2018
Annual Assessment of Operational Energy Capability Improvement Fund (OECIF) Projects

Office of the Under Secretary of Defense Research and Engineering


ISAF

EXECUTIVE SUMMARY

The Department of Defense (DOD) utilizes the Operational Energy Capability Improvement Fund (OECIF) to invest in science and technology (S&T) efforts that promote long-term technical advancements and improvements to military capabilities. Each project is aligned to the Department's National Defense Strategy to deliver warfighting lethality, strategic alignment, business reform and to support the 2016 DoD Operational Energy Strategy as well as supporting efforts from the Services or Joint projects. The program advocates for the standardization and interoperability of energy supply, transmission, and demand to rapidly increase technology development momentum, to create opportunity for department-wide improvements in areas like resilience and to generate potential cost savings across acquisition, operations, and logistics.

The 2010 Quadrennial Defense Review called for investments in Operational Energy (OE) technology. Since Congress established OECIF in 2012, over 65 projects across 9 focused themes have been funded. Annually the Department identifies a specific theme that reflects current priorities and focuses the evaluation and management of S&T investments. Following a review of the most promising proposals submitted by the Services and Combatant Commands, a board of OE experts selects the projects which will be funded for up to four years. From its beginning, the OECIF program has been located within the Office of the Deputy Assistant Secretary of Defense for Operational Energy (ODASD (E)). The projects in this report closed out prior to transitioning OECIF to the Office of the Under Secretary of Defense for Research and Engineering (OUSD R&E) effective 1 October 2018.

This assessment evaluates the eighteen projects that began in FY 2014, FY 2015 and FY 2016 and concluded by June 2018. Specifically, these projects were measured against their stated technical goals, the resulting activities, and transitions following the end of OECIF funding. Fourteen of the eighteen projects were successful, both from a technical and transition perspective, and their transition partners have taken responsibility for future funding of the efforts. Highlights of these projects include the following:

- Synthetic Theater Operations Research Model –Energy: The project was developed by the USMC as a campaign model that produces actionable insights to accurately quantify the cumulative effects of energy distribution and consumption.

- Comprehensive Operational Energy Toolkit: This Air Force-led project developed tools to examine the mission level effects of attacks on energy supplies at air bases and en-route to air bases.

- Persistant UAV: A Marine Corps project which demostrated small UAVs can use solar and soaring energy harvesting to stay aloft.

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INTRODUCTION

The Operational Energy Capability Improvement Fund (OECIF) is categorized as a Research, Development, Test and Evaluation (RDT&E) Program Element, Budget Activity 3 (Advanced Technology Development) appropriation ("6.3").[1] The fund supports projects with the aim of maturing operational energy technologies from Technology Readiness Level (TRL) 3, characterized by analytical and laboratory studies, to TRL 6, characterized by a model or prototype system tested in a relevant environment.

The OECIF program Element 0604055D82 was established in Fiscal Year (FY) 2012 and is overseen by the Office of the Under Secretary of Defense for Research and Engineering (OUSD)R&E effective 1 October 2018. All projects in this assessment closed out while OECIF was still located within the Office of the Assistant Secretary of Defense for Energy (ODASD (E)). The purpose of the fund is to act as "seed money" to start or consolidate promising operational energy initiatives that improve the Department's operational effectiveness. Once OECIF funding is exhausted, project funding switches to the identified transition partner, which is generally the Services, but also can be the Combatant Commands or the Office of the Secretary of Defense (OSD).

Table 1. OECIF Programs, FY 2012-FY 2019

Start Year	Theme
FY 2012	Reducing energy load at expeditionary outposts
FY 2013	Using consortia to attack key operational energy problems
FY 2014	Analytical methods and tools
FY 2015	Improving fuel economy for the current tactical ground fleet
FY 2016	Increasing the operational energy performance of unmanned systems
FY 2017	Thermal and power management technologies for high pulse power systems Wireless transmission of energy in the far-field Wireless transmission
FY 2018	Studies to identify operational energy science & technology gaps in the near-, mid-, and far-term
FY 2019	Enhanced Energy Storage to Improve Lethality and Warfighting Performance Nuclear Fuel & Reactor Study

1. Advanced Technology Development demonstrates the general military utility or cost reduction potential of technology when applied to different types of military equipment or techniques (DoD 7000.14-R, Financial Management Regulation).

OECIF projects are selected annually from Service and Combatant Command proposals that align with the Department's National Defense Strategy[2] and Operational Energy Strategy[3] and support that fiscal year's OECIF theme. Since OECIF's inception, specific themes are identified annually to reflect Department priorities and focus on science and technology (S&T) investments. OECIF themes are summarized in Table 1, and Appendix A includes more detail on the projects within each theme.

In 2016, the ODASD (E) initiated a review of completed OECIF projects. The inaugural 2017 assessment report was the result of this endeavor. The initial review included an evaluation of all the completed projects through FY 2015. The 2018 assessment report continues the analysis and summarizes the results of FY14, FY15, and FY16 projects that closed out by June 2018.

FUNDING

Historically ~$40 million is appropriated each year for new and on-going projects. The amount of OECIF dollars available has fluctuated year-to-year depending on Congressional plus-ups. ODASD (E) usually receives four times more proposals than can be funded, but once selected each OECIF project receives up to four years of funding. The projects are managed, executed, and transitioned by the Services or Combatant Commands under ODASD (E) oversight. In some cases, extensions to the four-year funding have been approved to account for unexpected technical challenges or contracting delays; however, these extensions typically only provide additional time, not resources, to complete project objectives.

Using this four-year funding model, new OECIF projects are started each fiscal year and previous-year OECIF projects are continued, resulting in a multi-year funding model as depicted in Figure 1.

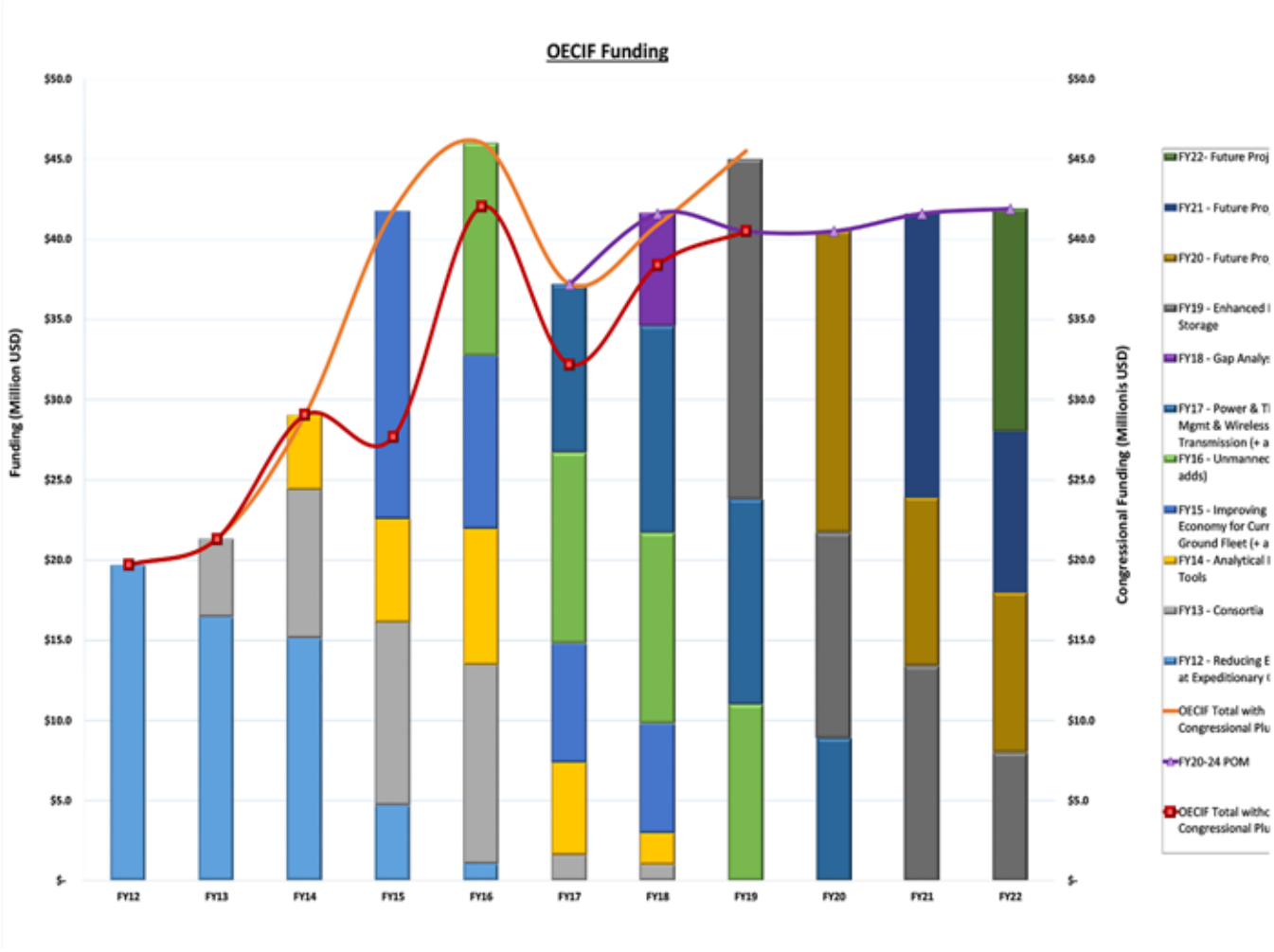
BENEFITS

OECIF is designed to fund innovation which improves the Department's operational effectiveness via targeted Operational Energy S&T today and in the future. The annual themes of the OECIF program align with the Department's National Defense Strategy and Operational Energy Strategy and reflect Department priorities related to specific operational needs and risks. In some cases, projects are selected to fill an investment gap; in other cases, projects are selected to complement Service investments. The goal is to improve operational energy performance in two key mission areas: first, to develop operational energy technologies and practices that will improve DoD military capabilities and possibly reduce costs; second, to

2 National Defense Strategy Department of Defense. "Summary of the 2018 National Defense Strategy of the United States of America". Found at: https://www.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

3 Department of Defense "2016 Operational Energy Strategy". Found at http://www.dtic.mil/dtic/tr/fulltext/u2/a627624.pdf

Figure 1. Overview of OECIF Program Funding from FY12 through FY22



establish within and among the military Services institutional momentum to continue those innovations.

For example, in FY 2012, the Department was focused on the risks in transporting fuel around the battlefield to support contingency bases. Little research or resources were being dedicated to the temperature control of shelters, which was a driving factor in the energy demand at these contingency bases. As a result, OECIF projects for that year focused on reducing energy loads at expeditionary outposts, with an emphasis on energy efficient shelters and cooling.

FY 2017 projects supported two main topics: Thermal and Power Management Technologies for High Pulse Power Systems; and Wireless Transmission of Energy in the Far-Field. These investments focused on the energy and power sub-systems that enable directed energy weapons as well as future warfighting concepts with unlimited power and communications. The efforts are demonstrating early success and pushing the technology forward across wireless transmission in the far-field, laser power beaming, space solar, and photovoltaic testing.

In FY 2018, OECIF selected projects that had analytical underpinned studies to identify operational energy gaps and S&T investment roadmaps for a variety of mission areas to include: distributed basing in the INDOPACOM theater; unmanned system refueling/ recharging; Naval bulk fuel storage and distribution; directed energy and electronic warfare systems; dismounted warfighters; and geospatial relevant vehicle range estimations. The outcome of these studies will be a community vetted, operational energy investment roadmap which is the pathway to inform efforts and feed a new, updated overarching operational energy S&T strategy for the Department. In addition, the results will inform the topic selection for FY 2020 OECIF proposals and beyond.

While the FY 2019 decision to select specific projects is pending, the OECIF tranche of proposals directly supports Enhanced Energy Storage that Improves Lethality and Warfighting Performance and is consistent with the National Defense Strategy. The focus of each proposed effort is to develop prototypes and demonstrate products designed to increase standardization, resiliency, advanced performance of energy storage solutions with consideration for business reform opportunities, and safety surrounding all aspects of energy logistics.

Ultimately, the true value of an OECIF project is dependent on the successful transition to the warfighter after OECIF funding ends. Whether these benefits are realized through materiel (e.g., more efficient fielded equipment, enhanced sub-systems) or non-materiel improvements (e.g., improved modeling and simulation (M&S) capabilities; development of standards; more effective tactics, techniques, procedures (TTPs); etc.), OECIF projects aim to improve the operational effectiveness of the Joint Force. One to two-page summaries of each OECIF project are included in Appendix B.

ASSESSMENT

This assessment consists of two evaluations: first, a technical assessment that evaluates the outcomes achieved by the project; and second, a transition assessment that evaluates the activities that followed the conclusion of OECIF funding.

The 2017 report titled, An Assessment of Operational Energy Capability Improvement Fund (OECIF) Programs[4], reviewed and documented projects that closed out by June 2017. This included FY 2013 studies initiated to take advantage of consortia solving operational energy problems, FY 2014 projects focused on analytical methods and tools, and FY 2015 projects which centered on improving fuel economy for the current tactical ground fleet. A one-time $14.1M Congressional plus-up for the FY 2015 OECIF projects started a number of shorter-term efforts which complemented existing OECIF projects. The current 2018 Assessment of Operational Energy Capability Improvement Fund (OECIF) Programs assesses the remaining FY 2014, FY 2015, and FY 2016 projects which concluded in June 2018. Of these 18 projects, 14 successfully achieved the desired technical goals and have transition partners that will continue to fund the efforts. The remaining four projects were terminated or deemed unsuccessful at the go / no-go evaluation point. OECIF embraces a fail early, fail fast approach in the life cycle of a project to determine whether the effort is maturing at the right speed to warrant further investment.

4 An Assessment of Operational Energy Capability Improvement Fund (OECIF) Programs. Found at http://www.dtic.mil/dtic/tr/fulltext/u2/1047768.pdf .

TECHNICAL ASSESSMENT

The first part of the OECIF assessment reviews the technical outcomes achieved by each project. To accomplish this, ODASD(E) evaluates the original milestones, objectives, and goals proposed by the Service organization or Combatant Command; assesses results from recurring and close-out progress reviews; reviews quarterly reports; and discusses project outcomes with the project managers.

Like research and development overall, operational energy technology development inherently is a risky endeavor that does not always yield the desired result. While every OECIF project is not expected to succeed, the Department continuously reviews and improves the effectiveness of its investments, and makes adjustments as required to reflect shifting Department priorities and changing operational environments to enhance the likelihood of success. Regular technical meetings allow changes to the project as necessary ensuring continued success or to identify failing projects as early as possible and redistribute the funds.

FY 2014 Technical Assessment

In FY 2014, the OECIF projects focus on developing the analytical methods and tools necessary to support a thorough analysis of operational energy issues throughout DoD's planning and management processes. This includes war gaming, force planning, requirements development, acquisition planning, operational planning and S&T planning. More specifically, these tools support higher level development of analytic methods and analysis used to inform decision makers and commanders.

Table 2 provides a brief description of the technical achievements of the completed projects, and Appendix C contains a more detailed technical assessment.

Table 2 Technical Achievements of FY 2014 Projects

FY 2014 Project Name	Technical Achievement
J-DEPLOI	Joint Deployment Energy Planning and Logistics Optimization Initiative delivered an analytic tool and associated policy / process improvements to facilitate energy analysis earlier in the Joint Operation Planning Process. Planners can now address logistic feasibility for energy to move quantities of people, equipment, fuel and material efficiently. This allows the operational planner to visualize, quantify, and collaboratively evaluate fuel logistics vulnerability of various Course of Actions (COA) which then informs the Commander's selection.
STORM-E	Synthetic Theater Operations Research Model – Energy was developed by the USMC as a campaign model that produces actionable insights to accurately quantify the cumulative effects of energy power distribution and consumption and update the model. The project developed scenario databases to inform future energy analysis at the unit level operating under various conditions and missions.
OEATF	Operational Energy Analysis Task Force established a foundational Operational Energy analytic capability leading to architectures that are capable of informing decisions related to energy impacts on the organization, materiel, and operations. The project identified shortcomings in data development, scenarios, and methods, models, and tools that can now be mitigated.

Table 2 Technical Achievements of FY 2014 Projects (continued)

FY 2014 Project Name	Technical Achievement
MEAM	Mission Engineering Analytical Method was designed to imbed energy analysis in mission planning and execution to improve decision making and to enable contingency planning when energy is limited, constrained or unavailable. The goal was to use kill chain analysis methods to identify energy gaps to drive RDT&E, S&T, budgetary decisions and future force composition to quantify energy demand. The project was UNSUCCESSFUL and the funds transitioned to another project – Joint Operational Energy Command and Control (JOEC2).
COE Toolkit	Comprehensive Operational Energy Toolkit developed tools to examine mission level effects of attacks on energy supplies at air bases or enroute to air bases. The process developed a toolkit of analytic models to ensure analysts have the data to provide decision quality information to Senior Leaders. This suite of tools is available for all Services. The unclassified computer code is available to Allies and serves as a common basis for discussion. The tools are written in state-of-the art programming techniques and available across DoD.
CAMEL	Capability Assessment and Modeling for Energy Logistics developed a robust methodology to evaluate impacts of advanced technologies and logistic variables on the campaign war fight and to assess the impact on operational energy consumption. It introduced energy delivery, resiliency, and security into operational planning while characterizing potential threats to future operations.

FY 2015 Technical Assessment

For FY 2015, the OECIF projects focused on improving fuel economy for the tactical ground fleet. Additionally, OECIF applied one-year Congressional plus-up funding to short-term projects which complemented existing OECIF projects or explored new OE relevant technologies.

Table 3 Technical Achievements of FY 2015 Projects

FY 2015 Project Name	Technical Achievement
AVPTA – TVEK	Tactical Vehicle Electrification Kit developed and demonstrated affordable truck auxiliary viability kits on tactical wheeled vehicle platforms which significantly improved vehicle operational energy, range, and future electrical warfighting system growth potential. With the analysis of alternatives completed, baseline M&S control models were developed, and an anti-idle system tactical vehicle integration was tested.
AVPTA-TBC	Thermal Barrier Coating developed a coating for military high power density engines. The engine cylinder would hypothetically transfer heat to achieve increased accuracy over a range of conditions relevant to both the military and commercial markets. Baseline testing compared an uncoated piston and coated piston with no operational energy advantage. The project was UNSUCCESSFUL and the funds transitioned to another project – Electrification of Terminal High Altitude Area Defense (THAAD).
AVPTA-Autonomy	Autonomy developed smart adaptive cruise control to optimize fuel economy during military missions, as well as for commercial driving applications. Phase I test reports were completed with single vehicle simulation and Phase II M&S of vehicle convoys and instrumentation was accomplished. The project was UNSUCCESSFUL with respect to operational energy and the funds transitioned to another project – Electrification of Terminal High Altitude Area Defense (THAAD).

Table 3 Technical Achievements of FY 2015 Projects (continued)

FY 2015 Project Name	Technical Achievement
AVPTA-Light Weighting	Under DoD and DOE partnership, Light Weighting developed a cost-effective suite of technologies to reduce fuel consumption throughout DoD and improve the operational energy posture of the ground vehicle fleet. M&S was intended to reduce and optimize weight of vehicle platform to lowest level while satisfying performance measures. An analytical framework and novel materials were identified. The project was UNSUCCESSFUL and the funds transitioned to another project – Electrification of Terminal High Altitude Area Defense (THAAD).
Waste Heat Recovery	Waste Heat Recovery, a two-year project, developed a series of modeling and demonstration projects to address technical challenges posed by recovering waste heat and evaluate the efficacy in military applications. A prototype heat exchanger was completed, assembled, and tested at the Naval Academy's Gas Turbine Lab.
JDW2E	In partnership with the Strategic Environmental Research and Development Program (SERDP) program, this project developed a prototype gasifier and syngas cleanup system to convert waste into energy to power equipment. Through the course of the Joint Deployable Waste to Energy (JDW2E) effort, the project codified a standard waste recipe and assessed a standard for future expeditionary W2E tests; coordinated a joint approach to W2E system evaluation and information sharing amongst tests conducted across the Army, Navy, and Air Force. It conducted a standardized test of a small-scale expeditionary W2E system in an operationally relevant environment with the US Environmental Protection Agency (EPA); and developed joint concept of operations (CONOPS) and TTPs to integrate W2E systems into operating forces.
MPACT	Maritime Prescreening Assessment for Conservation Technologies tested performance-improving energy technologies in Maritime Academy training ships. An on-board ship sensor suite was installed and "energy plus" modeling was developed and validated in partnership with the Department of Energy's National Renewable Laboratory (NREL) and Naval Surface Warfare Center (NSWC) Carderock. Installation and testing of variable refrigerant flow cooling system occurred on the Massachusetts Maritime Academy's training ship and the hardware and software system was tested during a 6-week winter cruise. The detailed testing results are published in the Naval Engineer's Journal (Barkyoumb, June 2018)[5]. OECIF funds were used to develop and support the first technology demonstration and model validation. A second technology demonstration – a magnetic bearing system – was installed in August 2018.
Persistent UAV	Persistent Unmanned Autonomous Vehicles (UAV) developed high efficiency, lightweight, and flexible photovoltaic (PV) solar arrays incorporated into UAV wings and provide power to on-board electronics and propulsion systems. This effort demonstrated cooperative soaring with two aircraft for over five hours by successfully integrating thermal soaring, PV, advanced power management, and command and control software. The project transitioned into the OECIF FY16 Hybrid Tiger project.
Federated Models	Federated Models identified which OE-related analysis tools offered greater utility than manual modeling and what approach would best ensure enduring capability.
Cyber	Cyber quantified the problem of cyber security for energy-related platform information technology (PIT) / industrial control systems (ICS) to guide DoD leadership. This effort analyzed key infrastructure and performed gap analysis at eleven DoD facilities for cybersecurity threats and analyzed workforce skillsets to determine required malicious cyber-attacks training. It transitioned into larger program analyzing DoD-wide cyber security.
Membrane Dehumidification	In partnership with Advanced Research Projects Agency – Energy (ARPA-E) and the Navy, Membrane Dehumidification utilized generator waste heat to power cooling units. Stirling cycle-based heat pumps used less energy and the dehumidification membrane reduced the required chilling energy. The project continues other efforts with oversight under ARPA-E and transitioned to Military Sealift Command (MSC) and Army Communications-Electronics Research, Development and Engineering Center (CERDEC).

