining inverse models for defect characterization in non-destructive evaluation methods, and instantiating automated analytics for transmission electron microscopy tomography data. • Used XAI approaches to optimize low-cost attritable aircraft design and for correlating how fuel composition is determined through advanced chromatographic techniques informs overall fuel properties. • Used XAI approaches for suicide risk prediction utilizing demographic, electronic health record, and prescription information for autonomous modeling to assesses force-wide, squadron-level risk and disseminate the analyses to forward deployed teams for prescriptive interventions. • Demonstrated XAI models related to 711 HPW data domains for concussion assessment from balance data, persistent physiological monitoring for EEG workload assessment, brain-computer interface translation, natural language processing for topic modeling in unstructured text, and predicting success or failure of special operator trainees. • Enabled integration of developed XAI approaches in cooperative cross-service international programs for developing autonomous guidance and control and obstacle avoidance approaches using the acoustic return signatures of micro-air vehicles, similar to bat echolocation. • Demonstrated capabilities with partners from the Air Education and Training Command and industry partners to assess factors related to critical career field retention.

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$1,085	Integrated Optics for Quantum Systems	Atom and ion systems continue to be at the forefront of efforts to develop precision sensors, to communicate with absolute security, and to compute solutions to classically intractable problems. While these highly-specialized lasers and optical systems routinely generate, manipulate and interrogate atoms/ions, they are difficult to miniaturize thus making fieldable prototypes an on-going challenge. This CRDF project has developed a low-risk, all-fiber native laser architecture that can drive the next generation of quantum sensors, while also pursuing longer-term solutions with photonic integration. In collaboration with the American Institute for Manufacturing (AIM) Photonics trusted foundry, our team is developing structures to interface with trapped ion quantum bits, and subsequently manipulate and transmit their stored quantum information. In addition, we have developed a magnet-free optical isolation technology, compatible with miniaturization, which addresses one of the most challenging requirements in precision sensing laser systems. The enhancements are highly desired by ACC, AMC, USSF, and STRATCOM to develop new optical and laser-system capabilities.
$1,825	Sensors for Low Cost Attritable Aircraft Using Additive Manufacturing Technology	The goal of this CRDF project is to exploit/develop additive manufacturing (AM) capabilities and design tools to embed optimized intelligence, surveillance and reconnaissance functionality into attritable Air Force platforms. Progress has been made in moving towards demonstration of a prototype array antenna fabricated using existing AM capabilities. Test fixtures based on the XQ-58A Valkyrie Low Cost Attritable Strike Demonstrator (LCASD) platform have been fabricated for integration of the prototype array antenna and evaluation of prototype array survivability in the LCASD aerodynamic load environment. Progress has also been made in development of multiphysics design and optimization tools, integrating Government-owned and Government-developed software tool sets, and developing new AM polymer materials and flexible conductive inks to improve the electromagnetic and structural performance of low cost 3D printed structures relevant to attritable RF sensors.

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$1,600	Deep Learning SAR ATR Baseline for Exploitation Relevance in Contested Environments	The goal of DL-SABER is to research, develop, verify, and validate deep learning (DL) algorithms for advancing the state-of-the-art (SOTA) in synthetic aperture radar (SAR) automatic target recognition (ATR) for intelligence, surveillance, and reconnaissance (ISR). DL-SABER's main objectives include: (1) Developing deep neural networks (DNNs) based multiple-channel (e.g., magnitude, phase and polarization) target recognition algorithms for SAR, (2) Innovating training algorithms for best learning outcomes with limited/sparse radar data and accomplishing this in real-time, (3) Experimentation of Deep Learning SAR ATR with realistic operational scenarios (e.g., various radar systems, complex targets, background clutter, and collection geometries), and (4) Optimizing ATR algorithms on neuromorphic architectures (e.g., IBM's TrueNorth) and embedded general-purpose graphics processing units (GPGPUs) to meet the size, weight, and power (SWaP) requirements for on-board ATR capabilities. During FY19, we made significant progress on our research tasks. Our key accomplishments include submitting a patent application, one journal articles for IEEE Aerospace and Electronics System, four conference abstracts for IEEE radar conference and SPIE Defense and Commercial Sensing symposium. We also developed a machine learning tutorial for SAR target recognition and working on writing an Artificial Intelligence / Machine Learning text book. For research task 1, we found that radar polarization improves target recognition accuracy and reduces false alarm rate in the presence of confusing targets. This finding is significant to discriminate similar targets in contested environments where we don't have access to target information as in permissive environment. For research task 2, we developed near real-time training for deep learning based target recognition. For research task 3, we examined performance evaluation of machine learning algorithms under various operating conditions and adversarial attacks. We submitted a patent for this research. Finally, for research task 4, we implemented deep learning based SAR ATR in GPGPUs and IBM's TrueNorth energy efficient computing system.

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$1,100	Fuel Biocontainment Sensing Using Bio-Functionalized Resonant Photonic Gratings and Field Effect Transistors	This CRDF project seeks to develop an in-tank sensor for early detection of fuel biocontamination. Effective monitoring of microbial growth in fuel systems is of great importance to prolong the lifetime of fuel systems and reduce maintenance costs. Currently, there is no simple and reliable method for detecting microorganisms within the fuel system. Microbial contamination is only detected once the system has been impacted. Successful detection of microorganisms in fuel relies on: 1) finding microbial biomarkers that are conserved in the different microbial groups that affect fuel, 2) developing robust biorecognition elements (BREs) that withstand the harsh fuel conditions for biofunctionalization of the biosensor for microbial detection, 3) developing a sensor capable of withstanding and working in the presence of hydrocarbons even when sensing platforms are usually meant for aqueous environments. This project has established technologies to meet and overcome each of these obstacles. The AFRL team applied state-of-the-art biomolecular tools including genomics, transcriptomics, metabolomics, bioinformatics and functional assays to develop these biomolecules. Multiple conserved biomarkers for all three microbial groups (i.e., Gram positive bacteria, Gram negative bacteria, and fungi) that contaminate fuel were identified. Multiple robust BREs have been developed based on peptides, nanobodies, and lectins to functionalize the sensing platform for microbial detection. Finally, the photonic optical sensor and electrochemical sensor were biofunctionalized with all three types of BREs and shown to detect the microbial targets in the presence of fuel. In the final year, we will finalize the development of the biosensors by validating multiple performance parameter and demonstrating functionality with contaminated fuel samples from the field. Besides the extensive progress obtained this year in the development of the sensor, the team also obtained a US Patent (No. 10,295,537; Biorecognition Elements for Rapid Detection of Biocontamination.) for the development and use of BREs for microbial detection and biosensing, a Patent Pending for a liquid microfluidic device for sensing, an Air Force Invention Disclosure (Num. AF1802) for additional fungal and bacterial BREs, and multiple peer-reviewed publications in prestigious scientific journals.