5 June 2018 Naval Engineer's Journal at: http://www.ingentaconnect.com/contentone/asne/nej/2018/00000130/00000002/art00020

FY 2016 Technical Assessment

The concluding FY 2016 OECIF project resulted from Congressional plus-up funds which directed the Services to focus on ways to use energy more efficiently in operations and integrate OE into the education and training processes. This effort supports the Operational Energy Strategy which recognizes the crucial role of energy in enabling U.S. forces to perform missions both at home and overseas. Therefore, a key goal of the FY16 strategy was expanding operational energy education and training in order to enhance the national security of the United States.

Table 4 Technical Achievements of FY 2016 Projects

FY 2016 Project Name	Technical Achievement
Education & Training	The Services created programs that integrated operational energy into existing education and training curricula and Service-level planners' courses.

Transition Assessment

In addition to evaluating the project's technical performance, ODASD (E) assessed the continuation of each specific OECIF project with transition partner funding. Once OECIF funding is exhausted, project funding switches to the identified transition partner, which is generally the Services, the Combatant Commands or OSD. Ensuring OECIF advancements are sustained by the transition partner is a key measure of success. To be truly successful, OECIF-funded technologies must bridge the 6.4 valley of death, reach the Warfighter, and improve military capability.

To accomplish transition assessment, ODASD (E) first determined the span of possible project transitions. Given the variety and different types of OECIF projects, transition outcomes are grouped into the following categories:

- S&T – Transition partner will continue developing technology in a follow-on S&T project
- Standards, Software, Services – Transition partner will implement or maintain new standards, software, or services across existing projects
- Equipment – Transition partner will continue equipment testing or may procure equipment for deployment
- Requirements – Transition partner will use the outcomes of the project to influence future requirements
- TTPs – Transition partner will use the outcomes of the project to revise TTPs resulting in better utilization of existing systems
- None – Transition partner will no longer fund or implement any element of the project

These categories reflect the diversity of S&T outcomes in defense technology development and allow for a variety of project transitions.

FY 2014 Transition Assessment

FY 2014 OECIF projects focused on developing analytical methods and tools. These projects have completed execution, and they are at the end of their OECIF funding cycle. The projects have transition pathways identified and continued transition partner funding or product use. Table 5 provides a summary of the transition outcome of the completed projects.

Table 5. FY 2014 OECIF Projects: Transition Assessment Results

FY 2014 OECIF Project Name	Transition Partner	Transition Category
MEAM	Unsuccessful	None
J-DEPLOI	US Army PM Mission Command	Standards, Software, Service/Equipment
STORM-E	Headquarters Air Force (HAF) A9 and the Group Users of STORM (GUSt)	Standards, Software, Service/Equipment
OEATF	TRADOC, AMSAA,TARDEC	Standards, Software, Service/Equipment
COE-Toolkit	A9	Standards, Software, Service/Equipment
CAMEL	LCMC, SDPF	Standards, Software, Service/Equipment

Mission Engineering Analytical Method for Operational Energy (MEAM). The Navy-led project was intended to embed operational energy into the Navy's Mission Engineering methodology and assess energy demand, energy delivery in a contested environment and energy requirements and relationships to warfighting operational effectiveness during the employment of forces. Due to a variety of issues, this project's funding was redirected. The effort's funding moved to support Operational Energy Command and Control, a Marine/Army project, JOEC2.

Joint Deployment Energy Planning and Logistics Optimization Initiative (J-DEPLOI). The INDOPACOM-led project developed an analytic tool and the associated policy to facilitate energy analysis earlier in the Joint Planning Process. The tool allows the operational planner to visualize, quantify, and collaboratively evaluate the fuel logistical vulnerability of various course of actions that support refinement and inform the commander's decision. The Army Map Based Planning System (MBPS) is the J-DEPLOI transition partner. J-DEPLOI was developed using MBPS' agile development process which ensures integration and interoperability of J-DEPLOI within MBPS' enclave. MBPS is the basis for JSJ5 Joint Planning Services. Both transitioned to Army's PM - Mission Command. Warfighter training and feedback continues to drive this effort.

Synthetic Theater Operations Research Model-Energy (STORM-E). This USMC-led project resulted in a capability to model operational energy in warfighting campaign analysis.

This effort developed, prioritized, and coordinated a STORM-E roadmap for software enhancements. Model modifications, scenario instatiation, and data development were accomplished. Scenario and data development described the supply and demand of energy associated with units operating under a variety of conditions and performing a range of missions. Resulting capability was immediately used by the USMC Joint and External Analysis group. All updates have been made, accepted by the government configuration control board, and incorporated in in the STORM baseline version. Transition partners are the STORM user community through HAF A9 and Global Users of STORM (GUSt).

Operational Energy Analysis Task Force (OEATF). OEATF enhanced the Fully Burdened Cost Tool, upgraded the Logistics Battle Command Model, performed verification and validation of the Shelter Thermal Energy Model, and produced a web-based prototype for expeditionary basing OE analyses. It developed tools that consider operational energy requirements to provide senior leaders with needed information to assess OE impact on mission effectiveness.

Transition partners include the Training and Doctrine Command (TRADOC), Army Materials Systems Analysis Activity (AMSAA), and the Tank Automotive Research Development and Engineering Center (TARDEC). Transition organizations regularly utilize the enhanced tools and scenarios developed through OECIF. Continued funding to provide operational energy analysis in support of Army decision makers will come from mission funding and future study sponsors.

Comprehensive Operational Energy Toolkit (COE-Toolkit). The Air Force developed modeling and simulation software to examine emerging enemy air/missile/space capabilities to disrupt / destroy allied operational energy. The fast integrated tool enables rapid output for decision making. The funding and further development of the COE-Toolkit has been incorporated into the next spiral development of the Airfield Damage-Assessment & Resiliency Model (AD-ARM), which has been funded with approximately $500K from A9 sponsorship. Additional funding is provided through A9 and A4 organizational partners. The tool is standardized across the services.

The next spiral of development will model the impact of Red attacks on Blue sortie generation and include the capability to examine the combined effect of attacks on multiple locations near-simultaneously.

Capability Assessment and Modeling for Energy Logistics (CAMEL). The Air Force developed a modeling and simulation tool that provides insight into the logistics infrastructure and base fuel resupply needed to produce required sortie generation rates. CAMEL has a robust methodology and the analytical team holistically evaluated the OE impacts and military utility of advanced air refueling, airlift, and alternative basing technologies/CONOPS at both mission and campaign levels. The strengths/functionalities of government off the shelf (GOTS), commercial off the shelf (COTS), and purpose-made modeling, simulation, and analysis (MS&A) tools were leveraged to identify the OE vulnerabilities of DoD logistics/combat fleets in anti-access/aerial denial (A2/AD) environments and the cost of mitigating (via technology and behaviors) these threats to warfighting capability.

CAMEL's advanced aerial refueling capabilities concepts project has transitioned to Air Force Life Cycle Management Center (AFLCM) and the Strategic Development Planning and Experimentation (SDPE) office has pledged funds to support its use moving forward.

FY 2015 Transition Assessment

For FY 2015, the OECIF projects focused on improving fuel economy for the tactical ground fleet. Additionally, OECIF applied one year Congressional plus-up funding to short-term projects which complemented existing or new OE relevant technologies. The projects have completed and transitioned through transition partner funding. Table 6 provides a summary of the transition outcomes of the projects.

Table 6. FY 2015 OECIF Projects: Transition Assessment Results

FY 2015 OECIF Project Name	Transition Partner	Transition Category
JDW2E	Army	Equipment
Membrane Dehumidification	MSC and CERDEC	Equipment
Waste Heat Recovery	Navy/CERL	Equipment
Maritime Prescreening Assessment Correction Test (M-PACT)	Navy	Equipment
AVPTA – TVEK	Army/USMC	Equipment
AVPTA-TBC	Terminated	None
AVPTA-Autonomous	Terminated	Equipment89
AVPTA-Light weighting	Terminated	None
Persistent UAV	OSD	S&T
Federated Models	OSD	Standards, Software, Service
Cyber	DoD	Standards, Software, Service

Joint Deployable Waste to Energy JDW2E. The Strategic Environmental Research and Development Program (SERDP) led this project to develop a prototype gasifier and syngas cleanup system to minimize the waste liability at overseas contingency operations and use it as a resource. Waste can be converted into energy for powering equipment via the development of next generation waste-to-energy conversions. Technical development and evaluation was conducted at the service level with a majority of the "small" scale W2E system demonstrations executed by the US Army – PM Force Sustainment Systems (PM FSS). USINDOPACOM co-funding has concluded, and the University of Hawaii Applied Research Lab (UH-ARL) completed the JDW2E final report.

Membrane Dehumidification. This cooperative effort between Advanced Research Projects Agency – Energy (ARPA-E) and the Navy utilized generator waste heat to power cooling units. It confirmed through testing that Stirling cycle-based heat pumps used less energy and the dehumidification membrane reduced the required chilling energy. The project transitioned to Military Sealift Command (MSC) and Army Communications-Electronics Research, Development and Engineering Center (CERDEC).

Maritime Prescreening Assessment for Conservation Technologies (M-PACT). The Navy led effort tested performance-improving energy technologies in ships by using Maritime Academy training ships. A sensor suite was installed and "energy plus" modeling was developed and validated which led to installation of variable refrigerant flow cooling system.

Waste Heat Recovery. The Navy led Waste Heat Recovery effort, a two-year project, developed a series of modeling and demonstration projects addressing technical challenges posed by recovering waste heat and evaluate the efficacy in military applications. A prototype heat exchanger was completed and assembled at Naval Academy Gas Turbine Lab for testing.

Tactical Vehicle Electrification Kit (TVEK). The Army-led project reduced fuel consumption through electrifying power pack auxiliary components and anti-idle controls positively improving vehicle operational energy range. Oshkosh was contracted to develop and integrate the TVEK system. Transition will be completed during FY19 with key partners PM Missile Defense Agency Terminal High Altitude Area Defense and the USMC Miramar Autonomous Vehicle Proving Grounds Initiative.

Thermal Barrier Coating (TBC). The Army led a project to increase engine efficiency, reduce engine parasitic cooling loads, and understand the in-cylinder heat transfer in order to design better engines for the Army's diesel engines. The project showed inconclusive operational energy relevance and so was terminated. Tank Automotive Research Development & Engineering Center (TARDEC) is using the research and data internally.

Autonomous Ground Vehicles. The Army-led effort intended to develop and test autonomy-enabled technology to reduce fuel consumption for legacy and future military vehicles through a smart adaptive cruise control. This device would optimize fuel economy during missions and have a commercial driving application. The project showed inconclusive operational energy relevance under combat conditions and so was terminated. TARDEC is using the research and data internally specifically with a communication effort.

Light weighting. The Army-led effort intended to develop a modeling and simulation analytical framework applying a methodology to reduce mass and while maintaining performance. Subsystem components are light-weighted through the optimization methodology which improves fuel economy. The project was unable to find a project to test with and so was terminated. TARDEC is using research and data internally.

Persistent UAV. The USMC led effort developed a high efficiency, lightweight, and flexible PV solar array to incorporate into UAV wings and provide power to on-board electronics and propulsion systems. The project demonstrated cooperative soaring with two aircraft for over five hours by successfully integrating thermal soaring, PV, advanced power management, and command and control software. The project transitioned to OSD for further S&T development under the OECIF Hybrid Tiger project with a goal of demonstrating significantly extended ranges.

FY 2015 Transition Assessment

Federated Models. The OSD-led effort identified which operational energy related analysis tools offer greater utility than stand-alone modeling and what approach would best ensure enduring capability. The modeling and simulation program integrated energy considerations into novel methods facilitating multi-resolution war gaming, analysis and requirements development. The project transitioned to the USAF Service Energy Office for use in energy key performance parameter assessments.

Cyber. The OSD-led project quantified the problem of cyber security for energy-related platform information technology/industrial control systems used to guide DoD leadership. The outcome analyzed key infrastructures and performed gap analysis at eleven DoD facilities for cybersecurity threats and analyzed workforce skillsets to determine required cyber training to address malicious cyber-attacks. The effort transitioned into a larger program analyzing DoD-wide cyber security.

Table 7. FY 2016 OECIF Projects: Transition Assessment Results

FY 2016 OECIF Project Name	Transition Partner	Transition Category
Education and Training (Services)	DoD	Services

The Services' projects focused on ways to use education and training opportunities to teach energy efficiently in operations. The Navy, through Naval Post Graduate School (NPS) led the Energy Education and Training Working Group (EETWG) to ensure sharing of information across the Services. Each Service individually focused on unique warfighting domains to avoid duplication.

Army: The Army integrated energy coursework into the junior Soldiers/Officers Contingency Base Operational Energy Awareness, Management and Planning (CB OE AMP) course. They also demonstrated the Contingency Base Resource Calculator (CBRC), a software/technology tool, which allows users to model resource needs –water, fuel, power, etc.– for various sized forces by changing input variables like camp size, population, climate, and quality of life.

Air Force: The Air Force identified its Officer accession-level education as an ideal place to integrate OE into training and education for the aviation domain. Other opportunities identified to share best practices included aircrew training and pre-command courses. The addition of modules focused on moral or ethical dilemmas in OE at the Profession of Arms Center of Excellence and inclusion of the Energy and Environment for Strategists course at the Naval War College/National Defense University move the Air Force's OE training and education efforts forward.

Navy: The Navy developed and video recorded the Defense Energy Seminars as part of its curriculum; which cover the best of operational energy relevant topics and are available on-line at: https://my.nps.edu/web/eag/seminars. Additionally, NPS developed a distance learning (DL) Defense Energy Certificate program and the first two cohorts are underway. The DL program is available to military and government civilian personnel. Additionally, NSP set up a Joint Knowledge Online OE page and developed a OE video to introduce Naval officers

and enlisted to operational energy and its importance in military operations. The video may be found at: http://fms1.nps.edu/CED3/EAG_Energy_161208.mp4.

Marine Corps: The Corps incorporated OE concepts into existing curricula, unit training, exercises, and wargames to increase operational reach and readiness while simultaneously decreasing mission risk. Within the ground vehicle domain, the Motor Transport (MT) community is one of the largest consumers of fuel, so an implementation strategy for inserting OE education into the MT period of instruction was developed. The USMC followed up with additional funding for metering training vehicles to provide both operator and instructor OE-relevant feedback.

OECIF IMPROVEMENTS

The OECIF Program, within Operational Energy Innovation, has recently been organizationally re-aligned to OUSD Research and Engineering (R&E). The new alignment of OECIF opens the aperture with DoD Labs ensuring greater and earlier visibility into the Services technology development investments. ODASD (E) is organizationally aligned within OUSD Acquisition and Sustainment. It remains responsible for the Departments Operational Energy Strategy, the OE Budget Certification, and retains its strong relationships with the Service Energy Offices. Regardless of organizational alignment, Operational Energy Innovation and ODASD (E) remain committed to supporting the warfighter, one another, and ensuring requirements and technology maturation flows seamlessly amongst all.

Realignment brings additional changes to the OECIF program. In addition to aligning with the National Defense Strategy and the DoD Operational Energy Strategy, OECIF projects will be evaluated for their alignment with the R&E Modernization Areas: Hyper-Sonics; Directed Energy; Fully Networked Command, Control, and Communications (C3); Space; Cyber; Artificial Intelligence; Micro-electronics, Quantum Science; and Autonomy. While OE does not specifically focus on any one modernization area, OECIF project outcomes will be assessed based on support and potential positive impact across one or more modernization areas.

Key improvements for the OE community include the following:

First, improved communication through creation and use of an Operational Energy Taxonomy and Ontology. This Operational Energy Framework provides a method to analyze the existing portfolio and communicate goals and strategy to researchers, the Services, CCMDS, and OSD. The framework readily demonstrates the connections between energy and power research and development to operational capabilities of weapons and platforms. Having a distinct taxonomy and common language across the DoD spectrum for operational energy, allows us to uniquely categorize efforts, and precludes double-counting of investment. OE Innovation advocates adopting this framework DoD-wide to provide clarity where confusion and duplication may otherwise exist.

Second, the development of a single OECIF Management System (OEMS) will increase accountability and provide the OECIF program management team with common tools to foster proposal solicitation, down selection, and project award. Once awarded, project management tools within the system enable better tracking of financial management against

OSD obligation and expenditure benchmarks and provide the ability to apply program management tools and techniques including standardizing risk management assessments and mitigation strategies. The OEMS will also create commonality amongst OECIF projects through use of standardized reporting tools, status updates, annual deliverables, and records management. The system leverages prior investment in similar tools created for the SERDP and ESTCP Management System (SEMS) which was originally built for those programs. The new tool should be available for use by OECIF beginning in FY20.

Third, an increase in Industry outreach has been highly effective allowing the OECIF team to work with industry creating strategic partnerships. The team partnered on two separate occasions with ManTech and DIU to host forums bringing industry representatives together from across the country. Each representative was given an opportunity to brief and showcase their product before their peers and Service members. Later, the industry representatives were given one-on-one time to discuss their innovative ideas directly with a potential partner from the Services and Service Labs. These were win / win events enabling team building for OECIF proposals and showcasing emerging operational energy innovations. OE Innovation will continue to facilitate strategic partnership opportunities with industry.

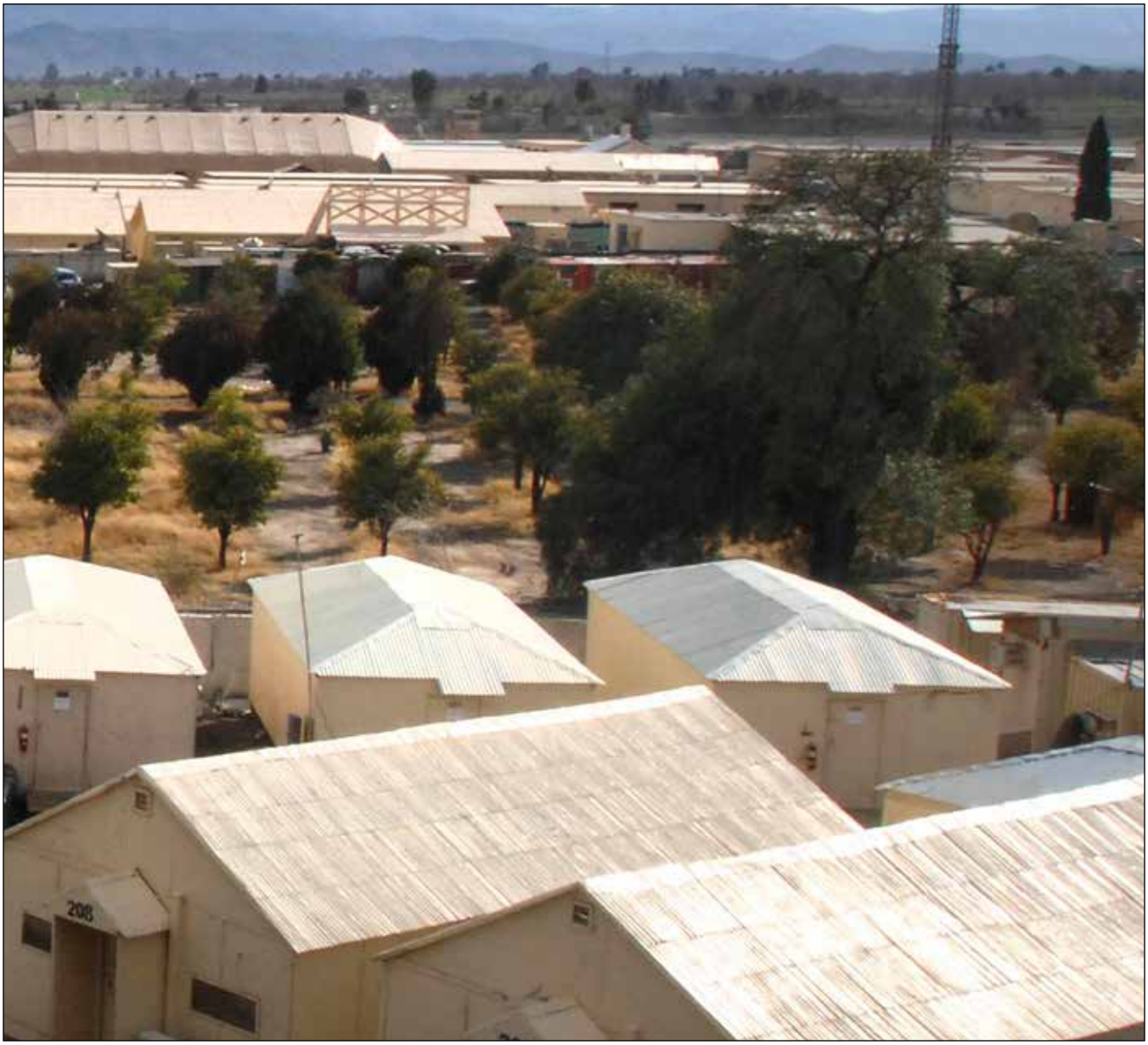
Fourth, OE Innovation works diligently to support the next generation of operational energy warfighters, civilians, scientists and engineers. Academic outreach is a strategic effort, and OECIF sponsors an Operational Energy Distance Learning Certificate through Naval Post-Graduate School. This certificate is available to all DoD military and civilians through a competitive nomination process. The tactical micro-grids OECIF project sponsored a Hacking 4 Defense (H4D) team at Rochester Polytech Institute. H4D Team members have taken summer and long-term employment at the Services Labs. OECIF also sponsored the 2018 CLEANTECH University DOD Prize competition. The winning pitch was a safer battery, with 3x the energy density, at half the cost per kWh. This technology is inherently safe (no leakage unlike existing batteries) and could mean an electric vehicle that can drive up to 1000 miles in one charge, warfighters going 3 days without needing to charge their phones, or significant improvements to mass scale storage of solar and wind renewable energy. Both the 2nd and 3rd place CLEANTECH University DoD prize winners are now working with on-going OECIF projects to support space solar technologies and under-water employment of hydrophobic coatings on sub-surface energy generation equipment. OECIF will continue to emphasize and support operational energy education and facilitate transition of scientist, engineers, and program managers into the Services labs to support operational energy innovation.