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$1,530	Cruise Missiles Navigation for A2AD, Long Range, Over Water Ingress	Long range, over water ingress in GPS-denied arenas is a significant challenge for the Air Force. This effort is addressing both the over-water and over-land navigation capabilities while building AFRL and partner infrastructure for this and future navigation research and development efforts. Our Magnetic and Vision Aided Navigation (MaVAN) program is using magnetometers and magnetic anomaly maps to aggressively and indefinitely bound positioning error in flight, specifically over water. At landfall the navigation system then leverages more traditional over-land techniques, in this case electro-optical camera inputs. With recent advances in the state of the art (from AF researchers on the proposed team) and additional development within this program we intend to bound position uncertainty to less than 150 meters for cruise missile trajectories over water, then refine to near-GPS levels over land. The effort to date includes software and hardware developments and multiple flights for data-collection, open-loop navigation tests, and even close-loop unmanned aircraft system (UAS) flights were the autopilot/controller used the image-aided (non-GPS) navigator solution generated in flight. All participating teams are now leveraging a common data infrastructure, a shared code repository, and shared simulation capabilities; teams then implement the navigation approaches on hardware assets unique to each directorate. The coordinated research and investments made during this CRDF will continue to buy-down risk and build in-house expertise to support the intended transition of these technologies to CM platforms.
$1,430	Study of Laser Induced Damage of Sensor Materials by Atmospheric Propagation of High Power Femtosecond Mid-IR Laser	The project goal is to evaluate effectiveness of very short laser pulse in the mid wave infrared (MIR) against electro-optical (EO/IR)/infrared materials at ranges of military interest. The program is addressing the need for advance strike technology for both offensive and defensive operations with both kinetic and non-kinetic options. A high intensity MIR laser source constitutes a non-kinetic option for specific targets at a distance and is a focus of this proposed program. Research to develop advanced strike technology is built on the science base that supports the development of high intensity, continuous and pulsed radiation sources. For that, we proposed to deliver a one-of-a-kind MIR laser system for evaluation of ultra-short pulse laser (USPL) military utility against electro-optical sensors. The project studies unprecedented MIR laser intensity, analyzes MIR USPL propagation through turbulent air, and explores the effects associated with EO/IR and optical material interactions. In order to accomplish the objectives, we proposed a well-diagnosed laser test range to study propagation effects and filamentary interaction with any material of interest, extendable to classified system studies. The team is wrapping up testing of relevant EO/IR systems materials for their response to MIR laser pulses. Several materials have been tested, are currently tabulated and the team is preparing journal publications in high impact journals. A low power prototype MIR USPL source was recently completed and configured to extend the material response testing to investigate damage threshold parameters for sensor materials. In parallel the team is developing a test matrix and acquiring the relevant materials to be tested. The one-of-a-kind mid wave infrared laser system built is underway and expected to be completed in the third quarter of FY20. The propagation range is well characterized and ready to be utilized.

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$800	Low SWaP Beam Combinable 10 kW Fiber Laser: A New Paradigm in Power Scaling	The purpose of this project is to enable a revolutionary breakthrough in the field of single-mode, beam combinable high power fiber amplifier systems. The project aims to demonstrate a 10 kW single all-fiber amplifier with near diffraction-limited beam quality; a 3-4x improvement over current commercial fiber amplifiers (and prior SOA). As such, we have investigated innovative gain fiber designs and novel methods to suppress adverse nonlinear and thermal effects to reach record fiber output powers. This year, we made key strides such as demonstration of a 5kW beam combinable single fiber amplifier; based on a novel AFRL fiber design. To scale the power further, we have developed a multi-kW (4.3kW) two-tone (or dual wavelength) fiber amplifier with significantly improved nonlinear (4x) and thermal (1.2x) mitigation performance. Notably, these results are limited by available pump power and further power scaling is possible, with current AFRL thermal models predicting fiber power levels of over 9.2kW. To overcome pump power limits, we have collaborated with a laser diode manufacturer to develop record brightness laser pump diodes needed to enable the proposed 10 kW fiber amplifier. Delivery of the pump diodes is expected in April 2020. Overall, the CRDF effort is on the path towards demonstrating the first 10 kW class, beam combinable fiber amplifiers.
$990	Real-Time Wavefront Sensing for ISR and DE Systems	The purpose of this project is to demonstrate a fundamentally new approach to real-time wavefront sensing via the development of a volumetric solution that is applicable to both intelligence, surveillance, and reconnaissance (ISR) and directed-energy (DE) systems. The presence of distributed-volume or "deep" turbulence presents unique barriers for ISR and DE systems which look to sense and correct for disturbances found all along the propagation path. This project extends the effective ranges for both ISR and DE systems by a factor of two or more over current wavefront sensing solutions. Such innovation drastically increases the operating envelopes associated with fielded ISR and DE systems.
$1,040	Lower C-SWAP Infrared Sensors	Current Air Force Mid-Wavelength Infrared (MWIR) imaging systems used for infrared (IR) search and track (IRS&T), long-range stand-off imaging, high altitude hyperspectral imaging, and Launch Detection Missile Warning (LD/MW) all use Mercury Cadmium Telluride (HgCdTe) detector technology. That technology has high performance, but also inherently high material cost due to low yield, foreign dependency on exotic substrate material, no inherent resiliency to the satellite laser threat and can suffer from defective blinker pixels and. These shortcomings also limit HgCdTe's future prospects for use in the upcoming proliferated sensing layer, where manufacturability and cost will be key. This project looks to integrate new optical limiters, which thwarts the burgeoning laser threat, and superlattice (SL) detectors into a single MWIR optical sensor from the onset. SL detectors have lower material cost, higher manufacturability, fewer blinker pixels, and performance approaching HgCdTe. New SL detector absorber materials and device architectures will be designed, grown, and tested to provide equivalent detector performance at higher operating temperatures. Optical limiters will be hybridized to detectors or monolithically integrated by using them as growth substrates.

CATEGORY 1 – INNOVATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$880	Novel Approach to Generation of Artificial Low Frequency Ionospheric Plasma Density Irregularities and Impact on Scattering of High Frequency Waves	The basic understanding of the beat-wave excitation and non-linear spectra formation mechanisms of low-frequency turbulence in the mid-latitude ionosphere is critically important for numerous applications in sensing and communications, since ionospheric density irregularities affect OTHR, UHF SATCOM, and GPS L-band signals. The main accomplishments of this project during the FY19 are listed below: • Model of nonlinear excitation of Lower Hybrid pump wave via the beat-wave process in the inhomogeneous ionospheric plasma was developed • Nonlinear equations describing development of the Lower Hybrid turbulence and creation of deep density irregularities in the ionospheric F layer were derived and solved numerically • New model of generation of non-Maxwellian energetic electron tails due to the presence of strong LH turbulence was developed and analyzed • Experiments on beat-wave excitation at the HAARP and Arecibo ionospheric heating facilities were performed during four experimental campaigns. The latest campaign at the Arecibo facility was supported by the Naval frigate USNS Waters. The goal of this effort was to detect and analyze EM signals propagating through a modified turbulent ionosphere due to a beat-wave process above the Arecibo facility, PR • A portion of collected experimental data was analyzed. Experimental results support analytical and numerical findings on parametric excitation of LH waves via beat-wave process and generation of density modulation in the ionospheric F-layer
$32,539	**SUBTOTAL CATEGORY 1**	

CATEGORY 2 – RAPID TRANSITION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$0	**SUBTOTAL CATEGORY 2**	Funded through other internal sources

CATEGORY 3 – WORKFORCE DEVELOPMENT		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$1,013	HQ – Gaming Research Integration for Learning Laboratory (GRILL)	Purpose: For the GRILL investment, 2019 was a very good year for effort and transitions. The largest event was the transition of the GRILL® from a technology incubator capability housed at the Tec^Edge to the Dayton Regional STEM School (DRSS). That move was supported by a million dollar grant from the State of Ohio to integrate the AFRL gaming research with STEM education and learning. For Summer 2019, the GRILL hosted a number of students, teachers and summer faculty researchers. This includes 2 summer research cadets from the USAFA and four Legacy teachers along with 6 returning teachers from the DRSS and the Ohio region. The GRILL team is working with the DRSS faculty to integrate the GRILL into the DRSS curriculum as a routine part of day-to-day education with the students. Many of the challenge problems the students and teachers typically work on are directly related to work supporting USAF training and education needs and represents a huge value add for the military while providing critical STEM opportunities for the students and teachers alike. Value: In terms of regional impact in 2019, the GRILL hosted our annual Full Throttle STEM event at the Eldora speedway in northern Ohio. The event was attended by over 300 middle and high school students from 9 school districts in mid and northern Ohio. The event has attracted such a following that in 2020, the team will host two Full Throttle STEM events, the traditional one at Eldora and a new event to be hosted in southern Ohio given interests from middle and high schools as far south as Cincinnati. In terms of technology transitions from the GRILL and in addition to the STEM curriculum content we share with schools around the world, the GRILL successfully transitioned a parachute simulator to the SERE schoolhouse at Fairchild AFB, WA, content for virtual reality aircraft maintenance to AETC as part of the maintenance training next concept, and performance measurement and feedback technology to virtual reality trainers at the F-15E Field Training Unit (FTU) at Seymour Johnson AFB, NC. The GRILL has started a promising multi-year collaboration with the Air Force Institute of Technology in online education and in multi-domain operations. Both of these efforts are leveraging the GRILL expertise and the capacity of the facility we have to support military personnel software development activities. Status: We are about 70% expended on the funds we received last year. We expect to fully expend those funds by mid-summer 2020.
$50	HQ – Inspire	Purpose: Inspire is a celebration of the people of the Air Force Research Lab and the technologies that are developed for the Air Force and the world. Value: The TED Talk-style event features topics designed to inspire collaboration with others working in the industry, as well as to inform the community and future workforce. Engages the workforce, enables collaboration, lets external world know the work we do for the AF, thereby aiding in recruitment of talent and fostering of external partnerships, and retention of employees. Status: FY19 funds being applied to conduct FY20 Inspire event at Eglin AFB.
$400	HQ – Workforce Studies	Purpose: Conduct Acquisition Workforce and General Schedule Workforce studies. Value: To gain deeper insight against a set baseline for directing future focus areas. Status: Studies to be awarded and begin mid FY20 with expected completion by late FY20.