Most importantly, OE Innovation will continue its focus on transitioning OECIF achievements to more than 1 program of record. This goal has forced the OECIF program to recognize and advocate for the standardization and interoperability of energy supply, transmission, and demand to rapidly increase technology development momentum, to create opportunity for department-wide improvements in areas like resilience, and to generate potential cost savings across acquisition, operations, and logistics.When taken together, these priorities improve overall project management, strengthen partnerships; and most importantly, ensure OECIF projects deliver increased military capabilities to the Warfighter.

CONCLUSION

This assessment is a recurring annual review of OECIF projects. Overall, the OECIF program successfully identifies and transitions operational energy capabilities in order to reduce risk and increase military capability. In addition to continuously improving the management and transition of OECIF projects, OE Innovation continues to invest in opportunities that align with the Department's National Defense Strategy and Operational Energy Strategy and supports Department-wide priorities.

Over the last year a comprehensive program review was accomplished and updates are reflected in the appendixes.



APPENDIX A – OECIF ANNUAL THEMES

FY Start	Theme	Programs Funded
2012	Reducing energy loads at expeditionary outposts, with an emphasis on energy efficient shelters and cooling	8
2013	Using consortia to involve a wide variety of organizations to persistently attack key operational energy problems	6
2014	Analytical methods and tools for considering operational energy in Department planning and decision processes	7
2015	Improving fuel economy for the current tactical ground fleet through automation/ smart cruise control, auxiliary electrification, thermally efficient cylinders, and M&S for light-weighting	4
	Congressional plus-up: Topics for short-term programs funded with the FY15 Congressional plus-up include energy harvesting for the individual Warfighter, tactical waste-to-energy, cyber security for industrial control systems, development of a lightweight ultra-capacitor, using behavior change techniques to decrease fuel use, novel dehumidification systems to reduce air conditioning energy use for ground forces and ships, waste heat recovery, energy harvesting small unmanned aerial vehicles, development of an instrumented maritime testbed program, and M&S federations to explore energy-related analytic questions	11*
2016	Increasing the operational energy performance of unmanned systems for the Pacific including air, surface, undersea, and ground systems	10
	Congressional plus-up: Theme for short-term programs funded with the FY16 Congressional plus-up is Service training and education opportunities focusing on how to use energy more efficiently in operations	4**
2017	1) Thermal and power management technologies for high pulse power systems 2) Wireless transmission of energy in the far-field	6
	Congressional plus-up: Theme for short-term programs funded with the FY17 Congressional plus-up is the same as the main OECIF call for proposals above	4***
2018	Studies to identify operational energy science & technology gaps in the near-, mid-, and far-term.	7
2019	Projects that enhance energy storage to improve lethality and warfighting performance.	10
	Nuclear Fuel & Reactor Study	1

*Funded through a one-year $14.1M Congressional plus-up
**Funded through a one-year $4.0M Congressional plus-up
***Funded through a one-year $5.0M Congressional plus-up

APPENDIX B – OECIF PROJECT SUMMARIES TABLE OF CONTENTS

Financial Summary Table

Start Year	Project Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	Total
FY12	Advanced, Energy Efficient Shelter Systems for Contingency Basing and Other Applications	$6.0	$5.9	$4.9	$0.6							$17.3
FY12	Innovative Cooling Equipment Development Demonstration Program	$3.5	$3.5	$2.6	$0.4							$10.0
FY12	Navy Expeditionary Technology Transition Program	$3.2	$2.8	$2.4	$0.9							$9.3
FY12	Operation Enduring Freedom Energy Initiative Proving Ground	$0.9										$0.9
FY12	PEO CS/CSS Modeling and Simulation	$0.7										$0.7
FY12	Super Energy Efficient Containerized Living Unit (Super CLU) Design and Development	$1.0	$1.5	$0.6								$3.1
FY12	Transformation Reductions in Operational Energy Consumption (TROPEC)	$3.9	$2.5	$4.3	$0.4	$0.9						$11.9
FY12	Waste to Energy for Forward Operating Bases	$1.5	$0.8	$1.1								$3.4
FY13	Energy Efficient Outpost Modeling Consortium		$1.4	$2.7	$2.8	$2.7						$9.4

Financial Summary Table (continued)

Start Year	Project Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	Total
FY13	Engineered Surfaces and Materials for Drag Reduction		$0.4	$1.6	$2.1	$1.9						$5.9
FY13	Fuel Price Hedging Study		$0.3		$0.3							$0.5 *
FY13	PACOM Operational Test		$0.3									$0.3
FY13	Soldier and Small Unit Operational Energy		$1.4	$4.6	$4.0	$3.3						$13.4
FY13	Tactical Microgrids Standards Consortium		$2.5	$0.9	$3.7	$1.7	$1.7	$0.4				$10.9
FY14	Capability Assessment & Modeling for Energy Logistics (CAMEL)			$1.0	$1.4	$1.5	$1.4					$5.3
FY14	Cluster Basing			$0.1	$0.0							$0.1
FY14	Comprehensive Operational Energy (COE) Toolkit (A9)			$0.2	$1.2							$1.4
FY14	Joint Deployment Energy Planning and Logistics Optimization Initiative (J-DEPLOI) PACOM			$0.4	$1.1	$0.8	$1.2	$1.4				$4.9
FY14	Mission Engineering Analytical Method for Operational Energy			$0.5	$0.7	$0.1						$1.3
FY14	OE Theater Supportability Analysis Toolkit (OEATF) (Army)			$1.0	$2.2	$2.6	$2.1					$7.9

Financial Summary Table (continued)

Start Year	Project Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	Total
FY14	Synthetic Theater Operations Research Model-Energy (STORM-E), USMC			$1.4	$0.4	$3.0	$1.3	$0.9				$6.9
FY15	Autonomy-Enabled Fuel Savings for Military Vehicles				$1.6	$1.0	$1.4	$0.8				$4.8
FY15	Tactical Vehicle Electrification Kit				$3.8	$2.2	$5.7	$3.3				$15.0
FY15	Thermal Barrier Coating and Heat Transfer in Engines				$1.7	$0.9	$1.2					$3.8
FY15	Vehicle Lightweighting Using Modeling & Simulation				$0.2	$0.2	$0.6	$0.2				$1.2
FY15	BeYond Behavior Program			$0.2	$0.9							$1.0 *
FY15	Cyber Security for Industrial Control Systems				$1.7							$1.7
FY15	Federated M&S					$2.0						$2.0
FY14	Joint Infantry Company Prototype (USMC)			$0.1	$3.3							$3.4
FY15	Marine Prescreening Assessment of Conservation Technology (M-PACT)				$2.5	$0.2						$2.7
FY15	Molecular Membrane Air Conditioner/ Dehumidifier				$1.1							$1.1
FY15	Persistant ISR UAV via Energy Harvesting			$0.6								$0.6

Financial Summary Table (continued)

Start Year	Project Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	Total
FY15	Small Unit Power and Battery Eliminator				$2.9							$2.9
FY15	Support to Joint Waste to Energy				$0.4							$0.4
FY15	UARC Funding			$0.0	$0.0							$0.0
FY15	Waste Heat Recovery Projects				$2.6							$2.6
FY16	Aluminum-Water Power for Unmanned Undersea Vehicles					$1.8	$2.8	$3.1	$4.5			$12.2
FY16	Autonomous and Robotic Remote Refueling Point (AR3P)					$0.4	$0.1	$ 0.6	$0.6			$1.7
FY16	Autonomous Robotics for Installation and Base Operations (ARIBO)					$0.4	$0.1	$0.1				$0.6
FY16	Hydrothermal Vent Exploitation for Undersea Energy					$1.3		$0.4	$1.2			$2.9
FY16	Joint Operational Command and Control (JOEC2)					$0.5	$1.2					$1.7
FY16	JP-8 Based Fuel Cell Power					$1.9	$2.4	$2.2	$1.6			$8.0
FY16	Multi-Day Endurance of a Group 2 UAS Utilizing Pacific Energy Sources (Hybrid Tiger)					$1.4	$2.2	$1.1	$1.9			$6.4
FY16	PV Test Standardization DOD w/NREL					$0.5		$0.2				$0.7

Financial Summary Table (continued)

Start Year	Project Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	Total
FY16	Reliable, Efficient, Tactical UAS Power System					$1.5	$0.8	$0.9				$3.1*
FY16	Small Turboprop Engine Range/Power Enhancement					$2.0	$2.0	$2.0	$2.0			$8.0
FY16	Army Training and Education Projects					$1.0						$1.0
FY16	Navy Training and Education Projects & EETWG					$1.1	$0.4	$ 0.5	$0.5			$2.5
FY16	Air Force Training and Education Projects					$1.0						$1.0
FY16	USMC Training and Education Projects					$0.5						$0.5
FY17	Open Systems for Controls of Integrated Propulsion, Power, and Thermal						$0.9	$0.7	$1.3	$0.7		$3.5
FY17	Ultra High Density Hybrid Energy Storage Module for Laser Weapon System and Electronic Warfare Operations						$0.7	$2.1	$2.5	$ 0.7		$5.9
FY17	Thermally Enabling Architectures for Pulse Power Systems						$1.8	$2.2	$2.7	$2.8		$9.5
FY17	Power Transmitted Over Laser						$1.5	$3.3	$1.8	$1.5		$8.1

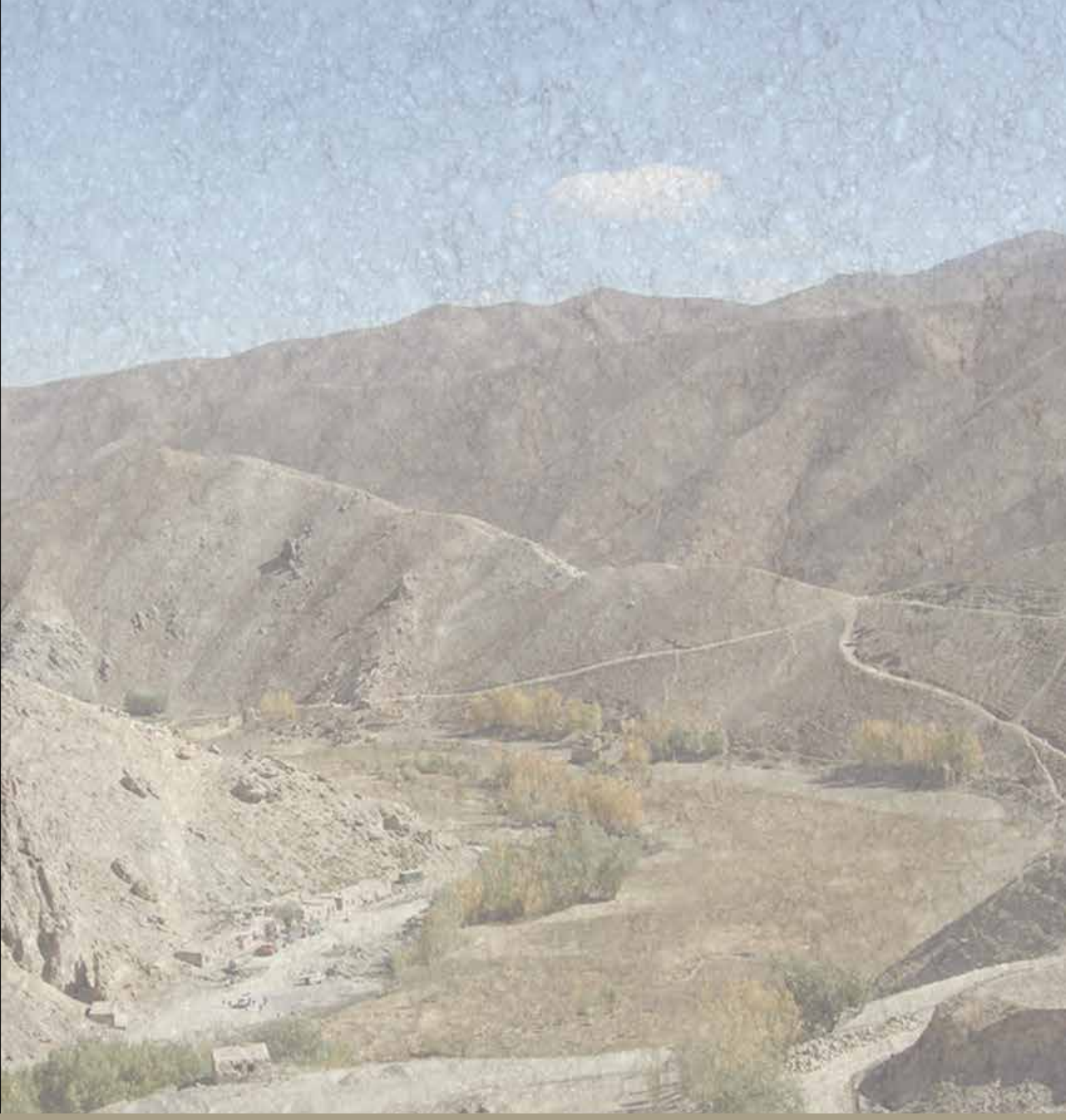
Financial Summary Table (continued)

Start Year	Project Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	Total
FY17	Millimeter Wave Ground-to-Ground Power Beaming Demonstration and Far-Field Wireless Power Transmission						$1.4	$1.4	$1.7	$1.7		$6.2
FY17	Space Solar for Forward Operating Bases and Remote Installations						$0.3	$0.4	$0.4	$0.4		$1.5
FY17	Space Solar Power						$2.4	$2.2	$2.0	$2.0		$8.6
FY17	Operational Energy Watson / SEMS 2.0						$2.2	$1.7	$3.1	$2.0		$9.0
FY17	FY18 Study Integration							$0.6				$0.6
FY17	FY17 DOD/DOE CLEANTECH UP PRIZE						$0.1					$0.1
FY17	FY17 Waste to Energy (W2E) co-sponsor with SERDP/ESTCP						$0.8		$0.8	$0.8		$2.3
FY17	Laser Optical Comms						$0.5					
FY17	AF Battery Commonality						$0.1					
FY17	USMC Virtual Energy Testbed						$0.1					
FY17	Hybrid-on-hybrid Tactical UAS (H2-UAS) Demo						$0.0					
FY18	AURAS							$1.2				$1.2

Financial Summary Table (continued)

Start Year	Project Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	Total
FY18	Dismounted Warfighter OE (DWOE)							$1.2				$1.2
FY18	EW-DE							$0.7				$0.7
FY18	Fuel Storage & Distro							$0.3				$0.3
FY18	FY19 Study Integration							$0.3				
FY18	Mobile Power Meter							$0.3				$0.3
FY18	POSEIDON							$0.9				$0.9
FY18	Range Data - OE Relevant Fuel Consumption							$0.1				$0.1
FY18	Space Solar D-HVPE/ Perovskites							$1.9	$2.6	$2.6	$2.6	$9.7
FY18	USN Battery Commonality							$0.7				$0.7
Total		20.653	23.238	31.129	44.795	40.255	41.122	39.773	31.040	15.115	2.600	289.7

*Rounding Errors Change Sums	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	Total



FY 2012 OECIF Program Summaries:

REDUCING ENERGY LOAD AT EXPEDITIONARY OUTPOSTS

ADVANCED ENERGY EFFICIENT SHELTER SYSTEMS (AEESS) FOR CONTINGENCY BASING AND OTHER APPLICATIONS

Lead Organization: U.S. Army Natick Soldier Research, Development, and Engineering Center (NSRDEC)

Other Key Participants: U.S. Air Force (USAF) Base Expeditionary Airfield Resources (BEAR) Global Management Office; Air Force Civil Engineer Command; Army Corps of Engineers, Engineer Research, and Development Center – Construction Engineering Research Laboratory

OECIF Funding Stream:

FY 2012 (M)	FY 2013 (M)	FY 2014 (M)	FY 2015 (M)	Total
$6.0	$5.9	$4.9	$0.6	$17.3

Description: This Army/Air Force Joint program addressed energy inefficiencies associated with shelter systems, particularly tents. The program instrumented and demonstrated energy efficient shelter system performance by testing them in relevant environments. Modeling and simulation were used to design and prototype highly energy efficient shelter systems with advanced insulation materials. The results of the initial demonstrations and technology development were used to design and demonstrate next generation optimized shelter systems in relevant operational environments.

Military Benefit: The ultimate products to be transitioned from this effort are energy efficient shelter systems that reduce fuel consumption on the battlefield and manpower requirements for the Warfighter.

Accomplishments:

- Initial demonstrations of current Army and USAF shelter systems were instrumented and evaluated in Kuwait and Guam. These tests identified a need for insulation with improved moisture-resistance and corrosion prevention in humid environments.
- Modeling and simulation of 2D and 3D technical baselines were developed and matured with boundary layer conditions applied to enable detailed airflow and thermal analysis.
- A shelter database was established and populated for geographic location, shelter manufacturer, shelter model and liner, fly material and shelter sensors that allowed users to input shelter and geographic location and receive an energy audit for that configuration.
- Large shelter efficiencies
- Evaluated new shelter skins (outermost layer of fabric) to reduce thermal loading

- Data collected on transformer liner (liner that can be used to increase or decrease the volume inside the shelter, as needed; reduces volume needed for heating/cooling)

- Follow-on demonstrations of prototype shelter designs with improved thermal performance, air distribution, system weight & cost, were completed during the Winter of FY 2015 at Fort Greely, AK (Cold Regions Test Center) and Ellsworth Air Force Base (AFB). Fort Greely results showed improvement of 30-40% over legacy baseline shelters; Ellsworth results demonstrated heating two shelters with one BEAR heater with a 50% fuel savings.

- Additional demonstration of prototype systems at Holloman AFB, New Mexico during Summer of FY 2015 showed the Army has a potential for an 82% power reduction over currently fielded shelter systems and 66% reduction for the USAF.

- Based on the Structural Insulated Panel "SIP-Hut" evaluation report, the Commander of the Combined Security Transition Command, Afghanistan procured 20 SIP-Huts.

- Static and operational data were collected during final evaluation of Army prototype system at Ft Polk, Louisiana during the Summer of FY 2016.

Transition: Technology transition agreements have been signed with U.S. Army Combined Arms Support Command, Product Manager Force Sustainment Systems, and Maneuver Support Center of Excellence. NSRDEC also has follow-on funding consisting of $5.7M from FY 2018-2020 for improvements of soft walled shelters. The work will focus on advancing shelter performance using the materials and prototypes developed under AEESS as a baseline. This effort will decrease the set up time and weight of the shelters as well as expand the operational environments in which the shelters can operate. Additionally, the Air Force is funding $14.98M from FY 2018-2025 for fielding new systems that were developed under the AEESS project.

INNOVATIVE COOLING EQUIPMENT (ICE) DEVELOPMENT / DEMONSTRATION PROGRAM

Lead Organization: Army Communications Electronics Research, Development, and Engineering Center (CERDEC)

Other Key Participants: Office of Naval Research, Army Research Laboratory, Army Materiel Systems Analysis Activity, Program Manager – Expeditionary Power Systems, Project Manager – Expeditionary Energy and Sustainment Systems (PM-E2S2)

OECIF Funding Stream:

FY 2012 (M)	FY 2013 (M)	FY 2014 (M)	FY 2015 (M)	Total
$3.5	$3.5	$2.6	$0.4	$10.0

Description: The U.S. Army CERDEC, along with its partners, has sought and implemented state-of-the-art advancements, technology readiness level (TRL) 5 (i.e., component and/or breadboard validation in relevant environment) to TRL 7 (i.e., system prototype demonstration in an operational environment), in thermodynamic cycles, electronics/digital controls, heating ventilation and air conditioning components, and waste heat recovery to improve the energy efficiency of environmental control units (ECUs). The program is supported by U.S. Marine Corps and Army, and focused on the 9k, 18k, 36k, and 60k British thermal units per hour (BTUH) units.

Military Benefit: Program goals included 10% (threshold) – 30% (target) fuel savings over the PM-E2S2 Improved Environmental Control Unit and the modernized US Marine Corps ECU fleets. The operational benefits of advanced environmental control technologies include a reduction in electrical energy required to produce cooling and heating for forward bases as well as Brigade and below environmental requirements, which in turn will result in a significant decrease in the amount of fuel required and a corresponding reduction in related battlefield logistics burden.

Accomplishments:

- Operational thermal energy model was developed to simulate the operation of an ECU in a variety of global environments and was used to estimate annual energy consumption to establish a baseline.
- After a series of component testing and system design activities, a TRL 6/7 (i.e., system/subsystem model or prototype demonstration in a relevant environment / system prototype demonstration in an operational environment) was effectively demonstrated across all capacities of interest.
- ECU prototype deliverables demonstrated the following efficiency improvements, which were validated through CERDEC calorimeter testing: 9k – 56%, 18k – 20%, 36k – 17%, 60k – 14%.
- Two 60k BTUH ECUs were demonstrated in an operational setting alongside baseline and other advanced ECU technologies at the Army's Base Camp Integration Laboratory (BCIL) at Fort Devens, MA.
- High yield, low-risk components were identified for incorporation into the Technical Data Packages, which will be used for the planned 2016 Army procurement and fielding of 9/18/36K BTUH units.
- Based on calorimeter testing and operational demonstrations, variable speed fans, micro-channel heat exchanger, variable speed compressor technologies, electronic expansion valves, and super hydrophobic surface treatments were implemented into a new set of ECU prototypes with a focus on the 60k BTUH.
- High-efficiency ducts were designed and incorporated into the prototypes.
- A new control system was integrated, which allows control by the Energy Informed Operations (EIO) operational grid.
- Prototype tests and demonstrations were conducted to establish battlefield power grid communications standards and incorporate needed control modules into all future ECUs.

Transition: Following conclusion of the program, the Army decided not to continue funding ICE because their technical approach did not follow the Army's acquisition process. While ICE identified energy efficiency improvements to specific ECU components, Army typically requests a more efficient ECU, without specifying which components should be improved. Additionally, the Army did not believe the energy benefits achieved in the program were worth the cost. However, the ICE program did benefit the M&S community as data from their analysis of ECUs has been incorporated into Army M&S tools.