CATEGORY 3 – WORKFORCE DEVELOPMENT		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$200	HQ – Coaching Initiatives	Purpose: AFRL is implementing the Air Force's 2030 S&T Strategy by providing executive coaching, facilitation, and developmental support for AFRL leadership at all levels to navigate the cultural shift within the organization. Value: This leadership development and support is of high value to the organization, as this type of organizational change will not be successful if approached as a scientific or engineering problem. Status: The 200K was used to complete diagnostic interviews, align senior leaders through facilitated discussions, consult on messaging, and provide executive coaching, as well as, planning/facilitation of senior leader offsite in December.
$454	HQ – 360 Assessments	Purpose: Workforce assessments supported extensive coaching services provided to AFRL targeted senior leadership in order to evaluate benefits of the coaching. Value: Fostering self-awareness and leadership competency development at a sustained objective for leaders at all levels, for the duration of their careers. Status: Ongoing
$270	Athena Workforce Development Environment (WDE)	Purpose: The Athena WDE application, developed in-house at AFRL, addresses the loss of intellectual capital in the area of Electronic Warfare. It consists of materials for self-taught learning, resources for research and development, and a knowledgebase for reference and continuity. The Athena WDE provides multiple educational curriculums, calculators, podcasts, M&S tools, exercises, and gamified learning. The Athena WDE is being used within AFRL and has been transitioned to AFLCMC and to US DoD ROTC Cadets. Value: We have had wide-spread positive feedback on the value and need for the capability provided by the Athena WDE. Status: The overall Athena effort is 60% complete. We are currently researching a cloud-based classified solution.
$60	Knowledge Capture and Transfer Capability	Purpose: Knowledge Capture and Transfer Capability funds were used to support two individual knowledge transfer efforts (one for chief engineer, one for branch chief), and also an advanced scientific and technical research document digitization and retrieval effort. Value: The individual knowledge transfer efforts were deemed hugely successful by participant, and directorate is considering policy implementation this year. Status: The advanced S&T document digitization and retrieval effort is now underway, and expected to provide faster, more complete access to the thousands of document artifacts produced by the directorate each year.
$275	RW University	Purpose: RW University (RWU) advances innovative workforce development initiatives for enhanced organizational performance. It is a workforce development platform that offers high-quality scholarship and distinctive curricular programs that complements the workforce's existing academic and analytical competencies while providing a framework to create, acquire, transfer and retain knowledge. Value: The RW University has achieved phenomenal results in 2019. RWU has conducted more than 15 events (courses, workshops, etc.) throughout 2019 for more than 150 participants with an easily repeatable process. It is estimated that over a third of RW's employees have participated in at least one or two of its events. RW's experts have delivered most of the content (i.e. Missile fundamentals, Python programming, Guidance, Navigation and Control, Emotional Intelligence and Contracting 101, etc.). There are still some challenges for RWU as it grows. Continued leadership involvement is critical to the sustainment of its success. Status: Complete
$360	Cal Institute Aerospace	Purpose: Cal Institute Aerospace funding has alleviated limitations for partnering with academia and industry, and created research opportunities on two research projects; Infrared Laser Absorption of Carbon Monoxide in Rockets, and High-speed Physics Electrospray Thruster Emission at UCLA. Value: AFRL researchers now engage with 20 interns working on Summer research and positioned as potential future hiring candidates after graduation. Status: Complete.

CATEGORY 3 – WORKFORCE DEVELOPMENT		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$7	Junior Force Council (JFC) Workforce Development	Purpose: Funds were applied to efforts focused on advancing junior workforce member's understanding of career paths in AFRL and processes or programs in place to assist in their progress as careers advance. Value: Maintaining goals and clarifying achievement strategies for junior member s helps relieve the frustrations often associated with maneuvering the vast possibilities and produces a more valued and committed workforce of the future. Status: Complete.
$24	Podcast Analytics	Purpose: Podcast Analytics Program gathers applicable data/feedback regarding the usage/consumption of the PRS podcasts that have been made available so far, in order to better understand the interests of the workforce and, ultimately, the value of the PRS Podcast Program. Value: All feedback that has been received to date has been very positive and supportive of the PRS Podcast Program. Value: As analytics are an integral part of assessing the value of the PRS Podcast Program, the value of the Podcast Analytics Program is high. Status: We are currently approximately 3-4 months into the process of gathering usage/consumption analytics and estimate that up to ¼ of the workforce is using the PRS Podcast Program, which is a good baseline for comparison. We will continue the Podcast Analytics Program as planned, which, when complete, will provide sufficient data to inform a more long-term decision on permanent funding for gathering analytics on the PRS Podcast Program going forward.
$195	Accelerating Innovation Culture	Purpose: Funds used to facilitate access to Google Cloud Computing resources and demonstrate the power to improve quality of IT life for S&Es. Value: Training to S&Es on these tools will allow them to push their ideas further, faster and become the technical experts for others on their research team. The project and training will focus on AI/ML as much as possible in support of the 2030 Strategy. Status: Funds on contract for Institute support 1st qtr. FY20, expect completion by 4th qtr. FY20.
$205	Leadership Coaching	Purpose: 4 CTC leads, 4 Technical Advisors, 2 Deputy Division Chiefs, and 7 Branch Chiefs received a blend of group and individualized coaching. Core leadership behaviors were identified for Deputy Division Chiefs, CTC Leads, and Tech Advisor roles with senior leader and Division Chief input. People in each role worked on a project that were presented to senior leadership. The projects were: Deputy Division Chiefs – Employment Physicals for Security Force, Tech Advisors – Improving Tech Soundness for 21 IS, Branch Chiefs - Increasing Retention and Building Moral By Changing RI First, CTC leads – CTC playbook. Status: Complete
$158	Secure Agile framework (SAFe) Training	Purpose: Three 3 day courses taught software development teams agile programming at the scale of a CAT1 program. Value: All software development attendees benefitted with increased skills. Additionally two executive courses were offered for management to understand implications of SAFe in budgeting, personnel, and strategy. Status: Complete
$75	Change Management Study	Purpose: Study conducted to identify primary communication and information targets of focus that would be most relevant for leadership to be attentive to during long-term, shifting organizational changes and ongoing planning phases. Value: Communication maintains a culture of trust and support during uncertain times of change for an organization. Results assisted leaders in providing supportive communication flow during and through periods of change. Status: Complete.

CATEGORY 3 – WORKFORCE DEVELOPMENT		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$50	Junior Force Council (JFC) re-bluing trips	PURPOSE: Re-bluing provided exposure for Junior Force members to military operations at an operational AF base, leverages research and/or collaboration opportunities with Warfighters and base operations, builds comradery, networking, and morale among Wing members, and increases odds of retention for Junior members. STATUS: Complete. VALUE: Exposure to operational AF needs and establishing contacts for research and consultation opportunities to increase retention among junior force members. Feedback from attendees show they are more likely to remain in the AF because of efforts like this to invest in their development and future.
$15	Institutional Animal Care and Use Committee (IACUC) Training in support of Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC) Accreditation	Purpose: Provided IACUC trainings, IACUC 301 in addition to IACUC 101. Value: Prepares employees for the annual AAALAC accreditation. Status: Complete
$13	Matrix Assisted Laser Desorption Ionization – Time of Flight/Imaging Mass Spectrometer (MALDI-TOF/IMS) training	Purpose: Government analytical chemists attended 5-day onsite technical training. Value: Expanded competencies and expedited skillset capabilities. Status: Complete
$500	ATR Center Summer Intern Program	Purpose: FLEX-4 funding supplemented the Autonomy Technology Research (ATR) Center's annual summer program which attracts a diverse group of students from schools across the nation working on research projects that address sensor and sensor exploitation challenges. In FY19 there were 82 students that participated. To accomplish this mission, students are matched with a mentor and topic of interest to them and the Air Force. Value: The experience students gain working at the Center opens doors for them by not only broadening their STEM education but, as a stepping stone to a hiring process giving this group an opportunity to become full-time researchers. The ATR Center is a significant asset to both the students and AFRL. This program also strengthens the AFRL workforce that participates as mentors. Status: All 500K has been executed.
$500	Centers of Excellence - Microelectronics	Purpose: The objective of the Center for Enabling Cyber Defense in Analog and Mixed Signal Domain (CYAN) Center of Excellence (COE) is to integrate domain experts from a variety of design, fabrication, and test backgrounds. Value: Address fundamental challenges related to securing design, fabrication, and operation of analog mixed signal technologies and analog emissions, while providing a pathway for future technology leaders to develop the skills and understanding of these fundamental challenges. Status: The effort kicked-off in June of 2019, is six months into a 72 month effort (8%), has spent roughly $500k to date of the $1.5M available and is on track with the planned $5M/5 year plan execution plan.

CATEGORY 3 – WORKFORCE DEVELOPMENT		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$15	Storytelling – thinking on your feet	Purpose: The theme of the project is introducing AFRL to improvisational communication skills. Basically, it is the new management strategy that industry is embarking on with their workforce. The key to improv is developing real listening skills and staying out of your head so that you can support the conversation. This workshop gives skills to effectively present ideas to an audience. Value: The workshop sparked so much enthusiasm, the project was approved for FY20 to conduct another session. The attendance was 15, the cost was $11,000, and the workshop is 100% complete.
$4,462	Wright Brother's Institute (WBI)	In FY19, over 16,000 collaborators from AFRL, small business, academia, industry, other federal agencies, and state, community and international organizations accessed and were supported by Wright Brothers Institute's resident experts, unique collaboration environments, cutting edge innovation tools, and extensive innovation networks. WBI approaches each project using a unique Runway Ready Innovation Framework of "UNLOCK the right problem", "CONNECT to new partners", and "SYNCHRONIZE transition pathways." High impact accomplishments using the Innovation Framework included: 600+ Collaborative Events. These included "Collider Events" organized by the WBI Small Business Hub to strengthen the participation of innovative small businesses and startups in AFRL's research programs. WBI supported a number of collocated, intensive team collaborations such as 3rd annual Summer of Innovation collaborative research program, the 2nd annual Summer of Topological Data Analysis (TDA) research program, the AFRL/RX MANTIS Team, and the ACT 3 AFRL Autonomy team. These efforts brought together AFRL in-house researchers, university students (BS, MS, PhD), and world-class visiting experts. Additional Junior Force Council (JFC) events, training events and showcases were executed, fostering collaboration from early research to commercialization. 22 Front End of Innovation Projects. These provided new insights and solutions to AFRL science, technology and workforce development challenges across topics. For example, the "Swarm and Search AI Challenge: Fire Hack" was the first international competition aimed at advancing AI algorithms for swarming UAVs. In partnership with DSTL and AFRL, WBI successfully led a months' long online challenge, followed by an in-person event at WBI's 444 facility. The next event is scheduled for 2020, with strong interest from additional NATO partners. 5 Tech / Commercialization Sprints to Accelerate Technology Development and Application. These combined the Google Design Sprint Methodology with WBI's Diverge/Converge problem-solving approach to create a high impact sprint process that is customized to Air Force needs. Each Sprint jump started solutions to an important research or operational problem in an intense one-week collaboration between AFRL researchers and outside innovators, or provided market insights that made AFRL technology more transition-ready. 22 Rapid Prototypes for Warfighter Needs. These were developed at the WBI Works "Monster Garage" and the WBI Maker Hub in collaboration with the AFRL Center for Rapid Innovation, University of Dayton Research Institute, Wright State Research Institute, and industry partners.

CATEGORY 3 – WORKFORCE DEVELOPMENT		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
		21 AFRL Scientists and Engineers Received Technology Transfer Support for Invention Disclosures, Cooperative Research and Development Agreements (CRADAs) and Licensing Agreements. Showcases that connected AFRL research with commercialization partners attracted 352 attendees. 30 scientists attended PROACTIVATE Training with provided the basics for protecting technology inside the lab, making it more appealing for multiple markets and accelerating transition. 35 AFRL Technologies Were Connected to Startups through the WBI-Dayton Entrepreneur's Center partnership. Efforts such as SBIR Technology Accelerator Program (TAP), which included 34 participants realized success with 93% awarded Phase II awards. 1,080 AFRL Employees Received Specialized Training via training events held at WBI. A broad spectrum of topics was covered such as hypersonics, advanced radar, machine learning and software development. PROACTIVATE Training was developed especially by WBI for AFRL employees to help protect critical, marketable technology.
$2,057	Doolittle Institute	BACKGROUND The Doolittle Institute, an AFRL Innovation Institute and DEFENSEWERX Hub, supports the Air Force Research Labs Munitions Directorate (AFRL/RW) by working to license and commercialize AFRL/RW technologies in the private sector, enable rapid technology delivery to the warfighter, identify and foster new R&D partnerships and develop AFRL's current and future workforce. ACCOMPLISHMENTS The Doolittle Institute recorded 595 meetings/events and over 15,000 collaborators from AFRL, industry, academia and other government organizations in FY2019. 8 TH!NK Thursday Events FY2019 TH!NK Thursday events included topics such as Lean & Agile Development; Preventing Burnout & Maximizing Productivity; Leveraging the Federal Laboratory Consortium and Intellectual Property (IP) 101; Unexpected Inspiration with Rodney Mullen, the Godfather of Modern Street Skating; AFSOC's Allison Group and the Defense Entrepreneurs Forum; STEM Outreach Innovation + FIRST® Season Kickoff; Design of Experiments; and the 3rd annual TH!NK SBIR Tech Showcase and Training Event. 2 Innovation Discovery Events Supporting the primary objective of Technology Transfer, the Innovation Discovery Event(IDE) is a forum for AFRL researchers to present their patent ideas to a supportive panel of regional business and technology experts, who provide feedback to enhance the quality and quantity of patent claims in the researchers disclosure. Beginning in the fall of 2015, the Doolittle Institute has consistently held 2 Innovation Discovery Events each year. IDEs have played a significant role in the growth of the AFRL/RW patent portfolio. 34 Facilitated Workshops Facilitated workshops enable the AFRL/RW to focus on the business of weapons research and development. From workshop design and setup to final reporting and follow up, AFRL/RW has learned the value of calling upon the Doolittle Institute to facilitate collaborative workshops on their behalf. Workshop topics and types facilitated in FY2019 include future weapons, requirements definition, engineering network analysis and redesign, organizational design, and capability assessment. 4 Sprint Events The Doolittle Institute facilitated 4 separate Sprint events, week-long collaborative events designed to result in a prototype. Sprint types/topics included one technology sprint on Hybrid Resilient Electronics, one business process sprint for the AFRL safety team to improve the customer experience, and two SBIR sprints. The first of