NAVY EXPEDITIONARY TECHNOLOGY TRANSITION PROGRAM (NETTP)

Lead Organization: Naval Facilities Engineering Command (NAVFAC)

Other Key Participants: Advanced Research Projects Agency-Energy (ARPA-E); Office of the Chief of Naval Operations, Navy Energy Coordination Office

OECIF Funding Stream:

FY 2012 (M)	FY 2013 (M)	FY 2014 (M)	FY 2015 (M)	Total
$3.2	$2.8	$2.4	$0.9	$9.3

Description: The goal of the NETTP is to develop and field advanced technologies that reduce the fuel consumption for expeditionary heating and cooling by 20-50%. The NETTP leverages the research and development efforts of the Department of Energy's ARPA-E program, Building Energy Efficiency through Innovative Thermo-devices (BEETIT), which intends to improve the efficiency of residential and commercial heating, ventilation, and air conditioning (HVAC) systems, and adapt these technologies to the rigors and constraints of the expeditionary environment.

Military Benefit: Over 50% of facility fuel use at expeditionary camps and Forward Operating Bases currently goes to powering environmental control units (ECUs) for HVAC loads.[6] The NETTP developed technologies to reduce this load, enabling tremendous benefits at the tactical, operational, and programmatic levels. Efficient ECUs translate to reduced fuel requirements, fewer fuel convoys in theater, improved resilience of contingency bases to disruption, and increased safety for personnel.

Accomplishments:

- Dais and ADMA Products/Pacific Northwest National Laboratory (PNNL) – Membrane Dehumidification (one year seedling projects):
  - Demonstrated proof of concept for evaporative cooling in conjunction with membrane dehumidification; 0.1 ton of cooling demonstrated.

- Georgia Tech – Absorption Heat Pump Utilizing Waste Heat:
  - Demonstrated a packaged system TRL-5 (i.e., component and/or breadboard validation in relevant environment) system with automated controls at the military required 125ºF ambient temperature.
  - Plan to optimize several system components and controls to reach the targeted project efficiency and cooling output targets.
- Infinia – Stirling Cycle Based Heat Pump:
  - Demonstrated a TRL-5 Stirling heat pump with integrated thermosiphons.
  - Tested multiple iterations of the metal foil regenerator using different design variations and manufacturing methods, in addition to a synthetic random fiber regenerator.
- PNNL – Adsorption Chiller Utilizing Waste Heat:

6 Baseline Camp Power Test, NMCB-3 Field Training Exercise, May 2013

Transitioned the lab demonstrated Metal-Organic Framework (MOF) production method to a pilot commercial production line. Pilot production line successfully demonstrated and currently running.

- Completed design of the complete TRL-5 system.
- Plan to complete fabrication and testing. Demonstrate the TRL-5 prototype.

Transition: The Georgia Tech absorption heat pump has shown sufficient promise to warrant the Navy allocating $4.2M in FY 2016 and FY 2017 to continue development to TRL 6/7 (i.e., system/subsystem model or prototype demonstration in a relevant environment / system prototype demonstration in an operational environment). Additionally, two dehumidification membrane approaches were selected by ARPA-E and NAVFAC for proof of concept demonstration; $3.2M in funding came from ARPA-E, OECIF, and Navy Military Sealift Command.

SUPER ENERGY EFFICIENT CONTAINERIZED LIVING UNIT (SUPERCLU) DESIGN AND DEVELOPMENT

Lead Organization: Naval Facilities Engineering Command – Engineering Service Center

Other Key Participants: Camp Lemonnier Public Works Department, U.S. Marine Corps Forces Pacific Experimentation, Western Area Research, Testing and Evaluation Center

OECIF Funding Stream:

FY 2012 (M)	FY 2013 (M)	FY 2014 (M)	Total
$1.0	$1.5	$0.6	$3.1

Description: Camp Lemonier, Djibouti, Africa is the primary base of operations for US Africa Command (USAFRICOM) that supports over 4,200 personnel. Many personnel live in converted shipping containers called Containerized Living Units (CLUs). Approximately 5.5 million gallons of diesel fuel are required annually to power cooling, lighting, and other functions at an annual cost of approximately $22 million.

This program improved the energy efficiency of the current CLU by renovating the existing design, and developing a highly energy efficient CLU, or SuperCLU. The existing CLU design was optimized by incorporating high energy efficiency Heating, Ventilating, and Air Conditioning (HVAC) systems, high R-value insulation, and well balanced interior air distribution. The SuperCLU design took into consideration energy reduction, maximizing interior space, increasing individual privacy, and reducing noise compared to the current CLU.

Military Benefit: This program developed energy efficient CLUs, demonstrating decreased energy and fuel consumption and reducing the cost of fuel.

Accomplishments:

- Developed renovated CLUs demonstrating a 54% energy reduction, 855,360 gallons annual fuel reduction, and $2,138,000 annual cost savings over existing CLUs.
- Developed a SuperCLU demonstrating an 82% energy reduction, 1,298,880 gallons annual fuel reduction, and $3,247,000 annual cost savings over existing CLUs.
- Camp Lemonier replaced window ECUs in all CLUs with 1000 split HVAC systems. Estimated savings is 40-50% reduction in unit energy use per replacement.
- Purchased and tested two Control Center type SuperCLUs in Guam and Florida. Reduced energy use by 75% compared to tents in Guam and controlled humidity at both sites.
- New SuperCLU design and Control Center concept tested with Transformative Reductions in Operational Energy Consumption (TROPEC) in Task Force Talon exercise in Guam in June and Air Force/NASA SWORDS demonstration at the Kennedy Space Center in Florida in June. Data collection, analysis, and reporting continuing.
- Drop-in-Replacement 40' SuperCLU designed and built; however, new requirements are being incorporated, such as internet, cable TV, and phone lines. Increased insulation ("R" value 50), split HVAC, subfloor foam.

Transition: The SuperCLUs are currently being purchased and deployed. The Navy Expeditionary Combat Command Pacific purchased three SuperCLUs for humanitarian support, and the Seabees deployed five SuperCLU structures to the Philippines for the U.S.-Philippines Exercise Balikatan in Panay. The Navy Engineering and Expeditionary Warfare Center coordinated with the NAVFAC Facilities Engineering Commands to improve new purchases of current CLUs with improved ECU systems. Additionally, the Naval Facilities Engineering and Expeditionary Warfare Center received $856K from the Navy Shore Energy Technology Transition and Integration Program to finish testing the SuperCLU and to develop a NetZero SuperCLU by incorporating renewable energy.

TRANSFORMATIVE REDUCTIONS IN OPERATIONAL ENERGY CONSUMPTION (TROPEC)

Lead Organization: U.S. Pacific Command (PACOM)

Other Key Participants: Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, Naval Facilities Engineering Command Expeditionary Warfighting Center's Field Experimentation Team

OECIF Funding Stream:

FY 2012 (M)	FY 2013 (M)	FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	Total
$3.9	$2.5	$4.3	$0.4	$0.9	$11.9

Description: TROPEC evaluates new and existing technologies, capabilities, tactics, techniques and procedures with an emphasis on the ability to reduce energy demand and water/waste logistics requirements associated with expeditionary operations, especially in tropical environments. The program offers end-to-end assessment reports, working closely with DoD and interagency partners, to develop customized test plans in controlled laboratory environments and/or deployed operational settings.

TROPEC assessments are conducted in the field environment and are uniquely integrated with military operations in the Indo-Asia-Pacific region. In this way, performance data as well as operator feedback and mission impact, can be gathered in an operationally relevant environment and incorporated into an assessment process for suitability and utility.

Military Benefit: TROPEC's military benefit stems from goals to reduce tropical base camp logistics related to energy, water and waste. According to Oak Ridge National Laboratory, the program demonstrated technologies at Technology Readiness Level (TRL) 6 (i.e., system/subsystem model or prototype demonstration in a relevant environment) or above, which, if implemented, would achieve the following documented results:

- Reduce total camp environmental control unit (ECU) energy use by 80% and reduce JP8 fuel usage by 40%.
- Further reduce JP8 fuel usage to 55% savings with use of an Advanced Medium Mobile Power Source (AMMPS) micro grid.

Accomplishments/Future Plans:

- Established formal partnerships with nine DoD organizations via Memoranda of Agreement
- Reviewed hundreds of energy efficiency technologies suitable to expeditionary operations
- Conducted 61 formal assessments in a combination of lab and field environments
- Findings
  - Shelter systems with radiant barriers, experimental ECUs, light-emitting diode (LED) lighting and hybrid lighting controls reduce energy consumption by 79%
  - Occupancy sensors save 48% of lighting loads and LEDs save 25% over fluorescent
  - Generators ran ~34% of capacity
  - Super Containerized Living Units reduce energy consumption by 32%-65%
  - Building Integrated Heat & Moisture Exchange reduces consumption 21%-35%
  - Magellan Expeditionary Wastewater Re-Use System reduces consumption 50%
- Future Plans
  - FY 2016/2017 – Joint Operational Energy Command and Control (JOEC2) assessment
  - FY 2017 – Joint Deployable Waste-to-Energy assessment
  - FY 2018-2020 – OECIF unmanned system assessments

Transition: TROPEC transitioned to a fee-for-service approach in FY 2015 that used a 50/50 cost share with users; however, OECIF funding was exhausted in FY 2016. The program can continue to provide testing services at the sole cost to the user.

WASTE TO ENERGY (W2E) FOR FORWARD OPERATING BASES

Lead Organization: Office of the Deputy Assistant Secretary of Defense for Installation Energy - Strategic Environmental Research and Development Program

Other Key Participants: U.S. Army Natick Soldier Research, Development and Engineering Center

OECIF Funding Stream:

FY 2012 (M)	FY 2013 (M)	FY 2014 (M)	Total
$1.5	$0.8	$1.1	$3.4

Description: Develop innovative approaches to decrease the size and increase the efficiency of battalion-scale W2E converter gasification systems that can work with existing tactical generators. The system had the following goals: 1) Process 1-3 tons of waste/day with an efficiency of >50%; 2) Produce non-hazardous residue; 3) Require minimal labor with no manual pre-sorting; and 4) Fit within no more than two 8'x 8'x 20' International Standards Organization (ISO) containers; overall goal is one ISO container.

The program pursued four complementary projects. Two projects developed updraft (countercurrent) gasification minimizing parasitic energy load. A third project pursued a rotary kiln based gasification technology, and the fourth pursued an optimized downdraft (co-current) gasification system.

Military Benefit: A W2E converter will supply base camps with electricity, make solid waste management less resource intensive, and decrease waste management health risks.

Accomplishments:

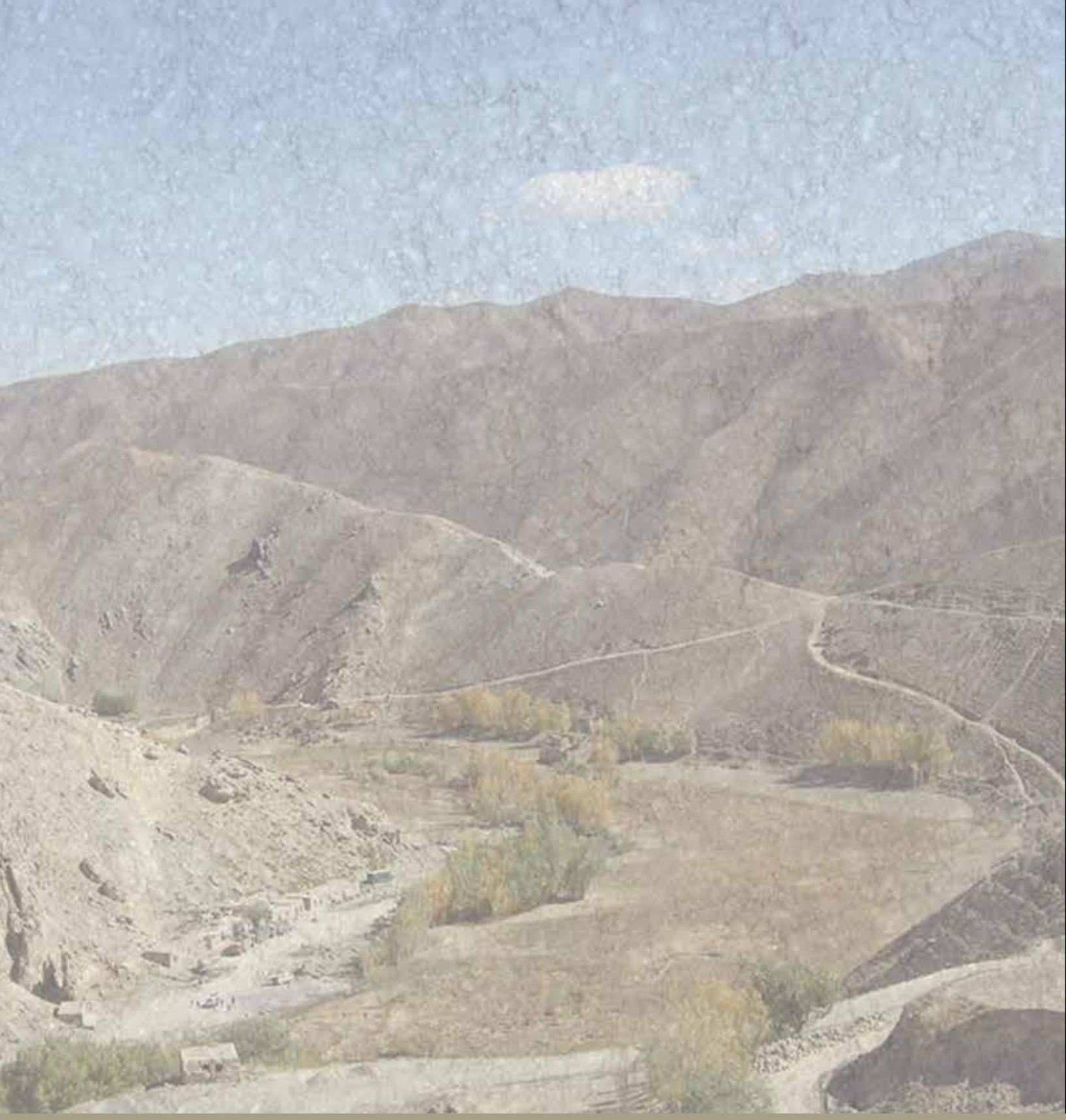
- Thermal Catalytic Syngas Cleanup for High Efficiency W2E Converters (WP 2210)
  - Completed tests, which indicate prototype system is able to meet established performance targets for field-deployable W2E converter.
  - Completed Integrated System Testing, which consisted of incorporating diesel generator with prototype system and evaluating syngas fuel substitution, emissions, and overall performance.
  - Prototype fully combusted waste fuel materials; surpassed 50% conversion target.
  - Future plans: Verify syngas product can be used as supplemental generator fuel.
- Rotary Gasification of Solid Wastes (WP 2211)
  - Achieved an 81% liquid fuel savings and 75% efficiency of gasifier to convert solid feedstock to fuel gas.

- Efficiency of entire process of converting feedstock to electricity varies from 12-20%.
- Developed and tested an entire WTE system based on a novel updraft rotary gasifier design.
- Future plans: Construct a version 2 gasifier that could be transported in ISO standard containers (Tricons).

- Shredded Waste Downdraft Gasifier (WP 2235)
  - Designed gasifier capable of processing three tons of mixed waste per day.
  - Results to date demonstrated lower producer gas energy than previously seen with paper/cardboard feedstock, possibly due to higher density of mixed waste shred.
  - Project with potential to enable lighter, more compact distributed W2E conversion solutions; transition opportunities exist with government/DoD and commercial market.

- Efficient Tar Management from Biomass and W2E Gasification (WP 2236)
  - Reactor system is probably too complex for a forward operating base W2E system.
  - Focus for future work: simplest method of getting waste energy into engine.
  - Transitioning system by constructing a Concord Blue (waste management company) waste to energy converter.

Transition: The Rotary Gasification system was the most applicable to contingency basing conditions. The program team submitted an FY 2017 proposal under the Office of the Secretary of Defense Environmental Security Technology Certification Program (ESTCP); however, final selections have not been made at this time.



FY 2013 OECIF Project Summaries:
CONSORTIA

TACTICAL MICRO GRIDS STANDARDS CONSORTIUM – FY13

Lead Organization: Army Corps of Engineers – Engineer Research and Development Center (ERDC)

Other Key Participants: US Army Communications-Electronics Research Development and Engineering Center (CERDEC), Massachusetts Institute of Technology Lincoln Laboratory (MIT-LL)

OE Funding Stream:

FY 2013 (M)	FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	Total
$2.5	$0.9	$3.7	$1.7	$1.7	$0.4		$10.9

Description: Micro grids are critical for improving DoD energy conservation in forward operating bases (FOBs) and Command Posts (CPs). Micro grids enable high efficiency utilization of diesel power generation and enhance DoD energy security through robust power distribution configurations. Consequently, interest in tactical micro grids is growing due to the potential for reduced fossil fuel consumption and greater integration of alternative energy sources. Tactical micro grids must be deployable and highly mobile. Standards for tactical micro grid communication and control are needed to enable interoperability, compatible, and ability to be easily integrated into a variety of systems. Once developed, the tactical micro grid can be applied to other military platforms such as ground vehicles and DoD installations

This program organized the Tactical Micro grids Standard Consortium (TMSC) consisting of military experts from all of the Services, Industry and Academia to:

- Develop, test, and publish a draft military standard (MIL-STD) for interoperable advanced power devices, including communications and control standards that will leverage existing and emerging micro grid standards to the greatest extent possible.
- Develop standards to fill gaps for resilient energy system implementation for Tactical Micro grids such as cybersecurity, electrical interconnection and islanding, and safety and grounding.

Military Benefit: The final deliverable is a non-proprietary open interoperability standard for open architecture micro grid devices (such as controllers, generation sources, intelligent distributions and smart loads) resolving the most significant impediments to widespread micro grid implementation. The payoff of the TMSC developed open interoperability MIL-STD is support to future cross platform advanced power, specifically:

- Ability acquire a family of interoperable advanced power components
- Modular, scalable, resilient, and cyber secure advanced power open architecture a host of DoD ground, sea, and air platforms
- Ability for mission commanders to precisely configure power equipment to specific missions over time

- Ability to incorporate any power source into ad hoc advanced power networks
- Increased power generation efficiencies
- Reduced logistics (transportation, fuel, and quantity of equipment) and maintenance

Accomplishments/Status:

- Accomplishments to date: Draft Tactical Micro grid Interoperability MIL-STD submitted to the Defense Standardizations Programs Office (DSPO) for approval. Successful development of four advanced open architecture micro grids, one developed by CERDEC and three developed by Industry.
- FY13 Accomplishments
  - Organized Tactical Micro grids Standards Consortium.
  - Conducted initial study and gap analysis of existing military and civil standards summarizing findings from 185 existing commercial and DoD standards, training manuals, safety manuals, and design guides
  - Identified key focus areas for the future draft interoperability standard including legacy equipment, planned tactical power acquisition programs, voltage drop on existing DoD cabling, legacy connector technologies, and DoD training and available personal protective equipment (PPE) compared to OSHA and the National Electric Code
- FY14 Accomplishments
  - Established three working groups of subject matter experts (SMEs) drawn from the Services
  - Identified five major gaps in existing micro grid standards and developed plans to address them
  - Established TMSC Industry Collaboration Group and virtual collaboration platform
- FY15 Accomplishments
  - Developed initial draft of the Tactical Micro grid Interoperability MIL-STD
  - Conducted significant reviews of the standard and advanced power discussions with Industry
- FY16 Accomplishments
  - Developed initial military micro grid prototypes
  - Published version two of draft MIL-STD

- Continued in-depth reviews with Industry
- Developed independent testing and verification protocols for draft standard

- FY17 Accomplishments
  - Initiated externally funded tactical micro grid interoperability verification
  - Conducted extensive draft reviews and revisions
  - Published version three of the draft MIL-STD

- FY 2018 Accomplishments
  - December 2017 demonstration of the basic functionalities of the open architecture using the phase 1 Industry developed micro grid prototype (two types of commercial generators)
  - July 2018 demonstration of the advanced functionalities of the open architecture using the phase 2 Industry developed micro grid prototype (phase 1 prototype plus two additional military Tactical Quiet Generators)
  - Began work on an open architecture vehicle to vehicle micro grid prototype (non-OECIF)
  - Published final draft of the Tactical Micro grid Interoperability MIL-STD and submitted to Joint Standardization Programs Office.

- FY 2019 Plans (On-going)
  - November 2018 demonstration of the Phase 3 Industry developed prototype micro grid (Phase 2 plus two non-modified commercial generators)
  - Conduct a NATO interoperability demonstration during another NATO country during NATO Exercise Capable Logistician 2019 (Poland) in May 2019
  - Receive approval of final draft as the new Tactical Micro grid Interoperability Standard

ENERGY EFFICIENT OUTPOST MODELING CONSORTIUM (EEOMC)

Lead Organization: Office of Naval Research

Other Key Participants: National Renewable Energy Laboratory; Army Communications-Electronics Research, Development and Engineering Center (CERDEC); Naval Postgraduate School; Navy Expeditionary Program Office

OECIF Funding Stream:

FY 2013 (M)	FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	Total
$1.4	$2.7	$2.8	$2.7	$9.4

Description: Reducing our military's reliance on fuel directly improves warfighting capabilities, making our troops more agile, lethal, and flexible; however, increasing battlefield use of renewables brings new challenges. Optimizing energy resources, their integration into a microgrid, and its ideal operation is crucial to improving battlefield fuel consumption. To do this, DoD requires new component and system-level energy modeling tools to aid decision-making by mission planners and operational commanders.

The EEOMC consists of a university-led consortium including Department of Energy (DOE) laboratories, DoD laboratories, and non-traditional defense contractors. This group executes research projects developed in conjunction with a DoD/DOE/Industry advisory board. The EEOMC effort has three pillars:

- Energy Resource Planning Tool – A modeling tool to determine the optimal mix of power resources (conventional and renewable sources, and energy storage) for a given operational scenario. The tool will also consider various energy efficient equipment combinations, such as space conditioning, lighting, and controls, and will simplify complex choices and provide recommendations for operational energy planners.