CATEGORY 3 – WORKFORCE DEVELOPMENT		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
		its kind, the SBIR sprint was developed by our Innovation & Collaboration Principal and applied to SBIR topic AF191-076: Advanced Power Source Technologies. The two participating small businesses said the sprint process saved them months of development time. 1 Crowdsourced Design Challenge The Doolittle Institute facilitated its first design challenge for AFRL/RW during FY2019. While we cannot share the details of the challenge topic in this summary, the challenge resulted in over 437 solvers from across the globe registering to view the challenge details. Of 57 vetted submissions, ten Phase 1 winners were selected to proceed to the next design phase, which is underway in FY2020. The final phase of the challenge will result in a single organization receiving an OTA contract award from AFRL to design and build 7 prototype systems for use across the DoD. 8 STEM Events Beyond the many FIRST® LEGO® League Jr Expos, FIRST® LEGO® League Tournaments, FIRST® TECH Challenge Tournaments and AFRL LEGACY® Craftsman Summer Camps facilitated and held offsite by the Doolittle Institute STEM Outreach Team, 8 STEM-focused events were held at the Doolittle Institute. These included a hands-on National Engineers Week event, LEGACY® Final Presentations and Open Houses, a STEM Teacher Workshop and FIRST® LEGO League Coach Training. 47 “Donuts with DI” Open-House Style Events Donuts with DI is a weekly open house style event where personnel from the Doolittle Institute, AFRL and the local community come together to explore and discuss opportunities to work together. The Doolittle Institute-AFRL/RW Technology Transfer team is always present to discuss technologies ideas for patenting and opportunities for external collaboration through Cooperative Research and Development Agreements (CRADAs), Educational Partnership Agreements (EPAs) and other mechanisms of technology transfer. 91 “Ad Hoc” meetings Ad Hoc meetings are unplanned meetings such as AFRL personnel utilizing the Doolittle Institute as an alternate duty location and serendipitous meetings between people who encounter one another at DI and need a private space to discuss business. Other Collaborative Events In addition to events designed and facilitated by the Doolittle Institute, we collaborate with the AFRL/Air Force Office of Scientific Research, Universities Space Research Association (USRA), Air Force Lifecycle Management Center (AFLCMC), the Eglin Small Business Office, local technical society chapters such as the American Institute of Aeronautics and Astronautics (AIAA) and American Society of Mechanical Engineers (ASME), and Onward to Opportunity to plan and execute meetings and events relevant to our AFRL customer. These events include technical program reviews, poster sessions for AFRL researchers and AFRL Scholar interns, industry days, technical lectures, and workforce development events. In many cases, we actively promote participation by lab personnel and the general public in these events and our team interacts with attendees in search of collaborative opportunities for AFRL/RW. Hosted Events & Meetings We also host a variety of meetings at the Doolittle Institute for Team Eglin, its non-AFRL tenants and regional Department of Defense organizations such as the 96th Test Wing, 53rd Test Wing, 54th Test Squadron, 96th Medical Group, 87th Electronic Warfare Squadron, Naval Surface Warfare Center, DoD High Performance Computing Modernization Program, and more. The Doolittle Institute facilities team provides scheduling, room setup and audio-visual support for these hosted events.
$1,291	New Mexico Institute	The AFRL-NM Institute leads external engagements with academia, industry and local/state government for AFRL’s Directed Energy and Space Vehicles Directorates and

CATEGORY 3 – WORKFORCE DEVELOPMENT		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
		has three areas of concentration: Economic Development, Current/Future Workforce Development and Strategic Communication. The AFRL-NM Institute works in partnership with the ORTA to perform tech transfer agreements, commercialization, marketing efforts and other activities to support AFRL's two New Mexico Directorates. The Institute has created new techniques to engage AFRL-NM scientists and engineers with industry and academic partners including; improved processes for coordinating agreements, targeted marketing campaigns, and conducting T3 overviews and trainings to teach researchers the different T3 mechanisms. The AFRL-NM Institute manages three AFRL Collaboration Centers including the AFRL Tech Engagement Office in the heart of Albuquerque's downtown innovation district called "Innovate ABQ". The three collaboration centers form the core of the AFRL-NM "Open Campus" concept bringing together a diverse array of capabilities that foster research & development, economic development, community development, and human development. The AFRL-NM Institute continues to engage in new technology transfer initiatives and relationships between the laboratory, state and local governments, academia, and industry, proving to further Air Force capabilities.
$1,743	Basic Research Innovation Collaboration Center (BRICC)	The Basic Research Innovation Collaboration Center (BRICC) supports the Air Force Office of Scientific Research (AFOSR) mission with an emphasis on partnership-building, science analytics, workforce development, and technology transfer and transition. The BRICC provides an innovative, collaborative environment and tailored-services built on data analytics capabilities that enhance basic research collaboration opportunities and create the foundation for successful technology transitions for the Air Force (AF). **Creating & maintaining a collaborative environment.** In FY19, the BRICC was fully operational in its new collaboration space located in the heart of the Ballston neighborhood in Arlington, VA. To further strengthen AFOSR's innovation and collaboration capacity, the BRICC focused on expanding the breadth of collaboration tools to better enable partner participation across government, academia, and industry. Professional Zoom licenses coupled with Polycom systems were procured to better facilitate teaming and collaboration opportunities with Air Force partners. This capability was particularly useful for facilitating outreach with AFOSR's Asian Office of Aerospace Research and Development (AOARD) located in Tokyo, Japan. The BRICC also utilized this reporting period to create & implement practices for tracking collaborators to allow for better traceability of AFOSR's 6.1 investments and research partners. Obtaining metrics tied to AFOSR's current partners via configurable registration systems will allow for the creation of more robust measures of effectiveness (MOE) corresponding to the achievement of desired results in FY20. Additionally, FY19 efforts focused on developing the external facing presence of the BRICC to better maintain relationships with existing partners and to attract new collaboration partners in academia and industry. The BRICC website received a complete overhaul with increased functionality to include a hot-desking capability to better facilitate collaboration with other AF partners, while the BRICC increased its social media outreach via Twitter to include live tweeting during engagement events with academic partners. FY19 also provided an opportunity to debut AFOSR Virtual Office Hours – a forum via Twitter that provides an opportunity for anyone in the basic research community to ask questions of AFOSR program officers, program managers, and staff about AFOSR programs & funding opportunities. **Enabling impactful basic research collaborations.** Being less than 5 miles away from the Nation's Capital, the BRICC is often visited by basic research partners from across the globe. In FY19, the BRICC hosted over 3,000 collaborators across government, academia,

CATEGORY 3 – WORKFORCE DEVELOPMENT		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
		and industry for a total of over 230 collaboration events ranging in scope from technical program reviews to innovative brainstorming sessions to training workshops. Government DoD partners included members of all three services, in addition to representation from federally funded research laboratories, federally funded science agencies (e.g. NIST, NSF, DARPA, IARPA, NASA, & NIH), and intelligence community partners such as CIA, ODNI, DTRA, FBI, & NGA. FY19 also saw participation from foreign government partners from Italy, Germany, Japan, and Portugal, as well as representation from international organizations to include NATO and the European Union. Academic partnerships in FY19 saw representation from over 200 research universities across the United States (42 out of 50 states) and included a diverse set of higher education institutions from historically black colleges and universities (HBCUs), Ivy League schools, those located in DEPSCoR states/territories, and both R1 and R2 research institutions. The BRICC also assisted with international academic engagements by hosting researchers from Australia, Germany, Italy, Canada, UK, France, Switzerland, The Czech Republic, Portugal, Saudi Arabia, Brazil, Poland, & Bulgaria. In partnership with AFOSR, the BRICC focused FY19 collaboration activities on lowering the barrier of engagement for basic research partners through targeted outreach and education of AFOSR funding opportunities. **Advancing an innovative workforce.** To enable the development of AFOSR's technical workforce, the BRICC focused on training opportunities to retain AFOSR's current workforce and identifying those opportunities to attract the next generation of scientists and engineers. In FY19, the BRICC worked with AFOSR to identify collaboration tools that would best enable program officers to better facilitate basic research connections. The BRICC team developed content for training modules on data visualization programs such as Tableau, scientific publication databases like Web of Science and Scopus, and helped to host training that will assist with impact tracking such as Records Management. Additionally, the BRICC worked with AFOSR's Executive Learning Officer to craft a Wellness Workshop Series designed to engage, motivate, and educate AFOSR's workforce and better equip them with the tools necessary to execute their workplace responsibilities. The BRICC also partnered with AFOSR to participate in the Air Force's Resilience Tactical Pause (RTP) and to virtually host the Diversity and Inclusion Speaker Series which featured Dr. Temple Grandin. To further extend AFOSR's outreach into the community, the BRICC created an FY19 STEM Directory to identify local opportunities for AFOSR officers to serve as volunteers, speakers & mentors. **Using analytics to facilitate research connections.** To best address the basic research and applied research challenges of AFOSR and AFRL, the BRICC focused FY19 efforts on providing S&T landscape analyses, conducting portfolio analytics, and characterizing potential research networks. Highlights from this reporting period's analytics products include a topic modeling report in Artificial Intelligence that identified research commonalities between US and Japan researchers. Data from the report was used in support of OSD's Future Directions Workshop which will be held in May 2020 and to broker additional diplomacy efforts between US and Japan. The BRICC also provided multiple analytics reports to AFRL's technical directorates (TD) for the purpose of quantifying and evaluating global research trends, as well as high impact publications, people, and institutions. FY19 topics included *Human-Agent Teaming*, *Algorithms for the Autonomous Identification and Targeting of Objects in Optical Images*, *Emergent Hierarchical Network Models*, *Combining Formal Verification and Machine Learning to Increase Safety, Performance, and Transparency of Autonomous Systems*, *Coupling*

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		Energetic and Reactive Materials, and *All-Dielectric Metamaterials and Metasurfaces*. FY20 analytic efforts will continue to provide AFRL scientists and AFOSR program officers with objective evaluation and assessment in support of program planning and portfolio management, while focusing on tracing knowledge transitions from AFOSR-supported basic research efforts to the Air Force Research Laboratory. **Enabling technology transition and transfer of basic research.** The BRICC team continued to make progress to enhance the technology transition potential of AFOSR-funded basic research through outreach efforts. Over the course of FY19, the BRICC hosted industry partners from over 85 companies across the country to include small businesses across technology areas of interest to the Air Force. Over 36% of companies that collaborated with AF partners at the BRICC had 100 or less employees, while nearly 85% of industry partners were local to D.C., Maryland, and Virginia. The BRICC further focused on extending AFOSR's network to local businesses by working with local economic development offices (e.g. Arlington Chamber of Commerce, Fairfax County Economic Development Authority, and Dulles Chamber of Commerce) to better track the impact of those companies that were initially seeded by AFOSR funding. To expand national outreach, the BRICC participated in events hosted by the Association of University Technology Managers (AUTM) to create touchpoints with university technology transfer offices, university grant offices, companies, venture capitalists, and foundations. To better promote a T2 savvy culture within AFOSR, the BRICC established a T2 workshop to identify best practices in technology transition and transfer across government, academia, and industry. The George Washington University kicked off the BRICC's FY19 T2 Best Practices Workshop series by identifying the T2 challenges of academic researchers, to include common myths and misconceptions regarding intellectual property. **Creating transformative opportunities and fostering an AF culture of innovation**. The BRICC continued efforts to support and manage the AFWERX-DC Innovation Hub which serves as a "first stop" for innovators external to the Air Force to connect with tools, resources, and other innovation products. In FY19, the AFWERX-DC Innovation Hub played a critical role in connecting Air Force organizations, other DoD services, and other DoD innovation organizations by providing analytics to support decision-making, networking, and the discovery of innovators capable of contributing to the USAF technological ecosystem. AFWERX DC hosted over 300 collaboration events which included a total of 1147 visitors from over 440 organizations across government and industry. Over the course of this reporting period, AFWERX helped to facilitate partnerships by hosting webinars for scalable external outreach, leading data-driven scouting efforts for targeted outreach in support of AF challenges, and utilizing analytic approaches to monitoring AFWERX impact. One particularly noteworthy highlight included technology and expert scouting in support of the AFWERX Microelectronics Prototyping and Design Challenge. While work from the AFWERX DC Analytics team constituted only 1.5% of the total traffic to www.AFWERXCHALLENGE.com, the companies identified via the AFWERX DC Analytics team made up 26% of challenge submissions, 29% of selected exhibitors, and 33% of companies ultimately awarded prototyping contacts. This overwhelmingly demonstrated the impact of targeted scouting and engagement of SMEs in complimenting broad marketing campaigns for Air Force challenge participation.
$1,271	Griffiss Institute	The Griffiss Institute (GI) is an independent 501c (3) supporting the Information Directorate (AFRL/RI) in their overall Technology Transfer mission. Over the years, the

CATEGORY 3 – WORKFORCE DEVELOPMENT		
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		GI Memorandum of Understanding (MOU) has gravitated to a more financially controllable contract via Collaborative Project Orders (CPOs) which are made possible by the injection of 219 seed funds. Although the GI primarily focuses on Technology Transfer, CPO1, by creating innovative collaborative opportunities in technology partnerships while focusing on workforce development, the CPO metrics below are made possible by the symbiotic relationships developed through successful efforts in T2. The GI has grown to assume much of the T2 responsibilities within AFRL/RI. The GI has been instrumental in facilitating the development of Cooperative Research and Development Agreements (AFRL/RI leads all AF), Educational Partnership Agreements (AFRL/RI leads all AF), and assisting in the development of licensees (AFRL/RI leads all of AF) largely through the Commercialization Academy. The GI successfully obtained a $2M three-year grant from New York State to enhance the financial awards provided during Demo Days, the culmination of the Commercialization Academy cohorts. The Commercialization Academy is a GI entrepreneurial education program focused on Lab IP and S&E involvement into the Startup community, making the program a unique means of motivating the S&Es while making the Lab a more interesting workplace for potential new employees. In FY19 the GI provided $664K in prize money for the $300K investment by AFRL/RI. The maturation of the Commercialization Academy has enabled a more focused startup campaign for companies that can benefit the Information Technology thrust of the Lab, in addition to the benefit of increased licenses based upon Lab IP. The nationally recognized GI led STEM initiatives such as Drone Camps, Engineering Camps, Arduino Camp, Cyber Camp, Robotics and newly introduced this year a Quantum Camp is setting the pace within the community as well as across the Air Force enabling the community to create and foster a future interest in STEM related occupations including working at the Lab. The AF has been so impressed by the managerial skills of the GI that in FY20, AF STEM will be moved to a separate GI PIA with a ceiling of $100M. The GI also assists the lab in recruiting new talent under their summer intern and co-op programs every year. In total, the Intern Program is composed of 6 separate projects to include a focus on minority institutions. In FY19, the program expanded to begin collaboration on internships at other AFRL sites besides AFRL/RI, via additional customer funding. The GI, through a new PIA recently signed at the end of FY19, has taken the next steps in securing a 38,000 sq. ft. facility in FY20 to provide an Open Innovation Campus which will facilitate the goal of unrestricted basic research in Quantum, AI, and Machine Learning, to name a few of the dedicated strategic research areas. A huge 219 leveraging Challenge was successfully executed by the GI this Summer enabling a unique cyber workforce development effort, culminating in a contest conducted in Las Vegas at DEFCON 19, the largest assembly of computer hackers worldwide. Dr. Roper, SAF/ATL, endorsed and praised the revolutionary workforce development effort and challenged the Lab to conduct another effort in FY20. **Metrics:** Of note, some metrics have been changed to **N/A** based upon PM direction. The main enabling of invention disclosures has been through Innovation Discovery Events. Unfortunately, the Lab was not able to support this effort last year. Provisional Patents are now the sole responsibility of the AFRL/RI Legal. CTAs have become the sole responsibility of the Lab. No nominees were provided to the GI for drafting of awards. HS Teacher internships were discontinued.