- Energy Resource Dashboard and Control – A dashboard 'app,' which will provide outpost commanders real-time control of energy resources. This Commander's app will take advantage of an integrated suite of sensors to monitor sources and loads and will include control features and health monitoring of equipment. Control standards will facilitate these applications and translate mission priorities into processes understandable by intelligent power systems.

- Energy Efficiency Training – Coursework incorporating energy concepts into operational planning will accelerate their adoption.

Military Benefit: During recent operations in Iraq and Afghanistan, thousands of troops were killed or injured moving and protecting fuel, much of it to support energy needs at combat outposts. Integrating the above three pillars will result in a balanced combination of tools and training, which will significantly improve the energy efficiency of contingency bases in the near future.

Accomplishments/Status:

- Completed Energy Resource Planning Tool (ver 2.0), including modules for photovoltaic, generator, and battery systems, shelter models, and optimization algorithm enhancements.
- Pre-release versions of the Commander's App were used to monitor and control hardware at the Base Camp Integration Laboratory, Contingency Basing Integration Technology Evaluation Center, and Network Integration Evaluation 16.1 demonstration events.
- Collected valuable feedback from over 30 participants across all Services at a pilot of the Energy Efficiency in Expeditionary Operations course.

Transition: The Navy has decided not to continue funding this program; however, Army CERDEC has programmed $1.5M in FY 2017 into continued development of the Energy Resource Dashboard and Control tool. Army Product Director Contingency Basing Infrastructure may continue funding the Energy Resource Planning Tool; however, no decisions have been made at this time.

ENGINEERED SURFACES, MATERIALS, AND COATINGS (ESMC) FOR DRAG REDUCTION

Lead Organization: Air Force Research Laboratory

Other Key Participants: Ohio Aerospace Institute (OAI) (prime contractor); Lockheed Martin (subcontractor)

OECIF Funding Stream:

FY 2013 (M)	FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	Total
$0.4	$1.6	$2.1	$1.9	$5.9

Description: In FY 2013, the Air Force consumed over two billion gallons of fuel per year at a cost of approximately $8B. As of 2014, jet fuel comprised about 8% of the total Air Force budget and 86% of the Air Force energy budget. Improving aircraft energy efficiency, which is a function of the lift-to-drag ratio (L/D), can lower these costs, improve range, and/or increase payload capacity. The goal of this research is to improve L/D by developing ESMC that will reduce aircraft drag by one or a combination of:

- Reducing skin friction (using 3d riblets, structured roughness, micro-fiber coatings), which accounts for approximately 50% of drag on transport aircraft;
- Making minor, non-structural, changes to the outer mold line of legacy fleet aircraft. These can be thought of as aircraft "fixes" enabled by modern day design tools, which were unavailable 30-50 years ago when the legacy fleet was designed.

Initial estimates have shown that ESMC may contribute as much as 2-4% reduction in drag. This program created a team of ESMC providers, government, industry, and end users. The goal of the team is to develop a forum for ESMC technology suppliers to work with end users to develop, test, and demonstrate drag reducing technologies.

Military Benefit: Reducing aircraft fuel consumption by reducing drag through ESMC will not only reduce the Air Force's fuel bill, but, more significantly, increase military capabilities. Range and payload capacity will improve, thus creating second order operational energy benefits, such as a reduction in necessary sorties, tanker support, and fuel requirements at forward operating locations. A drag reduction of X% will result in fuel savings or range increases of about the same percentage.

Accomplishments/Status:

- Contract awarded (June 2015) for ESMC Team, OAI and Lockheed Martin. OAI is maturing three skin friction reduction technologies – 3D riblets, structured roughness, and micro-fiber coatings.

- Completed a world-wide open innovation competition with the objective of reaching atypical (non-traditional) technology providers ("solvers").

    - Received 95 white papers from 26 countries and 19 US states.

    - Three subcontract awards made for technology maturation.

- Designed fairings for C-17 drag clean-up. The C-17 is a circa 1980 aircraft designed with 1970s tools. There are areas on the aircraft which have flow separation which result in a total drag penalty of ~5% - at the engine pylon/leading edge wing juncture and winglet/ wingtip juncture. In 2014, the C-17 fleet burned 461 million gallons of fuel, so even single digit drag reduction will have a very large impact on fuel burn.

    - Flight test of C-17 drag reduction fairings was conducted; however, only 0.3% drag reduction was achieved, which was insufficient for a convincing business case.

Transition: AFRL has programmed $500K in FY 2017/2018, along with $1M per year from FY 2019-2021 for drag reduction technologies. The first priority for the FY 2017/2018 funding is the C-17 fairings flight test (amount TBD). The remaining funds will be used for additional tech maturation of 3D riblets. The funding in FY 2019-2021 would be used to flight test technologies if they have been matured to Technology Readiness Level 5 (i.e., component and/or breadboard validation in relevant environment).

SOLDIER AND SMALL UNIT OPERATIONAL ENERGY (SSUOE)

Lead Organization: Army Natick Soldier Research, Development & Engineering Center (NSRDEC)

Other Key Participants: Army Communications-Electronics Research, Development & Engineering Center; Army Research Lab; Program Executive Office (PEO) Soldier; Maneuver Center of Excellence; PEO Command Control Communications-Tactical; and U.S. Marines Corps (USMC)

OECIF Funding Stream:

FY 2013 (M)	FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	Total
$1.4	$4.6	$4.0	$3.3	$13.4

Description: Dismounted troops and units perform difficult missions that require situational awareness, lethality, and mission tools that consume large quantities of energy – a typical Soldier carries 18 pounds of batteries for a 72-hour mission. The units must carry the power needed while facing harsh operating conditions, durations, environments, and terrains. The logistics burden placed on the small unit incurs significant operational, fiscal, and human performance costs. Reducing the number, resupply, type, and weight of batteries borne by Soldiers and small units requires a systematic approach that considers material and non-material solutions for the Dismounted Warfighter.

The program has four key goals:

- Develop system engineering architecture for power and energy use by Dismounted Soldiers.
- Bring together a wide variety of players, both inside and outside the government, in order to comprehensively attack the problem.
- Identify specific areas where the Soldier operational energy burden can be reduced and develop innovative technologies to bring about these reductions.
- Identify specific obstacles to reducing the operational energy burden on Soldiers and recommend materiel and non-materiel changes to address these obstacles.

Military Benefit: The Department of Defense will gain: 1) a comprehensive system engineering framework for understanding and managing the power and energy needs of dismounted Soldiers and small units, thereby limiting the burdens they create, and 2) an organizational structure to attack the problem, educate unit leaders, and create more efficient use of power. A comprehensive approach to the problem may be able to reduce the weight carried by

Soldiers or units by up to 30% through informed leadership, reduced waste, effective training, and more efficient and effective technologies. This activity will also provide an opportunity to capture and integrate soldier needs into existing modeling and simulation efforts throughout the DoD.

Accomplishments/Status:

- Worked with USMC to draft their Dismounted Forces Energy Requirements (DFER) Concept of Employment policy document, which provides fundamental guidance and an overarching concept for USMC equipment associated with the operations and employment of power related devices utilized by DFER throughout the range of military operations.

- Developed Power and Energy (P&E) Test Bed and characterized Nett Warrior baseline configurations. This effort has led to energy efficiency improvements to the fielded radio through software changes and informed Program Manager Soldier Warrior on the order of 50%.

- Using the SSUOE Test Bed, provided data to Program Manager Soldier Warrior to support Milestone C Decision for the Integrated Soldier Power & Data System.

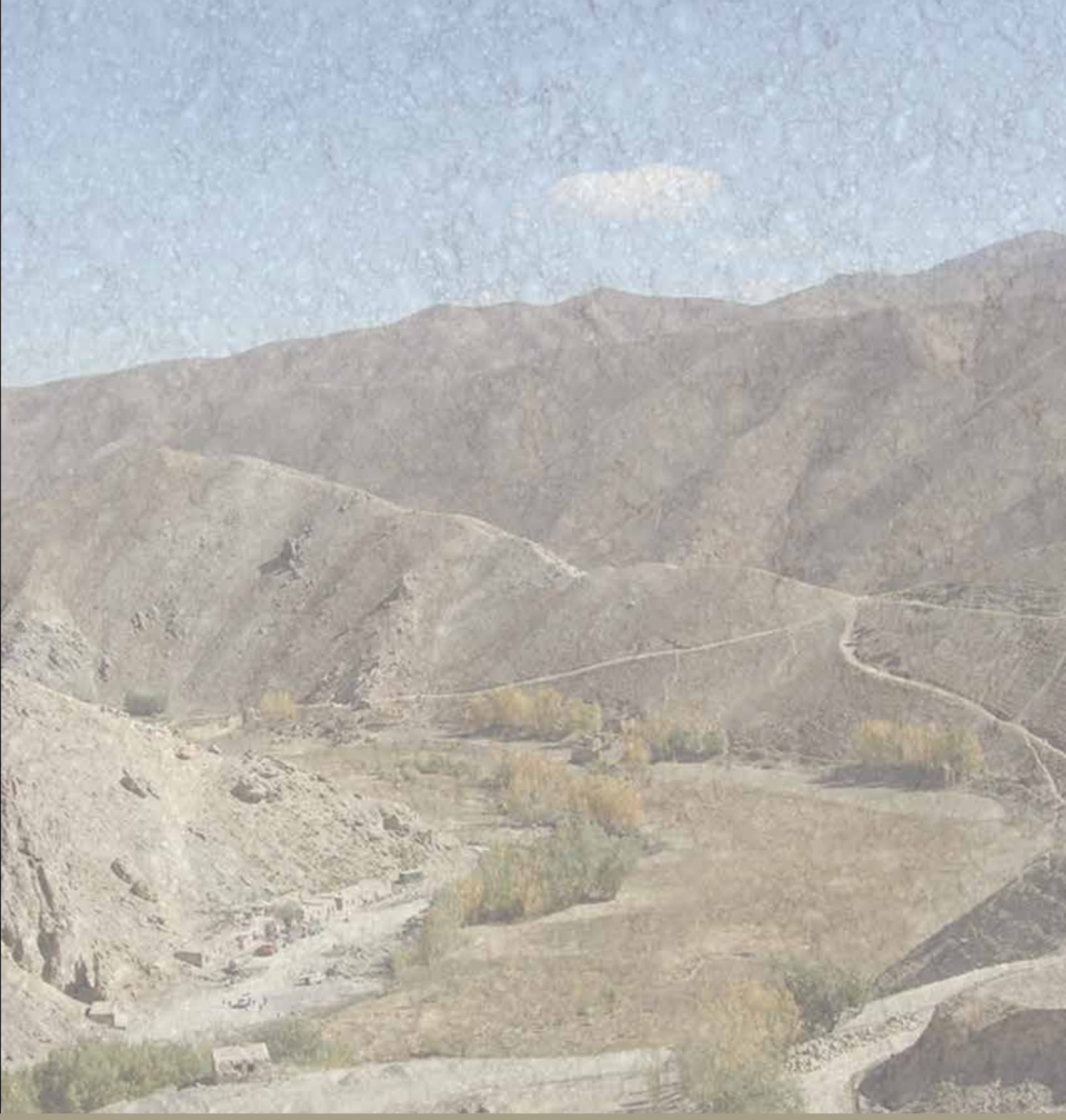
- Continued development of the Operational Wearable Configuration System to demonstrate Soldier power and energy equipment configurations under field conditions.

- Started Soldier load versus performance data collection, process, and draft results report.

- Validate software changes made to a fielded radio to improve energy efficiency by 30%.

- Plan and coordinate Dismounted Soldier/Marine efforts beyond FY 2016.

Transition: The P&E assessment tools will transition to the US Army Natick Soldier Research, Development and Engineering Center as an enduring capability. The Soldier load versus performance predictive tool will transition to PEO Soldier, Office of the Surgeon General, and US Army Institute for Environmental Medicine. For FY 2017, SSUOE is planning to fund multiple P&E planning tool apps via the Army and USMC that will provide the Warfighter on the ground the ability to look at the mission objectives and terrain and determine the exact P&E kit that will be needed during the mission as well provide a health check (state of charge) on all batteries during the mission. The planned transition path is to NSRDEC, Nett Warrior, Special Operations Command, and USMC. Several proposals have been developed to fund studies and continue SSUOE efforts; however, the Army has not approved any additional funding at this time.



FY 2014 OECIF Project Summaries:

ANALYTICAL METHODS AND TOOLS

CAPABILITY ASSESSMENT & MODELING FOR ENERGY LOGISTICS (CAMEL)

Lead Organization: Air Force Research Laboratory Aerospace Systems Directorate (AFRL/RQ)

Other Key Participants: Air Force Life Cycle Management Center (AFLCMC); Air Mobility Command (AMC); Pacific Air Forces (PACAF); U.S. Transportation Command (USTRANSCOM)

OEPP Funding Stream:

FY 14 (M)	FY 15 (M)	FY 16 (M)	FY 17 (M)
$1.0	$1.4	$1.5	$1.4

Description: Operational Energy (OE) strategy and mitigation of counter-OE threats plays a crucial role in US military/humanitarian objectives and directly equates to power projection. The overall goal of CAMEL is informing OE decisions to beneficially impact future warfighting capability. CAMEL assesses the impact of energy logistics within contested operational environments and the strategies, e.g., materiel and behavioral, to mitigate threats. CAMEL investigates Joint operational capabilities of strategic/tactical airlift, aerial refueling (AR), and maritime delivery. The costs and cost-effectiveness of solutions to mitigate counter-energy threats in an anti-access area denial (A2AD) environment and reduce mobility air force (MAF) and combat air force (CAF) OE needs are also studied.

AFRL applied CAMEL methodology to investigate mid- and far-term technology improvements to the mobility fleet and impacts on OE consumption, concept of operations changes, and ability to mitigate threats to the energy logistics chain. For a given scenario, CAMEL analytics: 1) identify OE capability gaps and vulnerabilities; 2) characterize technology threshold requirements to decrease vulnerabilities and achieve required operational capabilities; 3) decipher potential behavioral changes to reduce OE consumption; and 4) provide cost effectiveness data for both technology and behavioral solutions.

Military Benefit: The capability to identify and assess technology improvements and behavioral changes to reduce OE consumption, mitigate threats to the energy supply chain, and inform decision makers regarding future investments on how to reduce cost and improve military operations.

- Joint Force - Show risk to OE on a system-of-system basis to increase Warfighter capability.
- AMC – Fully account for OE challenges to logistics and highlight the Joint implications.
- AFLCMC - Created a tool suite that measures/compares OE impact to current and concept aircraft.
- PACAF - Inform basing decisions within a contested environment and required aircraft capabilities to meet extended range demands.

- USTRANCOM - Joint mobility planning/modeling that mirrors Joint mobility operations.
- AFRL - Quantitative data/insight to inform S&T investment decisions/strategy.

Accomplishments/Status: CAMEL methodology has been applied to inform OE decisions that beneficially impact future warfighting capability by assessing the military worth and value of MAF-related capabilities to the joint war fight.

- FY 2014 Accomplishments (funding received December 2014)
  - Refined analytical approach to reveal impacts of alternative basing, MAF/CAF technology concepts, TPFDD changes, and CONOP/CONEMPs on OE
  - Assessed impact on CAF fuel demands Analysis of OE impacts on aerial fueling requirements given Adaptive Engine Technology Development (AETD) performance improvements during future combat air force operations
  - Evaluated existing MAF and future concepts in permissive and constrained ISC-A, ISC-B scenarios on OE-focused analysis of advanced strategic airlift technologies
  - Integrated USTRANSCOM's Analysis of Mobility Platform (AMP) data into DoD Synthetic Theater Operations Research Model (STORM) to allow for analysis projecting effects from mission- to campaign-level
- FY 2015 Accomplishments (funding received August 2015)
  - CAMEL project placed on AMC Rapid Global Mobility Roadmap
  - KC-46 Capabilities Based Assessment (CBA) team adopted CAMEL methodology/ results
  - AMC/A5 requests CAMEL leadership participate in KC-46 CBA as AR/MS&A SMEs
  - Collaborated to increase design of experiments (DOE) capability. Optimization of COTS PIANO software generates optimized DOE investigating strategic MAF deployment utilization
  - Worked with USTRANSCOM on AMP upgrades enabling automated and distributed execution of AMP to facilitate large DOE
- FY 2016 Accomplishments (funding received September 2016)
  - CAMEL sponsored a 2 day operationally-focused workshop at HQ AMC with AR and airlift operators to aid them in identifying and evaluating advanced AR concepts and CONEMPS
  - KC-46 CBA report contains CAMEL analysis, informs Initial Capabilities Document (ICD)
  - Tanker Fuel Cost & Base Enhancement/Assessment Tool (TFC-BEAT) MILCON costing tool
  - Sponsored/beta-tested cargo bay options in USTRANSCOM's Analysis of Mobility Platform (AMP). Allows user-specified modeling/analysis of increased volume/payload configurations
- FY 2017 Accomplishments (funding received April & September 2017)

- Tanker Battlespace Operations & Logistics Tracking (T-BOLT) AR tool
- Increased fidelity of legacy/concept MAF (tanker, airlift) fuel calculations in AMP modeling tool. User option overrides static database fuel tables and allows for accurate assessments
- Leveraged/applied CAMEL methodology and completed phases 1 and 2 of Advanced Aerial Refueling Concepts Capabilities (AARCC) study with the AFLCMC

- FY 2018 Accomplishments
  - Collaborated with SAF/IEN to modify BEAT (subset of TFC-BEAT). The MOG calculator and infrastructure functions were used for Global Engagement 18 OPORDs and war-game
  - Completed first stage of application to optimize AR track/orbit locations given a scenario/campaign. Factors include AR time, dissimilar receivers, dissimilar tankers, threat avoidance, required routing, etc. AR asset use is crucial in logistics-strained A2/AD ops

COMPREHENSIVE OPERATIONAL ENERGY TOOLKIT (COE TOOLKIT)

Lead Organization: Air Force A9 (Studies, Analyses, & Assessments)

Other Key Participants: Air Force Life Cycle Management Center; Air Combat Command; Air Force Material Command; Air Force Global Strike Command; Air Force Research Lab; Office of the Chief of Naval Operations

OE Funding Stream:

FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	Total
$0.2	$1.2		$1.4

Description: Currently, a comprehensive way of examining the effectiveness and impact of enemy attacks against airbase infrastructure does not exist. This program performs research into the development of a comprehensive modeling and simulation toolkit to help examine these vulnerabilities to operational energy and the impact it could play on both energy use and combat operations. This program would be a holistic look at operational energy (aviation fuel, vehicle fuel, electricity, etc.), not just at a base, but would tie in delivery of energy resources to a base. The toolkit will consider the interactions of the force "tooth" and "tail" in a contested environment. The results would be of decision quality and could be used to inform senior leaders across DoD and the Services as well as provide information for other analytic tools, such as the Synthetic Theater Operations Research Model or the Bayesian Enterprise Analysis Model military enterprise level examination tool. The designed tools will be 'side agnostic,' which allows for not just a defensive look at operational energy, but could be used to see the impacts of denying operational energy to potential adversaries. The program will follow a two-phase analytic approach to achieve the goals of providing insights to senior leaders and data for use in campaign level tools. Phase 1 will develop a tool to examine

current and projected future 'Red Side' munitions against a variety of energy related targets. Phase 2 will develop a detailed air base model that can then be attacked by "red" with automation tools allowing for a large series of runs to determine various attack options/effects.

Military Benefit: This program will fill existing gaps in DoD analysis capability and provide a traceable scientific methodology as a DoD standard to examine the use of energy at air bases and how that energy can get to the base. This suite of tools will inform joint campaign analysis efforts and include inputs from all Services. The results will be available to all Services (and potentially allies as well) at no cost as a common basis for discussion. The tools will be developed using state-of-the art programming techniques and should be viable and modifiable for the next 10-20 years.

Accomplishments/Status:

- Completed stage 1 development to take existing weapons and infrastructure data and apply current/forecast adversary weapons capability to attacks on energy-related airfield infrastructure.
- Completed stage 2 development of the detailed, single installation air base model. This uses automation techniques to attack the energy-related infrastructure in a large series of model runs and measures the damage. Using the model, the analyst can determine various attack options/effects on the infrastructure. Initiated development of the multi-installation attack and measurement of impact on sortie generation.

JOINT DEPLOYMENT ENERGY PLANNING AND LOGISTICS OPTIMIZATION INITIATIVE (J-DEPLOI)

Lead Organization: U.S. Pacific Command (USPACOM)

Other Key Participants: U.S. Transportation Command; Institute for Defense Analyses; Space and Naval Warfare Systems Command, Defense Logistics Agency-Energy, US Army Core of Engineers Geospatial Research Laboratory, Group W

OE Funding Stream:

FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$0.4	$1.1	$0.8	$1.2	$1.4	$4.9

Description: The J-DEPLOI program deliverable is an analytic tool and associated policy and process improvements to facilitate energy analyses earlier in the Joint Planning Process (JPP). It allows operational planners to visualize, quantify, and collaboratively evaluate fuel logistical vulnerability of various COAs during the COA Development, COA Analysis and War gaming, and COA Comparison steps of the JPP. These evaluations would then support refinement of COAs and inform the Commander's COA selection.

Military Benefit: J-DEPLOI addressed policies, procedures, and developed a collaborative information technology tool for fuel logistical COA comparison which draws upon authoritative joint databases. These efforts facilitate operational energy consideration during planning and visualize fuel supply chains and their potential vulnerabilities earlier in the Joint Planning Process (JPP). Tools developed and refined for USINDOPACOM's fuel logistics planners are being developed in a way to facilitate planners across the combatant commands, tested in a realistic environment through designed experimentation, and prepared for transition to use by joint and service planners.

Accomplishments/Status:

- Accomplishments to date: Product condensation on walls eliminated with dynamic water blanket; Aluminum powder fuel has been made to flow reliably; system and combustor modeling conducted; three laboratory tests executed; and laboratory hardware design improvements implemented to support future breadboard component testing.