CATEGORY 3 – WORKFORCE DEVELOPMENT		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**

Metric	Annual Goals	FY19
CPO1 – TECHNOLOGY TRANSFER		
Technical SMEs	**5**	14
Invention Disclosures Facilitated	**8**	-
Provisional Patents	**N/A**	N/A
Potential Licensees	**6**	16
CRADAs	**10**	32
CTAs	**N/A**	N/A
EPAs	**10**	33
Training Sessions	**10**	29
Potential customers brought to AFRL as collaborators	**24**	294
Potential small business customers brought to AFRL as collaborators	**12**	156
T2 Outreach - Related Technical conferences, workshops, and seminars	**4**	8
FLC Award Nominations	**4**	-
CPO 2 – LOCAL STEM		
STEM Summer Camps	**6**	10
Students Participated within STEM Camps	**100**	101
Student STEM internships	**2**	4
HS teacher summer STEM internships	**2**	-
Students in AFRL Challenge Competition	**16**	20
Schools Participated in AFRL Challenge Competition	**8**	10
Schools we service through STEM Outreach	**20**	49
CPO4 – AF STEM		
Number of AF STEM grant checks processed	**N/A**	114
Dollar Value of grant checks issued	**N/A**	$2,858,154
Number of AF STEM materials requests processed	**N/A**	64
Dollar Value of STEM materials purchased	**N/A**	$197,780
Number of repeat Grants from last year	**N/A**	41
Number of repeat Material Requests from last year	**N/A**	14
Number of Bases Funded	**N/A**	30 AFB plus AFOSR, AF STEM Office, AF Diversity Office, AF Academy, & FIRST Robotics
Number of US States represented	**N/A**	22 + Italy & Japan
CPO4-LEGACY		
OSD Funding	**N/A**	$1.2M

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<tr><th colspan="3">CATEGORY 3 – WORKFORCE DEVELOPMENT</th></tr>
<tr><th>AMT ($K)</th><th>TITLE OF EFFORT</th><th>SHORT DESCRIPTION OF EFFORT</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><th>Metric</th><th>Annual Goals</th><th>FY19</th></tr>
<tr><td>STEM Material Purchased</td><td>N/A</td><td>$123K</td></tr>
<tr><td>Craftsman Students (Grades 6-10)</td><td>N/A</td><td>355</td></tr>
<tr><td>Junior Apprentice (Grades 10-12)</td><td>N/A</td><td>42</td></tr>
<tr><td>Apprentice (College)</td><td>N/A</td><td>45</td></tr>
<tr><td>Craftsman Supervisors</td><td>N/A</td><td>15</td></tr>
<tr><td>CPO5 – INTERN PROGRAM</td><td></td><td></td></tr>
<tr><td>Student Interns applied</td><td>750</td><td>644</td></tr>
<tr><td>Student Interns selected</td><td>70</td><td>128</td></tr>
<tr><td>US States Represented</td><td>N/A</td><td>20</td></tr>
<tr><td>Student Intern extensions</td><td>N/A</td><td>18</td></tr>
<tr><td>Interns with AFRL for more than 1 year</td><td>N/A</td><td>41</td></tr>
<tr><td>Interns hired by AFRL within last years</td><td>N/A</td><td>6</td></tr>
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</td></tr>
<tr><td>$659</td><td>Information Institute (II)</td><td>The Griffiss Institute PIA-administered Information Institute® is a partnership of over 80 universities allied with the Air Force Research Laboratory's Information Directorate (AFRL/RI) for the purpose of promoting, fostering, and enhancing collaborative research between academic institutions and the Information Directorate. The II partners concentrate their research activities on jointly developed topics in the areas of Command, Control, Communications, Computers, Intelligence (C4I) and Cyber technologies. Research teams are assembled from II membership through a variety of means, but primarily through GI facilitated Educational Partnership Agreements (EPAs). The II provides extended onsite research programs by executing the visiting faculty research program, the summer faculty fellowship program, the graduate student internship program, National Research Council Fellows program, and post-doctoral programs. The II hosted 53 researchers from these programs, representing 30 academic institutions in 2019.
<table>
<tr><th>CPO3 – INFORMATION INSTITUTE</th><th>Current Goals</th><th>FY19</th></tr>
<tr><td>Number of VFRP faculty</td><td>N/A</td><td>24</td></tr>
<tr><td>Number of VFRP faculty sponsored students</td><td>N/A</td><td>7</td></tr>
<tr><td>Number of SFFP faculty (AFOSR)</td><td>N/A</td><td>18</td></tr>
<tr><td>Number of SFFP faculty sponsored students (AFOSR)</td><td>N/A</td><td>4</td></tr>
<tr><td>Number of different participating universities</td><td>N/A</td><td>30</td></tr>
<tr><td>Number of extension grants</td><td>N/A</td><td>30</td></tr>
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</td></tr>
<tr><td>$16,322</td><td>SUBTOTAL CATEGORY 3</td><td></td></tr>
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CATEGORY 4 – FACILITIES REVITALIZATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$4,700	Kinetic Kill Hardware-In-the-Loop Simulator (KHILS) 2.0	The purpose of this project is to provide future warfighting solutions with interoperable & distributed systems. This MS&A solution is a unique capability that provides continuously reconfigurable space to support an array of leading edge munition GN&C technology programs. KHILS must expand & upgrade to a multi-level security facility to meet customer & warfighter needs to modernize a 1970s lab to provide complex, adaptive HWIL & SWIL of concept weapons in a system-of-systems synergistic environment. This project provides room to support simultaneous customers with multiple classification needs & critical research thrusts, which would otherwise be limited to testing one type of seeker at a time or one all-up-round (AUR) which takes up 80% of the lab. This technology is critical to efforts with alternate navigation, autonomy, collaborative strike, hypersonics, special operations, space, etc.
$6,000	AFRL Wright Site Corporate Secure Facility	The purpose of this project is to establish a corporate AFRL secure facility that meets the current and future demands for Wright Site with efficiencies of scale in execution by placing multiple classified activities under one roof. Completion consolidates security and IT/IA manpower, secure network infrastructure, alarms (incl. 24/7 manning during alarm outages), & facility accreditation. Providing this mechanism for standardized security procedures improves HQ oversight and insight into centrally located activities. It also enables AFRL Directorates to perform highly classified science and technology of great relevance to current & future warfighter While facilitating collaborative work across the spectrum of classification levels.
$6,000	Wargaming & Advanced Research Simulation (WARS) Laboratory	The purpose of this project is to provide a much needed R&D facility that allows researchers to operate at multiple levels of security, is immersive in all domains virtual environment, and links AFRL Technical Directorates/research partners. This reconfigurable battlespace connects with supercomputing facilities for higher fidelity analyses, and bolsters capability for distributed events & analysis with DoD Partners across multiple gamechanging technology areas. The WARS Lab strengthens core MS&A capabilities and integrates technologies with other advanced concepts to provide state-of-the-art warfighter solutions. It increases warfighter exposure by enabling capstone events and analytical studies. This new facility expands mission support by eliminating security limitations and removing physical constraints. This facility provides secure VTC, data transfer, and computing at multiple security levels, providing AFRL and external stakeholders with higher fidelity analyses at security levels not previously possible.