- FY 2014 Accomplishments

  - Project Kickoff
  - Program Plan Completed
  - Approved Problem Statement

- FY2015 Accomplishments

  - Conducted Gap Analyses and Requirements Review
  - Evaluated over sixty (60) information technology tools and modeling & simulation programs against priority functions and capability gaps identified in process map
  - Course of Action (COA) Voting and Tool Selection

- FY 2016 Accomplishments

  - Identified non-material solutions to address within scope of J-DEPLOI. Requested assistance from DLA-E
  - Drafted J-DEPLOI Implementation Directive
  - Published Phase I Report: Improving Operational Analysis for Deliberate Planning
  - Awarded tool development contract to Group W
  - Group W begins MBPS onboarding process

- FY 2017 Accomplishments

  - Group W completes MBPS onboarding process
  - Begin tool development using MBPS agile development cycles
  - Finalized J-DEPLOI Implementation Directive and Program Requirements Document

- Completed first Feature Requirements Specification (FRS) on Sustainment Application and Sustainment Attributes (includes data and user interface functionality)
- Completed Verification Plan

- FY 2018 Accomplishments/Plans
  - Conducted User Demonstration for feedback
  - Continue tool development: complete second FRS on Sustainment Sketch and Feasibility
  - Published J-DEPLOI Verification & Validation Roadmap
  - Evaluating User Assessment options (in process)
  - User Assessment (planned)

DEVELOPING AN OPERATIONAL ENERGY THEATER SUPPORTABILITY ANALYSIS TOOL KIT OPERATIONAL ENERGY ANALYSIS TASK FORCE (OEATF)

Lead Organization: U.S. Army Training and Doctrine Command Research, Analysis Center / U.S. Army Materiel Systems Analysis Activity and Tank Automotive Research Development and Engineering Center

Other Key Participants: Center for Army Analysis

OE Funding Stream:

FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	Total
$1.0	$2.2	$2.6	$2.1	$7.9

Description: The Operational Energy Analysis Task Force (OEATF) was initiated to establish a foundational OE analytic capability, eventually leading to an OE analysis architecture capable of informing Joint decisions related to capability needs [requirements] analysis (CNA); cost-benefit analyses (C-BA); force design/force structure alternatives; analyses of alternatives (AoA); and operational plan (OPLAN) development and refinement. This program will address identified gaps in data, scenarios, and methods, models, and tools (MMT) to more adequately represent and assess effects of OE disruption on force effectiveness. Specifically, it will be used to enhance current data, scenarios, and models to develop a campaign sustainability assessment toolset from the item to theater-level.

Military Benefit: By integrating select data, scenarios, and MMT, the Army will be able to evaluate the effects of OE requirements across the entire force, and support the evaluation of materiel solutions, trade studies, and C-BA. The planned capabilities will support the science and technology community, requirements developers, and ongoing acquisition analysis activities at both the Army and Joint levels by helping to identify opportunities for energy-saving investments.

This capability will quantifiably answer three questions: 1) how does system-level OE performance change, 2) what is the effect on unit OE demand, and 3) what are the sustainment implications of OE changes? Additionally, this effort will develop a sustainment planning tool to support military operational planners during OPLAN development.

Accomplishments/Status:

- Developed and demonstrated the analytic capability to conduct OE analysis, including the fully burdened cost of fuel, up to the theater level.
- Have made progress towards mitigating identified gaps:
  - Completed V&V of the Shelter Thermal Energy Model (STEM) and the Fuel Consumption Prediction Model (FCPM) for wheeled vehicles
  - Completed building the framework for an Equipment Characteristics Database.
  - Completed baseline M&S representation of Scenario 3, for both Phases 3 and 4.
  - Completed scenario enhancements for both Scenarios 3 and 6. Have begun building Scenario 7, the third and final scenario that will be enhanced under the OECIF effort.

SYNTHETIC THEATER OPERATIONS RESEARCH MODEL - ENERGY (STORM-E)

Campaign-Level Perspective on Operational Energy (STORM-E)

Lead Organization: U.S. Marines Corps/Deputy Commandant, Combat Development and Integration/Operations Analysis Division (OAD)

Other Key Participants: Deputy Commandant, Combat Development and Integration/Futures Division/Ellis Group; Office of the Assistant Commandant/Expeditionary Energy Office (E2O)

OE Funding Stream:

FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$1.4	$0.4	$3.0	$1.3	$0.9	$6.9

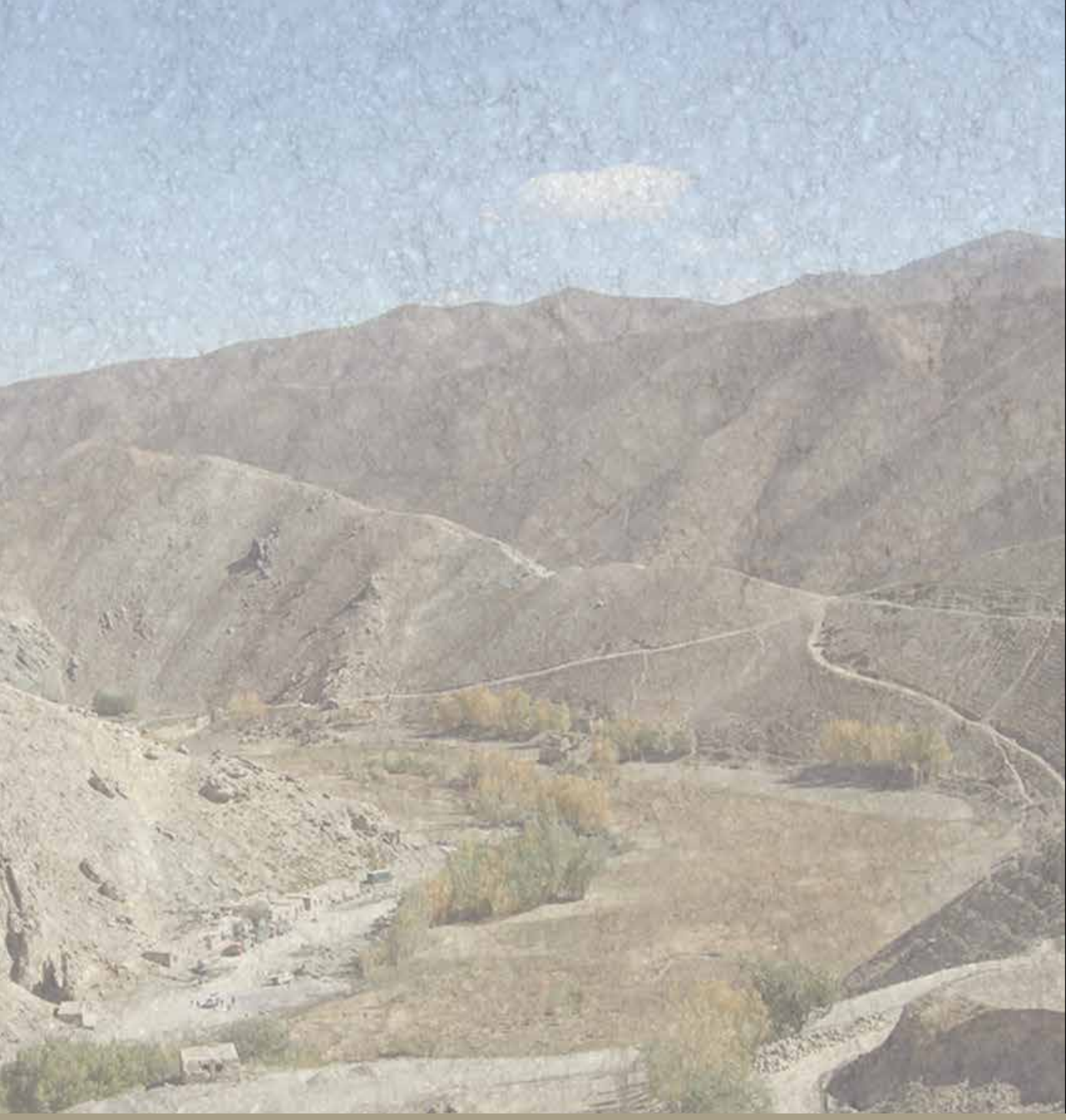
Description: Large-scale force sizing and shaping decisions are typically informed by campaign-level analyses supported by specially developed methods and tools. Currently, there is little capability within DOD to provide senior-level audiences accurate and credible insights into the implications of operational energy (OE) for force effectiveness and operational risk above the tactical level. The Marine Operating Concept (MOC) provides an ideal opportunity to make OE a primary factor in campaign analysis by providing guidance for concepts and service capabilities and informing force posture, organization, and emerging capabilities This program will develop a campaign perspective on OE that:

- Answers properly framed questions with measurable differences between alternatives;
- Adds resolving power to the Synthetic Theater Operations Research Model (STORM) campaign model to produce actionable insights; and
- Integrates analytical results into decision-making processes in time to influence plans and programs.

Military Benefit: A coherent, campaign-level perspective on operational energy will give the Marine Corps a rigorous method for exploring the relationship between energy supply and demand for the employment and effectiveness of systems, concepts and capabilities, and in turn, assess the impact of energy availability and use on higher level military outcomes and force effectiveness. The ultimate goal is the institutionalization – across the DoD analysis community – of an authoritative and accepted way to evaluate the implications of energy supply and demand.

Accomplishments/Status:

- FY 15-17 Accomplishments
  - Implemented incremental energy-focused improvements to the STORM to facilitate energy analysis at the campaign level.
  - Conducted multiple iterations of STORM Operational Energy Studies (SOES) exploring operational energy implications for the MOC.
  - Produced and instantiated classified scenario in STORM for use in SOES-18.
- FY-18 Accomplishments (Funding received July 2018)
  - Implementing additional incremental energy-focused improvements to the STORM to further enhance energy analysis at the campaign level.
  - Conducting this year's iteration of SOES (SOES-18) which continues exploring operational energy implications for the MOC in the new scenario created during FY 2017.



FY 2015 OECIF Project Summaries:

IMPROVING FUEL ECONOMY FOR THE CURRENT TACTICAL GROUND FLEET

AUTONOMY-ENABLED FUEL SAVINGS FOR MILITARY VEHICLES

Lead Organization: U.S. Army Tank Automotive Research, Development & Engineering Center (TARDEC)

Other Key Participants: Department of Energy (DOE) Argonne National Laboratory (ANL), DOE National Renewable Energy Laboratory (NREL), Aberdeen Test Center (ATC), Auburn University, Michigan Department of Transportation (MDOT), ASRC Federal Services

OE Funding Stream:

FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total (M)
$1.6	$1.0	$1.4	$0.8	$4.8

Description: Leverage TARDEC, DOE, ANL, NREL, Office of Naval Research (ONR), Army Program Executive Office (PEO), and Marine PEO expertise to develop and test autonomy-enabled technologies to reduce fuel consumption for military vehicles which will yield a smart adaptive cruise control to optimize fuel economy during military missions, as well as for commercial driving applications to include vehicle convoys.

Reducing fuel consumption allows more flexibility in mission options. Saving fuel with convoys provides another opportunity to extend, reduce or optimize the logistics. The ability to develop a Model Predictive Controller (MPC) is an optimal control technique which can be used to reduce fuel consumption by using a priori knowledge of the route which is well suited for the M915's operations. TARDEC Analytics (Modeling & Simulation Group) is consistently tasked with predicting fuel consumption rates for vehicle modifications or future vehicles. Knowledge and simulation methods learned on this project are applicable to the current and future work load. Collaboration with commercial (i.e. Federal Highway Administration and Department of Transportation [DOT]) to on-road platooning for fuel savings which is a hot topic in the DOT community.

Military Benefit: This OECIF proposal for research on autonomy-enabled technologies will provide the following benefits to the US DOD.

- Reduce fuel consumption by greater than 5% with potential of 10-20%
- Increased range of vehicles
- Reduction in fuel transport missions
- Increased Safety – Reduce rear end collisions of vehicles in convoys
- Decreased cost and downtime through reduced vehicle brake maintenance

Accomplishments/Status:

- Accomplishments to date: The program has developed accurate detailed models of the M915A3s and M915A5s by testing the vehicles individually and then feeding the results back into the models in Phase I. In Phase II the focus was to add additional vehicles to the models and maximize the benefits of smart cruise control and fuel economy focused gap control that is not able to be accomplished by a human driver. The project was terminated by OSD however in May 2018 just days prior to actually validating three years of work to determine the performance of the vehicles in real life versus the models along with the ability to provide answers to several theories on what happens when vehicles operate in close gaps.

- FY 2015 Accomplishments (funding received July 2015)
  - Program planning and start-up administration
  - Funded and formed 35+ member IPT
  - Defined requirements
  - Started modeling of M915s

- FY 2016 Accomplishments (funding received third quarter FY16)
  - Completed physics based M915 model with initial validation
  - Completed algorithm development, which included driver aggressiveness analysis
  - Received a delivery of MATV convoy data logs from Afghanistan
  - Vehicle instrumentation installed in two test vehicles
  - Successfully completed Phase I testing at Aberdeen Test Center (ATC)
  - HIL/SIL created models that have fed the Autonomous Ground Resupply (AGR) program

- FY2017 Accomplishments (funding received third and fourth quarter FY17)
  - Generated Phase I test reports
  - Reviewed data to update and validate M915 models from actual vehicle testing from Phase I in FY16
  - Started Phase II to evaluate three vehicle convoy scenario
  - Worked instrumentation installation for Phase II
  - Determined technology path for vehicle convoys
  - Tested on Blue Water Bridge from US to Canada
  - Two papers were brief at GVSETS
  - Ordered AVL fuel meter

- FY 2018 Accomplishments (still waiting on termination funds)
  - Dedicated Short Range Communications (DSRC) Phase II Testing
  - Convoy vehicle integration on M915s
  - Smart Cruise and Convoy Algorithms delivered
  - Shake out testing of technology in prep for official testing at ATC
  - Project terminated by OSD prior to official validation testing of program efforts at ATC

TACTICAL VEHICLE ELECTRIFICATION KIT (TVEK)

Lead Organization: Ground Vehicle Power and Mobility (GVPM-TARDEC)

Other Key Participants: Army Tank Automotive Research, Development & Engineering Center (TARDEC), Missiles Defense Agency - PM THAAD, Marine Corps PEO Land Systems, OSHKOSH Defense, Office of Naval Research (ONR), and Department of Energy Vehicle Technologies Office (DOE-VTO).

OE Funding Stream:

FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$3.8	$2.2	$5.7	$3.3	$15.0

Description: TVEK project goal is to develop and demonstrate an affordable truck auxiliary system electrification kit on one or more existing Heavy Tactical Wheeled Vehicle (TWV) platforms to significantly improve vehicle operational energy efficiency. TVEK project is funded by the Operational Energy Capability Improvement Fund (OECIF) as part of the Operational Energy Program Planning (OEPP) from Office of the Secretary of Defense (OSD). The funding is for improvement of the Department's operational effectiveness via targeted science and technology investments that are intended to improve the energy performance of key elements of our forces. The project aims to leverage DOE, Army, ONR, and Marines electrification investments in development of the kit. The project will validate the kits capability and business case for transition. The estimated total combined fuel savings is in the range of 15% to 25% over current performance on current HEMTT A4, and HEMTT A2 variants. The kit and the results are relevant to most tactical vehicles.

Military Benefit: The TVEK project will provide the following benefits to the transition partner, PM THAAD, and other services as follows:

- Intelligent start/stop (anti-idle) strategy, auxiliary system electrifications and smart system controls to Demonstrate (T) 15%/ (O) 25% fuel use reduction.

- Affordable auxiliary system electrification kit for tactical vehicles. Project directly supports HEMTT A4, A2 Missile Launcher, MTVR, and FMTV.

- Shore power connection for base power or vehicle auxiliary functions.
- Capability to support future electrical needs for silent watch, jamming, communications, e-weapons, and e-armor.
- Reduced maintenance burden and elimination of hydraulic systems.
- Achieving safe integration of high voltage power generation.
- Specifications and evaluation of TRL at auxiliary systems and system level.
- Universal (platform agnostic)
- Common M&S model architecture and supervisory software Accomplishments/Status:
  - Accomplishments to date: The TVEK project has recently completed a critical milestone of down-selecting of TVEK kit components for procurement for System Integration Lab (SIL) testing and vehicle build/test.
- FY 2016 Accomplishments
  - Completed Market research and trade off study for HEMTT A4 baseline components.
  - Successfully awarded contract award to HEMTT A4 vehicle OEM for TVEK support, OSHKOSH defense.
  - Setup System integration lab for baseline vehicle and component testing activities
- FY2017 Accomplishments
  - Obtained HEMTT A4 vehicle for TVEK testing and demonstration
  - Completed HEMTT A4, LVSR vehicle space claim and packaging study for electrified TVEK component feasibility study
  - Completed anti-idle control strategy for supervisory controls in MatLab Simulink.
  - Completed CAT15 engine fuel map testing for baseline fuel economy study, Modeling and Simulations.
  - Completed GTSuite models for HEMTT A4 vehicles to simulate baseline vehicle fuel economy based on known vehicle drive cycle.
  - Setup and tested TVEK candidate 20kW inverter with the 20kW motor – demonstrated stable power generation capability for high voltage generation system.
  - Setup and tested 15kW candidate DC/DC converter for
  - Obtain letter of endorsement and agreement for TVEK systems/component to transition/demonstration for PMTHAAD's HEMTT A2 Missile launcher system.
- FY 2018 Accomplishments to date and future plans (ongoing)

- Demonstrated CAT15 engine start/stop operation in GVPM SIL, a major milestone for anti-idle system control development.
- TVEK subsystems down select completed – Selected Components are sent to OHSKOSH for procurement for intended SIL testing throughout FY18
- Successfully connected and enabled basic engine controls with the CAT15 engine via selected Supervisory Controller in place of FlexECU (demonstrated in March visit)
- Completed HVAC compressor testing – analyzing performance data for OSHKOSH Phase II modeling and placement of the complete HVAC system (Condenser, AHU, motor) on HEMTTA4.
- Completed HEMTT A4 fan characterization and powertrain cooling test. Data gathering and analysis are ongoing.
- OSHKOSH's contract modification is in process to replace the LVSR vehicle with HEMTT A2 missile launcher vehicle, design and integration of TVEK components for transition partner PM THAAD.
- Anti-Idle Demonstration – GVPM in house laboratory
- Procurement of TVEK components for vehicle integration

- FY 2019 Plans

  - TVEK vehicle integration at vehicle OEM, OSHKOSH, WI
  - Safety Release testing and data collection– APG
  - TVEK vehicle Anti-Idle Demonstration
  - GVPM PEVEL lab evaluation of TVEK integrated vehicle for comparison with baseline vehicle performance.
  - PM THAAD system demonstration for PM THAAD transition
  - Complete compilation TVEK project test data collection, system performance analyses,
  - Return of Investment (ROI) and final reporting
  - Provide TVEK final data package to all stakeholders and inform requirements to requirement communities (TRADOC, MCOE, other Services)

VEHICLE LIGHT-WEIGHTING USING M&S

Lead Organization: Tank Automotive Research Development Engineering Center (TARDEC) - Analytics

Other Key Participants: PM – Transportation System, PdM Bridging / PEO – CS&CSS

OE Funding Stream:

FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M))	Total
$0.2	$0.2	$0.6	$0	$1.2

Description: The Analytical framework methodology developed during the 'Vehicle Light-weighting using M&S' effort on the FMTV platform will directly go towards being a part of the core competency Modeling & Simulation capability across TARDEC and Army M&S. The knowledge gained from this capability development will help TARDEC support current and future vehicle platforms for reducing weight and improving fuel economy.

This effort funds development of analytical framework for structural and topology optimization capability in-house for vehicle light-weighting using M&S. This will allow TARDEC Analytics to support other Army ground vehicle platforms to improve fuel efficiency and reduce logistics burden. This will also help support technology transition / ECPs for current platforms and vehicle prototypes by conducting vehicle light-weighting using structural optimization.

The project was terminated by OSD-OE, which disables the completion of light-weighting with structural optimization M&S, using loads data collection from Aberdeen Test Center, use of novel materials for light-weighting and transition of methodology to other vehicle platforms.

Military Benefit: This OECIF proposal for vehicle light-weighting using M&S will provide the following benefits to the US Army.

- Analytical Framework – The Analytical framework methodology for light-weighting developed can be leveraged to support technology transition / engineering change proposals for current Army / Marine Corps combat and tactical ground vehicle fleet platforms. This capability will be part of core M&S work at TARDEC to support TARDEC vehicle prototypes like the JTTS, emerging ground vehicle systems like the MPF and FFV and potentially in the commercial automotive industry.

- Novel Light-weight material transition - TARDEC will utilize the knowledge gained from incorporating novel light-weight metallic material M&S for weight optimization of the FMTV vehicle platform on other current and future vehicle platforms. The lessons learned and models developed will be used to inform future requirements for vehicle light-weighting.

- Vehicle Platform transition - TARDEC is currently working with PM – Transportation Systems, which is part of the Army Program Executive Office (PEO) Combat Support and Combat Service Support (CS&CSS). PM - TS is providing input and guidance in shaping the light-weighting

- M&S effort and the lessons learned from this project will be rolled across other Army ground Vehicle platforms.

Accomplishments/Status:

- Accomplishments to date: Developed analytical methodology framework for vehicle light-weighting using M&S. Developed in-house optimization capability for structural optimization and light-weighting. Identified target components for light-weighting. Generated new designs showing weight savings vs current design, with same performance. Developed test plan to collect loading data for the FMTV, which will be used as input in FEA model to conduct structural optimization for light-weighting.

- FY 2016 Accomplishments (funding received August 2016)

- Obtained 3D CAD data, material data and System Specification documents.
- Created detailed Finite Element Analysis (FEA) models from 3D CAD data and Technical Data Package (TDP).
- Generated loads on certain isolated components using Multi Body Dynamics (MBD) models to obtain forces / loading information to provide the input to FEA model for conducting weight optimization.
- Light-weighted components using structural topology optimization.

- FY 2017 Accomplishments (funding received June 2017)
  - Cargo bed material change (Al) resulting in 470 kg (~53%) weight savings, as compared to the current design.
  - Light-weighting i.e. reducing thickness of the cargo-bed and frame rails resulted in savings of 145 kg (~18%) mass as compared to the original design.
  - Developed the analytical framework – data collection, material and loads data, model development, baseline model performance and light-weight optimized model.

- FY 2018 Plans (ongoing)
  - Developed test plan, statement of work (SOW), instrumentation plan and duty cycle for FMTV loads data collection at ATC and TARDEC Physical Simulation Labs.
  - Conduct structural optimization on FMTV with the collected loads for light-weighting.
  - Conduct light-weighting using novel materials (e.g. FeMnAl) for reducing weight without sacrificing strength, for FMTV vehicle platform.
  - Obtained test and design data to conduct a case study for AVLB Bridge for structural optimization using the analytical framework developed.

- FY 2019 Plans
  - No further plans because project terminated by OSD.

THERMAL BARRIER COATING AND HEAT TRANSFER IN ENGINES

Lead Organization: U.S. Army Tank Automotive Research, Development & Engineering Center

Other Key Participants: Department of Energy Vehicle Technologies Office (DOE-VTO), Office of Naval Research, State University of New York- Stony Brook

OE Funding Stream:

FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$1.7	$0.9	$1.2	$0.0	$3.8

Description: This program seeks to leverage DOE's SuperTruck Program on the technical commercial advancements in powertrain systems. Specifically the program focuses on the development of a Thermal Barrier Coating (TBC) that is relevant to military high power density engines and applicable to DOE's 21st Century Truck Program. A TBC will allow increased in-cylinder gas temperatures while lowering heat rejection without compromising piston durability. The effort also includes a significant thrust area for developing engine wall heat transfer models which is an important topic for both TBC development and high efficiency engine design tools.

As military operations extend to points throughout the globe, the amount of fuel required by the Warfighter increases as well. The Army and Marine Corps ground tactical vehicle fleet numbers in the hundreds of thousands of platforms and make up a large portion of the platform fuel consumption for the DoD. There is opportunity to improve the overall operational energy effectiveness of the ground vehicle fleet for even modest efficiency improvements because of the number of miles traveled and sheer number of platforms in the tactical fleet.

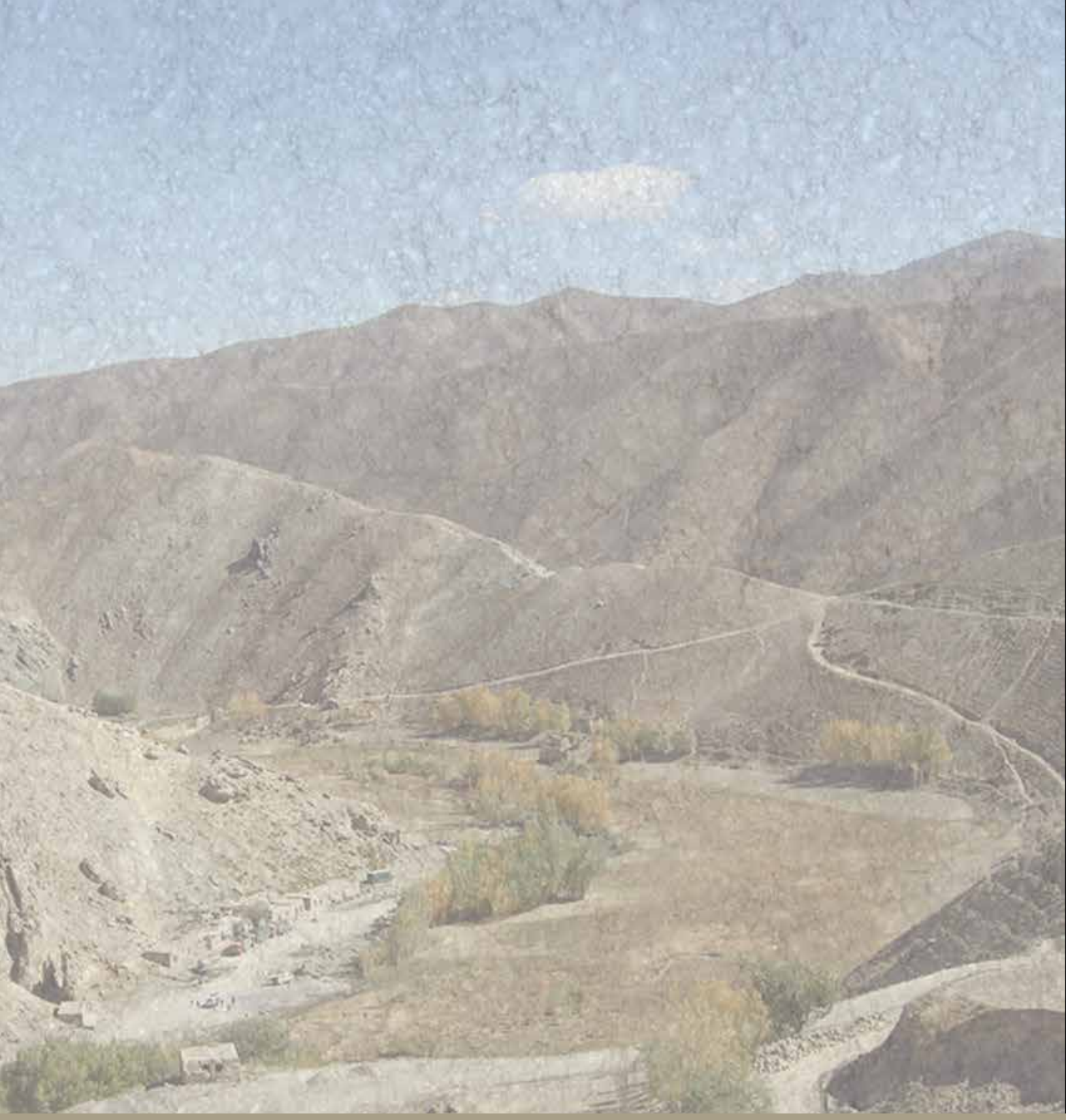
Military Benefit: This program will focus on developing thermal barrier coating technology for application to military engines. Expected outcomes of the program are:

- Power dense propulsion system operating on a wide range of fuels with reduced engine heat rejection.
- Modified commercial engines with heat rejection and favorable thermal efficiency specifically for the military application.
- Better engine design tools for both commercial and military application.
- More durable TBC for military and commercial use

Accomplishments/Status:

- Accomplishments to date: Single-cylinder research engine testing has shown a relative increase of gross indicated thermal efficiency of up to 4% when a TBC-coated piston with optimized surface roughness was compared to the metal baseline piston.
- FY 2016 Accomplishments
  - Prepared and reconfigured single-cylinder engine test laboratory for efficiency and heat rejection measurements.
  - Development of testing and modeling and simulation plan
  - Awarded research grant to Stony Brook University titled: "Thermal Management Coatings for High Performance Diesel Engines"
- FY2017 Accomplishments
  - Completed single-cylinder engine testing with metal baseline piston.
  - Designed thermocouple instrumented piston for advanced piston boundary conditions quantification.

- FY2018 Accomplishments
  - Completed single-cylinder testing of three thermal barrier coated pistons.
  - Demonstrated a relative increase of gross indicated thermal efficiency of up to 4% when a TBC-coated piston with optimized surface roughness was compared to the metal baseline piston.
  - Began multi-cylinder engine testing preparations by purchasing a Caterpillar C7 engine as a test article. This engine was planned to demonstrate the fuel economy benefits in the tactical FMTV platform.
- FY 2019 Plans
  - No further plans because project terminated by OS



FY 2015 OECIF Project Summaries:
CONGRESSIONAL PLUS-UP PROGRAMS

WASTE HEAT RECOVERY SOLUTIONS IN MILITARY APPLICATIONS

Lead Organization: Office of Naval Research (ONR)

Other Key Participants: Naval Surface Warfare Center - Philadelphia; Army Research Laboratory; United States Naval Academy (USNA); Army Construction Engineering Research Laboratory (CERL)

OE Funding Stream: FY 2015 - $2.6M (short-term program funded by FY 2015 Congressional plus-up)

FY 2015	Total
$2.6	$2.6

Description: Throughout military propulsion and power generation operations, about two-thirds of the fuel energy is lost as waste heat. Capturing this heat has been considered an important energy savings measure, but the implementation of waste heat recovery (WHR) technologies has encountered a myriad of challenges. In addition to challenges associated with technology development, which ONR and other DoD agencies are addressing in separate efforts, the uptake of WHR systems is hindered by difficulties: 1) realistically estimating their performance benefits and costs, 2) assessing the impact of integration into an already complex military platform, and 3) establishing confidence in their installed performance and robustness.

This project will address these challenges through the following three tasks:

- A WHR Application Analysis Tool will simplify and standardize predictions of the fuel savings that can be achieved. The bottoming cycle components and the exhaust gas heat exchanger will be modeled, and these models will be run against measured operational profiles of platforms to predict an application's net fuel savings.

- An Analysis of WHR Integration will assess technical risks, estimate installation cost, and document impacts associated with integrating a WHR system into a naval combatant. This study will identify all of the necessary system interfaces, including controls, and analyze the effect of interfacing with the exhaust stream.

- Demonstrations of WHR Systems will assess reliability and effectiveness through two sub-scale demonstrations. An exhaust gas heat exchanger will couple an Organic Rankine Cycle (ORC) to the waste heat from a gas turbine engine, and thermoelectric generator (TEG) modules will be fitted to the exhaust of a prime power diesel generator. Tests will measure steady state performance and robustness under thermal cycling.

Military Benefit: Capturing and converting waste heat into useful energy could provide an effective means for DoD platforms to increase mission endurance and operational reach, enhance capabilities through additional power for advanced sensors and weapons, and lighten the logistical burden of fuel resupply.

Accomplishments/Status:

- WHR Analysis Tool: Established thermodynamic system modeling framework and associated models for heat exchangers, gas turbine generators, and ancillary equipment.
- Analysis of WHR Integration: Assessed system arrangements for notional 800 kW supercritical CO2 waste heat recovery system.
- Demonstration of WHR Systems: Complete testing of exhaust gas heat exchanger on gas turbine and procuring COTS ORC system for integration at USNA. Completed final design of TEG waste heat recovery system.

SMALL UNIT POWER (SUP) AND BATTERY ELIMINATOR

Lead Organization: U.S. Army Communications Electronics Research, Development, and Engineering Center (CERDEC)

Other Key Participants: Natick Soldier Research, Development & Engineering Center (NSRDEC), PEO-Soldier, UEC Electronics, General Capacitor

OE Funding Stream: FY 2015 - $2.9M (short-term program funded by FY 2015 Congressional plus-up)

FY 2015	Total
$2.9	$2.9

Description: The Small Unit Power (SUP) program along with the Nett Warrior program will develop and conduct evaluations of the Integrated Soldier Power and Data System Core (ISPDS-C) system and Battery Eliminators for Dismounted Soldier radios and peripherals. As part of a 12 month effort, cutting edge intelligent battery eliminator technology based on innovative lithium ion ultra-capacitor and intelligent Soldier power management will be developed to feed into these programs. The intelligent battery eliminator will use low power communication developments achieved under the OECIF Soldier and Small Unit Operational Energy (SSUOE) Initiative to provide up a 50% reduction in power and weight and allow the Army to keep pace with increasing power and energy demands and minimize the logistics needed for fuel and power sources.

Military Benefit: Current Soldier equipment power needs are rapidly outpacing the available power and energy technology capabilities from traditional power sources such as batteries. While battery technologies currently in development may meet the basic need for reducing a portion of the overall power weight burden, alternative intelligent high-power source technologies are necessary to address power sustainment of peripheral handheld devices and communication systems such as ISPDS-C. The Radio Power Adapter (RPA) with Ultra-

Capacitor will have the ability to sustain radio communications while hot-swapping the central energy source, meet the high power density requirements for increased data and voice transmission to the network and enable energy information to be made available to the Small Unit commander for effective mission planning. The system provides the following benefits:

- RPA eliminates the need to carry and recharge ~90 PRC154 batteries/platoon/day
- RPA reduces individual Soldier load by ~1.7 lbs./day
- RPA ultra-capacitor technology provides >100,000 cycles vs 100s in the PRC154
- Supports Intelligent Power Management architectures and improves peripheral electronics
- Provides high power ultra-capacitor technology spin-off to Navy's undersea vehicle platforms

Accomplishments & Plans:

- FY 2015/2016 Accomplishments
  - Characterized ultra-capacitor cell and pack performance
  - Established power consumption profiles
  - Performed Critical Design Review (CDR)
  - Tested power and power management performance
  - Prepared hardware performance specification
- FY 2017/2018 Plan
  - Build and ruggedize PRC-148/152 and PRC-154 RPAs from two vendors
  - Evaluate USB data performance of ruggedized RPAs
  - Develop test plan with PEO-Soldier
  - Develop Safety Assessment Reports
  - Demonstrate Hardware to User Community
  - Develop performance specification
  - Conduct field experimentation at multiple venues
  - Requested and received $1.5M funding from other sources to complete testing

SOLAR, SOARING, COOPERATIVE UAV (PERSISTENT UAV)

Lead Organization: Marine Corps Expeditionary Energy Office (E2O)

Other Key Participants: Navy Research Laboratory (NRL), Naval Postgraduate School (NPS), Packet Digital, Semprius

OE Funding Stream: FY 2015 - $0.560M (short-term program funded by FY 2015 Congressional plus-up)

FY 2015	FY 2016	FY 2017	FY 2018	Total
$560K				$560K

Description: The goal of this effort is a persistent tactical UAV utilizing thermal soaring and solar energy to complete its mission without the need for fuel. This effort targets the development of high efficiency, lightweight, and flexible photovoltaic (PV) solar arrays that are incorporated into the UAV wings and provide power to on board electronics and propulsion systems. Optimization of autonomous soaring and cooperation algorithms will allow multiple autonomous UAVs to identify and communicate the locations of thermal updrafts to remain aloft without expending energy for propulsion.

NRL has developed the soaring algorithm, generated code, conducted modeling and simulation, and integrated the system onto the glider airframe. NRL and Semprius partnered to grow and develop the high efficiency PV solar cells. Packet Digital has developed the power management electronics, battery module, and power system.

Military Benefit: USMC ground maneuver elements at the tactical level lack specific capabilities, such as persistent ISR and over-the-horizon communications, these can be achieved by the Persistent UAV program without any requirement to use fuel. The UAV for this program is a tactical aircraft with a 14 foot wingspan and is intended to be deployed with troops at the company level.

Accomplishments:

- FY 2015 – Accomplishments
  - Built power management system at Packet Digital
  - Grew High Efficiency Photovoltaic (HEPV) cells
  - Fabricated UAV wing molds
  - Built initial solar arrays

- Transitioned soaring algorithm to flight controller
- Generated cooperative soaring code

- FY 2016 – Accomplishments
  - 1st UAV flight demonstration
  - Continued refinement/testing and algorithm improvement
  - Glider HEPV integration
  - 2nd UAV flight demonstration

Transition: The Persistent UAV technologies transitioned into FY 2016 OECIF Hybrid Tiger program, which is combining solar and soaring technologies with a hydrogen fuel-cell UAV. The Hybrid Tiger program is funded at $6.3M from FY 2016-2019.

M-PACT ("IMPACT") – MARITIME PRESCREENING ASSESSMENT OF CONSERVATION TECHNOLOGIES

Lead Organization: NSWC Carderock Division

Other Key Participants: Department of Energy's National Renewable Energy Laboratory (NREL), U.S. Department of Transportation Maritime Administration (MARAD), State Maritime Academies, Naval Sea Systems Command (NAVSEA), Military Sealift Command (MSC)

OE Funding Stream: FY 2015 - $2.68M (short-term program funded by FY 2015 Congressional plus-up)

FY 2015	FY 2016	FY 2017	FY 2018	Total
$2.5M	$0.2M			$2.7M

Description: The M-PACT initiative aims to accelerate the adoption of energy efficiency technologies in maritime applications. M-PACT will establish a lasting capability for testing of nascent, performance-improving energy technologies in a ship environment early in a technology's validation and certification process, leveraging the Maritime Academy training ships and crews. This project will engage industry to expand the pipeline of potential technology improvements, and then perform shipboard performance testing as a first screening step to narrow the field of candidates for the follow-on more rigorous certification (certification is not part of the M-PACT screening process). Proposed technologies will be derived from several sources such as Military or DOE labs, universities, and industrial partners through Requests for Information (RFI). The quantitative assessment of energy use will be a key focus.

Military Benefit: The M-PACT initiative will directly contribute to the CNO's energy goal to reduce fuel consumption afloat by 15% in 2020 by filling a gap in the ability to stimulate ideas from industry for energy conservation capabilities in a maritime environment. While this program does not test in a truly military context, migrating preeminent energy conservation concepts into a working maritime environment will "prime the pipeline" for further development and adoption into programs of record. This will be inherently less costly than going directly through Navy acquisition programs. A typical M-PACT technology demonstration can be conducted in 1 year at a cost of $1M-$1.5M as opposed to 3-5 years and $3-$5M for a similar demo going through the current Navy acquisition equivalent process. This program enhances operational capability by bringing together industry, Navy, DOE and MARAD early on in the process, empowering all stakeholders to contribute to and gain from the exposure to new and innovative technical solutions to maritime energy conservation challenges.

Accomplishments/Status:

- Installed sensor suite on TS Kennedy in fall of 2015 to gather the thermal and electrical data necessary to validate maritime-specific changes made to EnergyPlus, a physics-based thermal and electrical modeling engine for terrestrial applications. Data were collected during the underway period in January & February 2016. Model development and validation efforts completed, with final results reported in October 2016.

- Conducted market research for technology demonstrations by way of direct industry outreach and via publishing a "Sources Sought" on FedBizOps. Significant interest expressed by multiple providers via outreach activities.

- Selected two technologies for demonstration – Variable Refrigerant Flow (VRF) heating and cooling system and a magnetic bearing, variable speed compressor central water chiller.

- VRF system was installed in fall of 2016 and demonstrated during underway activities in January 2017. Currently performing post-test analysis and modeling, culminating with a final report in August 2017.

- Magnetic bearing water chiller planned to be installed in August of 2017, with pier-side demonstration occurring from September 2017 through December 2017, followed by underway demonstration in January 2018.

JOINT INFANTRY COMPANY PROTOTYPE (JIC-P)

Lead Organization: USMC Expeditionary Energy Office (E2O)

Other Key Participants: Naval Surface Warfare Center Dahlgren (NSWCD) Soldier and Small Unit OE Effort (Draper Labs) Soldier Research, Development, and Engineering Center (NSRDEC) PEO-Soldier

OE Funding Stream:

FY 2015 (M)	FY 2016 (M)	Total
$0.1	$3.3	$3.4

Short-term program funded by FY 2015 Congressional plus-up

Background: Dismounted companies perform some of the most physically demanding missions using considerable quantities of energy. In order to meet this growing energy requirement, a typical Marine carries up to 20 pounds of batteries in addition to his combat load for a 72-hour mission. Batteries severely limit a ground force's ability to penetrate deep into enemy territory and the use of renewable energy harvesting capabilities can address this issue.

Problem: Individual materiel prototyping has failed to convince leadership to adopt renewable energy harvesting technologies that would significantly reduce the battery weight and resupply requirement of Marine Corps infantry units. Past attempts to define power requirements were conducted by reviewing product specification sheets and adding up the total power requirements. This approach has failed to accurately capture the power usage profile, and as such, the joint Services are misinformed regarding the actual power requirements in a tactical environment. The Joint Infantry Company Prototype (JIC-P) is an umbrella effort to provide the Marine expeditionary rifle company with a unique, self-sustainable capability set that enables dismounted multi-day operations in an austere environment while informing joint requirements.

Military Benefit: The JIC-P effort will be a 24 month joint effort between the Army and the Marine Corps combining kinetic energy harvesting technology development efforts with operational testing. The JIC-P will develop the bionic knee harvester, the Lightning Pack, packable solar, and wearable power managers to integrate each technology solution into a functioning system. Both the USMC and Army will conduct a user evaluation with a mix of this equipment, largely focusing on conceptually evaluating the tactical performance of the kinetic harvesters. The resultant technical data will be shared, contrasted, and compared to better inform joint requirements for operational energy sustainment regarding dismounted troops in austere environments. This effort will be accomplished through collaborative partnership between the NSWCD, NSRDEC, Army PEO-Soldier, and the Marine Corps.

Accomplishments: The infantry company prototype will:

- Provide sufficient statistical sample opportunity to demonstrate the value of renewable tactical energy harvesting in lightening the load and increasing self-sustainability.
- Leverage ongoing efforts within the Army and Marine Corps regarding kinetic energy harvesting development.
- Measure the power usage for the Army and Marine Corps squad, platoon, and company to capture energy requirements in a tactical environment.

- Inform the joint community of the best form, fit, and function for a power distribution solution through shared prototype performance data comparison feeding into the standardization efforts of the Soldier and Small Unit Operational Energy consortium (SSUOE).
- Inform future energy harvesting acquisition by understanding performance and logistical implications.
- Provide a platform for SSUOE to observe human behavior in a tactical environment to address non-materiel issues with small unit and individual power.

Prototyping new harvesting technologies will arm the joint community with the quantitative and qualitative data necessary to demonstrate that kinetic harvesting technologies can meet power consumption requirements and provide an indispensable capability to the Marine expeditionary rifle company and the joint community. The unique capability set will lighten the load, extend the operational reach of the rifle company, decrease metabolic rates of foot mobile Marines, meet the Commandant's Expeditionary Force 21 requirement attribute of being "Self-sustaining under austere conditions," and has the potential to reduce injuries from overburdened loads.

Status/Transition: The OECIF-funded portion of this effort is complete. The Army is planning their user evaluation in August 2017, and the USMC in September 2017. The Army and USMC have provided approximately $600K and $300K, respectively, for these efforts. The Army and USMC are also funding continued development of the M&S tools created with the OECIF funding for approximately $400K and $300K, respectively in FY 2017. These M&S efforts will most likely continue in FY 2018 and beyond as both Services are pursuing system of system models for dismounted Warfighters; however, specific funding amounts have not been determined.