CATEGORY 4 – FACILITIES REVITALIZATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$5,800	Additive Manufacturing (AM) Process and Imaging Laboratory	The purpose of this project is to provide an environmentally controlled, agile laboratory space suited for AM research and quality assurance. It fully satisfies the wide range of AF form, fit and function requirements for process control and quality assurance for AF unique applications. Near term capabilities support industry standards development for microstructure and defect control. Long term goals will result in process tailoring and 3D imaging quality assurance to enable high performing and reliable components. The AM Lab will enable timely, cost effective, innovative solutions for the warfighter by creating capabilities to tailor and control AM process routes to meet wide array of Air Force requirements. This capability will reduce defects in AM parts and assure quality with dedicated 3D X-Ray Computed Tomography. Additionally, it will pave a path for rapid certification of AM parts for Air Force applications, and support broad AF interests to exploit advantages of AM to design and transition critical, complex components. Completion of the lab will offer a long needed, flexible open space with controlled HVAC (meet equipment temperature / humidity tolerances), consolidated "plug and play" lab utility (specialized , power, gas, etc.) to re-arrange lab modules and maximize long term research agility, and offer fire safety/suppression; risk reduction for electrostatic discharge; powder handling capabilities. Additive Manufacturing is a game-changing, agile technology that the AF seeks to pervasively exploit to provide AFRL the ability to tailor AM processes and non-destructively inspect parts to rapidly produce reliable, high performing components that can be certified to become new capabilities for the warfighter.
$4,965	Develop Advanced Non-Energetics Chemistry Laboratory	The purpose of this project is to renovate 10,048 SF of unoccupied space to create new advanced inert ingredient discovery laboratory. The completed process will install "automation-ready" exhaust hoods, HVAC, electrical and data-connected laboratory work areas, fire detection/notification and suppression, eyewash stations and showers, electrical circuits, LED lighting/facilitate machine vision, suspended ceiling and insulated walls for temperature controlled lab space, and modify facility access for ADA compliance. These renovations enable capabilities for advanced data collection equipment (X-ray diffraction, FT-IR microscopy, microdroplet goniometry) installation, networked instrumentation, and AI-based materials selection and performance prediction algorithms. These extended capabilities will result in research that will expand temperature range and cycling capabilities of propellants, will enable use on 5th / 6th generation fighters, improve mass efficiency of tactical and strategic weapons to enable greater range, maneuverability, and payload capabilities, and improve system lifetime of in-space propulsion systems.

CATEGORY 4 – FACILITIES REVITALIZATION		
AMT ($K)	**TITLE OF EFFORT**	**SHORT DESCRIPTION OF EFFORT**
$3,900	Skywave Laboratory	The purpose of the project is to create lab facilities critical for developing the technology needed to sense, measure and correct for better object position registration. This investment leverages existing infrastructure and creates a national facility for Skywave technology development. The facility provides a remote, RF quiet, specialized 3,500 sq. ft. laboratory and test range that is climate controlled, stable, and isolated to protect sensitive scientific instrumentation. The RF shielded rooms allow for HF radar testbed and diagnostics. The facility offers specially prepared multi-antenna surface area with protected cable runs and control lines, 24/7 living quarter support for very long term testing campaigns, on-site electronic support for analysis of extremely large data sets, and external ground and internal high bay staging areas to support operational exercises and field campaigns. This project creates a unique AF/DoD facility to advance critical understanding of Skywave technologies for situational awareness, mitigation, counter technologies, and capability enhancement. It provides capability to develop high-payoff, high-demand technologies with a laboratory that is dedicated to long-term studies of Skywave propagation and ability to support the user's future program of record investments of over $20M. This project also benefits multiple Technical Directorates and stakeholders (ACC, AFSPC, AFGSC, PACOM, STRATCOM, NORTHCOM, SOUTHCOM, and DTRA), and supports multiple mission areas.
$1,000	RC22 High Speed Test Facility; Classification Upgrades	The purpose of this project is to upgrade the classification level of large scale in-house continuous flow hypersonic scramjet facility. Physical security improvements include replacing five Entry/Exit door packages, electronic controlled access, security system for monitoring facility, HVAC system barriers, floor / roof penetration protection, exhaust system access denial, and video/audio surveillance. Driven by an anticipated increase in hypersonic classified work requirements, this project provides the capability to handle increased work by converting existing space to classified personnel space, upgrading operational classification to existing operating facilities, and provides a unique national capability for long-duration secret tests that enable continued growth in scramjet propulsion required for next generation scramjet propulsion system development. This upgrade allows RC22 continued relevance in program and applied research. The addition of an AFRL secret scramjet testing capability enables engine performance and operability evaluation, component verification, and risk reduction activities in a relevant independent environment. Current DoD programs require additional laboratory resources to ensure program success. The addition of this capability gives DoD, NASA, and our industry partners additional testing options and capabilities.
$4,827	Additional Technical (TD) Directorate revitalization projects	AFRL allows each TD the ability to contribute TD-specific projects which fall within the Cat 4 description. AFRL captures these contributions within the FLEX-4 PEC, to amplify the overall Lab percentage. Projects range from design work, to space optimization upgrades, HVAC, egress compliance, and non-technical space requirement additions. Other contributions provide technical lab space such as the Closed-Loop Electronic Warfare (EW) Analysis Radar Surface-to-Air Threat Missile (CLEAR-SAM) Systems. Offering the ability to capture these non-competitive projects provides flexibility in managing the planned and unplanned expectations to meet mission requirements.
$37,192	**SUB-TOTAL CATEGORY 4**	

APPENDIX

AIR FORCE IMPLEMENTATION OF FLEX-4 AUTHORITIES

Please address any challenges with implementation and how you plan to mitigate the issue.

Today, a Category 4 project approval package could easily take 6 months or more. If there was a way to allow our RDT&E projects to have special dispensation for project approval authority down to the installation (with no congressional notification requirement), it would greatly streamline the process. Reducing the need (i.e. increase the threshold) for approval and congressional notification for our $6M Lab Unspecified Minor Construction (10 U.S. Code 2805) projects would save months' worth of precious resources.

The Air Force established and continues to refine the use of a separate PEC for FLEX-4 funds, 0602212F, where the funds would be internally reprogrammed in the year of execution after receipt of the appropriation. This provides the AFRL Commander flexibility to align funds for this authority as needed.

What is the percentage of your FLEX-4 funds as a portion of your RDT&E funds (at least 2% but not more than 4%)? Are you maximizing the funds legally permissible to be used on the program? If not, why?

In FY19, AFRL captured 3.25% of the RDT&E funds (Total PB, not including Congressional Adds) to be identified in support of FLEX-4 projects.

Appendix D: Acronyms List

APPENDIX D: ACRONYMS LIST

The following is a list of terms with their acronyms.

A

AAV	Assault Amphibious Vehicle
AETDA	Autonomous Environmental Tactical Decision Aid
AFB	Air Force Base
AFRL	Air Force Research Laboratory
AO	Action Officer
AM	Additive Manufacturing
ANTX	Advanced Naval Technology Exercise
ARL	Army Research Laboratory
AvMC	Aviation and Missile Center

C

CBC	Chemical Biological Center
CCDC	Combat Capabilities Development Command

D

DoD	Department of Defense

E

ERDC	Engineer Research and Development Center

F

FLEX-4	Funding Laboratory Enhancements Across (X)
FY	Fiscal Year

L

LCASD	Low Cost Attritable Strike Demonstrator

M

MCP	Multi-Core Processor
MILCON	Military Construction
MR U-AAV	Mission Ready Unmanned Assault Amphibious Vehicle

N

NAWC	Naval Air Warfare Center
NAWCAD	Naval Air Warfare Center Aircraft Division
NDAA	National Defense Authorization Act
NDS	National Defense Strategy
NISE	Naval Innovative Science and Engineering
NIWC	Naval Information Warfare Center
NSWC	Naval Surface Warfare Center

O

OCO	Overseas Contingency Operations
OMA	Operations and Maintenance Army
OPA	Other Procurement Army

P

PCMs	Phase Change Materials
PFAS	Perfluorinated Alkylated Substances

R

R&D	Research and Development
RDT&E	Research, Development, Test, and Evaluation
RI	Information Directorate (AFRL)
RW	Munitions Directorate (AFRL)

S

S&Es	Scientists and Engineers
S&T	Science and Technology

U

U.S.C.	United States Code

W

WBI	Wright Brothers Institute