JOINT DEPLOYABLE WASTE TO ENERGY (JDW2E)

Lead Organization: US Indo-Pacific Command

Other Key Participants: U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC), Product Manager Force Sustainment Systems (PM FSS), Air Force Civil Engineer Center (AFCEC), Army Research Laboratory (ARL), Air Force Institute of Technology (AFIT), Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC), U.S. Marine Corps Forces Pacific (MARFORPAC)

OE Funding Stream:

FY 2015	Total
$0.4 M	$0.4 M

Description: The Joint Deployable Waste to Energy (JDW2E) Operational Management, i.e. joint management and coordination by HQUSINDOPACOM and its partners of DoD efforts to holistically develop deployable systems and the necessary non-material information needed to address the issues identified in instructions & directives:

- (a) NDAA 2010 §317, "The Secretary of Defense shall prescribe regulations prohibiting the disposal of covered waste in open-air burn pits during contingency operations except in circumstances in which the Secretary determines that no alternative disposal method is feasible. Such regulations shall apply to contingency operations that are ongoing as of the date of the enactment of this Act, including Operation Iraqi Freedom and Operation Enduring Freedom, and to contingency operations that begin after the date of the enactment of this Act.
- (b) DoDI 4715.19, "Use of Open-Air Burn Pits in Contingency Operations" prohibits plastic and other "covered waste" from burn pits and directs Combatant Commanders to justify operation of a burn pit every 180 days
- (c) DoDD 3000.10, "Contingency Basing Outside the United States" directs that contingency basing pursue joint, scalable, optimized capabilities that use operational energy efficiently; minimize waste; manage environmental concerns; consider health and safety; and minimize logistics footprint
- (d) DoDD 4180.01, "DoD Energy Policy" establishes policy and assigns responsibilities to enhance military capability, improve energy security, and mitigate costs in its use and management of energy

Resources will be used synchronize development of Tactics, Techniques, and Procedures (TTPs), Joint Requirements, Joint Standardized Testing Protocols, and Joint Testing & Evaluation (JT&E) of waste-elimination and waste to energy (W2E) systems.

Military Benefit: JDW2E Operational Management will synchronize W2E evaluations and insertions across DOD as well as provide the leadership for joint management and coordination of non-material tasks and testing needed to transition developed systems. This integration and coordination effort will support joint solution development and implementation for safer and more efficacious disposal of nonhazardous solid waste at current and future austere and contingency base locations.

Accomplishments:

- Information exchange and coordination of efforts between Services, agencies outside the Department (e.g., Drug Enforcement Agency, Customs and Border Protection, National Oceanic and Atmospheric Administration), and international partners
- Hosting JDW2E Community of Interest
- Reviewed several technologies including the Battalion-Scale Waste to Energy Converter, Solid Waste Destruction System, and Expeditionary Waste Destruction Box
- Jointly hosted Virtual JDW2E Industry Day
- Compiled lessons learned

DEHUMIDIFICATION MEMBRANE & COOLING SYSTEMS

Lead Organization: Naval Facilities Engineering Command (NAVFAC)

Other Key Participants: Advanced Research Projects Agency-Energy (ARPA-E); Navy Military Sealift Command (MSC)

OE Funding Stream: FY 2015 - $1.125M (short-term program funded by FY 2015 Congressional plus-up)

FY 2015	Total
$1.1M	$1.1M

Description: Environmental Control Unit (ECU) loads currently account for over 32% of facility fuel use at expeditionary camps and Forward Operating Bases (FOBs). When used in cooling/air conditioning applications, membrane dehumidification can enable separation of sensible and latent cooling when combined with traditional vapor compression ECUs and enable evaporative cooling to be used even in humid environments. Due to high performance of the membranes, a relatively small amount of membrane area is needed, allowing for energy efficient, compact dehumidification modules that are much smaller than existing dehumidification technologies. These modules can be either designed into new ECUs or deployed as add-on dehumidifiers to existing ECUs.

The dehumidification modules can be used alone as a dehumidifier only, together with an evaporative cooler, or together with any ECU. The modules utilize a porous metal/zeolite membrane and an efficient low pressure H2O vapor compressor to draw moisture directly out of the moving air stream. Water produced by the dehumidifier can be recycled as potable water. Three designs/prototypes will be developed.

- Design 1 for FOBs: 1-Ton Dehumidification Module, linear compressor; demonstrated combined with a traditional vapor compression ECU.
- Design 2 for Ships and Commands: 10-Ton Dehumidification Module, centrifugal compressor; demonstrated as dehumidifier only and combined with an evaporative cooler.
- Design 3 for Data Centers: A 10-ton Dehumidification Module, centrifugal compressor; demonstrated combined with an evaporative cooler.

Military Benefit:

- Reduces fuel used for expeditionary cooling by up to 12% in humid environments when combined with near term production Improved ECUs.
- Enables improved dehumidification, potentially coupled with evaporative cooling for energy efficient cooling, for MSC ships in both the maritime and port environments.

- Residential unit application increases likelihood of high volume production and commercialization; residential potential as 1-Ton unit for ARPA-E.

Accomplishments & Plans:

- Cost sharing: Total funds $3.125M [ARPAE $1.625M, Office of the Deputy Assistant Secretary of Defense (Operational Energy) $1.125M, MSC $500K]
- Design compressors and move to fabrication
  - 10-Ton compressor moving to fabrication
  - 1-Ton compressor configuration being finalized
- Test and deliver prototype membranes and other materials
  - Delays in furnace installation and debugging
- Test and deliver centrifugal compressor prototype (10-ton) and linear compressor prototype (1-ton)
  - Anticipating delays
  - Proceeding with balance of system testing
- Verify performance at targeted temperature/humidity; deliver reports
  - Anticipate end FY 2017

ADVANCING CYBER SECURITY FOR PLATFORM INFORMATION TECHNOLOGY (PIT) AND INDUSTRIAL CONTROL SYSTEMS (ICS) (CYBER)

Lead Organization: OASD (Energy)

OE Funding Stream:

FY 2015 (M)	FY 2016 (M)	Total
$1.7	$0	$1.7

Short-term program funded by FY 2015 Congressional plus-up

Description: The overarching objective of this effort was to quantify the problem of cyber security for energy-related platform information technology (PIT)/industrial control systems (ICS) to aid DoD leadership in their decision making process.

PIT/ICS is defined by DODI 8500.01 as IT, both hardware and software, that is physically part of, dedicated to, or essential in real time to the mission performance of special purpose systems.

Military Benefit:

- Help identify and address challenges and provide leaders with a snapshot to help them make decisions.
- References of best practices, security architectures, security controls and/or compensation controls that increase resilience to known attack tools.
- Provide solution for both operational energy and installation energy missions.
- Provide analysis to guide future energy-related R&D.
- Improves collaboration and professionalism of DoD ICS stakeholders/workforce.

This program focused on three primary thrust areas. Each area is distinct but supports the other thrusts in resolving DoD challenges.

- ICS Exposure to Cyber Threats - This thrust determined the exact ICS systems and their energy security network configurations (topology, protocols, accessibility, etc.) on nine installations supporting DoD's top critical missions. Analysis occurred onsite with facility engineers / public works personnel and information technologists to conduct a complete and accurate cyber key terrain mapping.
- Gap Analysis of Technical Solutions to Monitor DoD ICS - ICSs use different communication protocols and have different priorities than information systems. The focus of this thrust was to conduct an industry survey of ICS cyber security tools, identify gaps in existing tools and techniques, and then propose a development plan to mitigate the gaps. The survey encompassed technology providers from the Defense Industrial Base, Academia and Government.
- Workforce Training Evaluation and Development - This thrust evaluated the delta between the current published competencies and emerging requirements for facility energy managers across DoD with existing skillsets currently at installations. Evaluation occurred across nine installations supporting DoD's top critical missions. The evaluation included working with industry to gather best practices and identify effective training programs that can be incorporated into DoD programs and institutions.

Transition: The results of the CYBER analysis have been incorporated into the Platform Resilience Mission Assurance (PRMA) program, which is providing Department-wide technical direction, consistency, and integration of base control system cyber security. The PRMA program is being funded by OSD at $1M a year from FY 2016-2020.

ENERGY-INTEGRATED MODELING & SIMULATION FEDERATIONS

Lead Organization: Office of the Deputy Assistant Secretary of Defense for Operational Energy (ODASD (Energy))

Other Key Participants: Air Force A9 (Studies, Analyses, & Assessments); Office of the Secretary of Defense Cost Analysis and Program Evaluation; Defense Advanced Research Projects Agency; United States Army Tank Automotive Research, Development and Engineering Center

OE Funding Stream: FY 2016 - $1.998M (short-term program funded by FY 2015 Congressional plus-up)

FY 2016	Total
$1.2M	$1.2M

Description: The Energy-Integrated Modeling and Simulation (M&S) Federations program will utilize integration methods to facilitate multi-resolution war gaming, analysis, and requirements development.

Military Benefit: Current Service-wide campaign level M&S tools have three shortfalls related to the incorporation of operational energy risks and opportunities.

1. Understated Logistical Disruptions. The Synthetic Theater Operations Research Model (STORM), a prominent campaign-level analysis tool, does not fully account for collateral damage. Base attack models artificially limit Red's strategic attack, focusing target type rather than target effect. Respectively, the shortfalls hinder tracking energy-affected attack effects and the identification of energy related components as critical to base and port operations.

2. Continuing Energy Integration into War-games. Rendering and integrating energy into war games rarely occurs. "Stochastic war gaming" to produce a reasonable range of quickly produced, reasonable outcomes is more of a concept than a practice.

3. To the "Left" of Acquisition. ODSAD(Energy) wants to explore possibilities for an energy-informed (not exclusive) approach to specifying a trade space and navigating it to shape requirements future platforms and systems.

The Energy-Integrated M&S Federations program seeks to answer these concerns by:

1. Developing mission-level modeling insights on the relationship between operational procedures, asset proximity, and survivability. These insights will be used to calibrate a) STORM b) build a more realistic Red in base attack models, and c) provide an adjunct tool for war gaming.

2. Establishing logistics modules across air, ground, and sea domains within an integration environment and linking them to other functional modules (e.g., combat). The program will define, develop, and test a methodology for stochastic post-game analysis and linking war-game and campaign M&S.

3. Establishing a knowledge baseline regarding trade space definition through a survey of acquisition programs. The program will assess the level of rigor, utilize appropriate prototype tools for analytic support, and document prospects for further changes in doctrine, organization, training, materiel, leadership and education, personnel and facilities (DOTMLPF), as needed.

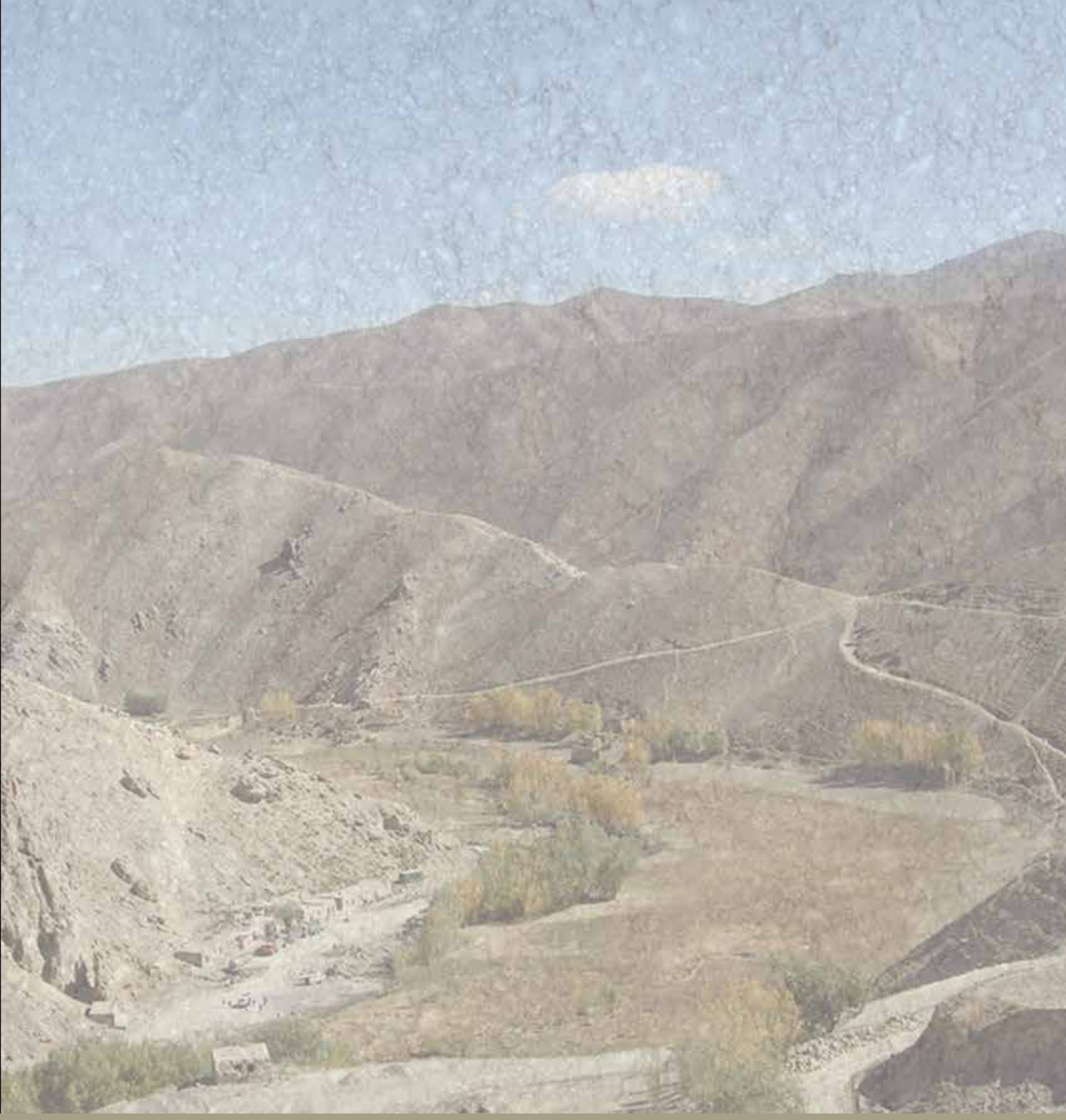
Accomplishments & Plans:

FY 2016 Accomplishments

- Contract modified to use a $30M Government off-the-shelf software product (COMPOEX) to support M&S integration.
- Partnerships established to leverage and complement existing Departmental efforts:
  - multi-resolutions logistics war gaming and analysis with DARPA; and
  - energy integrated, stochastic war gaming with A9.

FY 2017/2018

- Kickoff program and establish working groups.



FY 2016 OECIF Project Summaries:
UNMANNED SYSTEMS

IMPROVED PERFORMANCE TECHNOLOGY ENGINE (IPTE)

Lead Organization: Air Force Research Laboratory, Aerospace Systems Directorate

Other Key Participants: Honeywell Aerospace, General Atomics Aeronautical

OE Funding Stream:

FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	Total
$2.0	$2.0	$2.0	$2.0	$8.0

Description: The MQ-9 Reaper Unmanned Aircraft System is a workhorse for strike and Intelligence Surveillance and Reconnaissance for the Air Force. The maximum platform range on the MQ-9 is 3,800 nm at a cruise altitude of 30,000 feet for the clean configuration and 4,800 miles at a cruise altitude of 30,000ft for a clean MQ-9 Extended Range (ER) configuration. The ER version was also equipped with a new heavier propeller and distilled water/alcohol injection kit to increase takeoff power and compensate for the increased weight associated with the external fuel tank and additional fuel. The ER upgrade specifically targets the United States Africa Command (AFRICOM) and the Unites States Pacific Command (PACOM) theaters due to the long range required to reach and operate in these theaters.

The Air Force Research Laboratory, Aerospace Systems Directorate, Turbine Engine Division (AFRL/RQT) has initiated the IPTE for the Pacific program to design, develop, and test a technology transition demonstrator engine by 2021 for a potential upgrade to the MQ-9 Reaper. The goals of the program are the demonstration of 15% cruise fuel burn reduction, 30 percent increase in horsepower at sea level and cruise altitude, and to enable 90 kVA in electrical power for the MQ-9 ER.

After several component level risk reduction tests, the IPTE program will culminate in a series of TRL 6 technology demonstrator engine tests in 2020-2021. The Air Force Research Laboratory will fund approximately $26M of the effort and leverage $41M of contractor cost share, $6M from the Air Force Life Cycle Management Center (AFLCMC/WI) MQ-9 Program Office and $8M from the Office of the Secretary of Defense Operation Energy Capability Improvement Funding.

After successful ground demonstration on the IPTE for the Pacific project, Honeywell has made plans to pursue Federal Aviation Administration (FAA) Certification of the improved engine for use on several commercial aircraft. In addition to proving the airworthiness of the engine, the FAA Certification will significantly reduce the military certification requirements and resources required to flight test the new engine in the MQ-9 Reaper. This strategy enhances the transition opportunity for the new engine technology to AFLCMC/WI.

Military Benefit: This OECIF proposal for research on the Improved Performance Technology Engine will provide the Air Force's MQ-9 Extended Range platform the following military benefits:

- Up to +611nm combat radius or up to +4 hours loiter
- Removal of Water/Alcohol injection for the MQ-9 ER
- Support UAS Expeditionary and Extreme Climate Ops with hot day takeoff, shorter runways, ability to self-deploy (versus airlift)
- Increase engine time on wing, decreased scheduled engine inspections, overhauls, required spares
- Provide electrical power for future payloads
- Add acceleration, climb, and dash capability

Accomplishments/Status:

- Accomplishments to date: Product condensation on walls eliminated with dynamic water blanket; Aluminum powder fuel has been made to flow reliably; system and combustor modeling conducted; three laboratory tests executed; and laboratory hardware design improvements implemented to support future breadboard component testing.
- FY 2016 Accomplishments (funding received April 2017)
  - Completed Request for Proposal
- FY2017 Accomplishments (funding received December 2017)
  - Completed proposal evaluation and awarded IPTE Contract
  - Completed Operational Benefits Analysis
- FY 2018 Plans (ongoing)
  - Completed Conceptual Design Review
  - Awarded General Atomics Aeronautical an aircraft/engine integration support contract
  - Completed Integrated Baseline Review
  - Completed Preliminary Design Review
  - Approve Engine Requirements Document
  - Complete aircraft/engine inlet distortion testing
- FY 2019 Plans
  - Complete Detailed Design Review
  - Complete Combustor Rig Tests #1 and #2
  - Order engine hardware and begin manufacturing

ALUMINUM-WATER POWER FOR UNMANNED UNDERSEA VEHICLES

Lead Organization: Unmanned Maritime Systems Program Office (PMS 406)

Other Key Participants: Applied Research Laboratory (ARL) of the Pennsylvania State University

OE Funding Stream:

FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	Total
$1.8	$2.8	$3.1	$4.5	$12.2

Description: T he Penn State Applied Research Laboratory (ARL) has demonstrated proof-of-concept of a power plant based on the combustion of treated aluminum powder with water. ARL estimates that neutrally buoyant energy densities of this system can reach over four times that of similarly sized Lithium-Ion Batteries. The Large Displacement Unmanned Undersea Vehicle (LDUUV) and Extra Large Unmanned Undersea Vehicle (XLUUV) are likely hosts for this technology.

This effort funds development of hot-side components (combustor, steam generator, heat exchanger, and start system) and cold-side components (solid product separator and solid product removal system) of the primary power loop, and fuel treatment. This will mature the technology from proof-of-concept to a documented sequence of breadboard system tests of the aluminum-water-thermal power plant.

Military Benefit: This OECIF proposal for research on aluminum-water combustion will provide the following benefits to the US Navy.

- Increased Range – The high energy density of an aluminum-water combustion system is expected to allow large UUVs a mission transit enabling a sustained presence in the far Pacific. This range enables vehicle deployment from a Navy base.

- Force Multiplication – Given that the submarine fleet is a primary mode of sea access, use of large and extra-large UUVs has potential for critical force multiplication and force protection (specifically for large UUVs with Intelligence Preparation of the Operational Environment and Intelligence, Surveillance and Reconnaissance missions). The ability to deploy from a forward base and rendezvous with a submarine or ship platform, or vice versa, circumvents the difficulty of underway refuel/recharge at the end of a mission.

- Increased Safety – Aluminum powder fuels are non-reactive at room temperature in liquid water.

Accomplishments/Status:

- Accomplishments to date: Product condensation on walls eliminated with dynamic water blanket. Aluminum powder fuel has been made to flow reliably. System and combustor modeling conducted. In-house fuel treatment capability established. Component hardware designed and fabricated for all subsystems, and proof testing nearing

completion. Eight system tests executed with increasing level of integration.

- FY 2016 Accomplishments (funding received August 2016)
  - Aluminum-Water energy system model developed for system configuration trade study evaluations.
  - Laboratory support hardware design improvements evaluated.
  - Subsystem design requirements defined.
- FY2017 Accomplishments (funding received June 2017)
  - Laboratory support hardware designed, fabricated and tested.
  - In-house fuel treatment capability restored and processed fuel to meet testing needs.
  - Subsystem design reviews for start system, recuperative steam generator, primary heat exchanger, and separator.
  - Plasma Torch design review
  - Computational Fluid Dynamics (CFD) modeling final report completed.
- FY 2018 Plans (initial funding received January 2018) (ongoing)
  - Combustor, Recuperative Steam Generator, and Primary Heat Exchanger fabricated and tested.
  - Plasma Torch fabricated and tested at low-pressure conditions
  - Separator fabrication and testing
  - Plasma Torch high-pressure testing
  - Solid product removal testing
  - Water recirculation testing
- FY 2019 Plans
  - Fuel treatment scale-up evaluation and final report
  - Round 1 System Test Readiness Review and test (Mar 2019)
  - Round 2 subsystem design reviews (combustor, recuperative steam generator, primary heat exchanger, separator, sump, product removal, water replenishment)
- FY 2020 Plans
  - Round 2 subsystem fabrication and testing
  - Round 2 System Test Readiness Review and test (Jul 2020)

MULTI-DAY ENDURANCE OF A GROUP 2 UAS UTILIZING PACIFIC ENERGY SOURCES (HYBRID TIGER)

Lead Organization: Naval Research Laboratory (NRL) Tactical Electronic Warfare Division

Other Key Participants: NRL Chemistry, Electronics, and Marine Meteorology Divisions; Pennsylvania State University's Air Vehicle Intelligence and Autonomous Laboratory; Naval Postgraduate School's Aerospace Department

OE Funding Stream (by funding year):

FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	Total
$1.4	$2.2	$1.1	$1.9	$6.4

Description: This program is developing and demonstrating a multi-day, Group 2 UAS at TRL 6 with flight endurance of 4+ days and range of 3,000 NMI. The endurance and range are enabled by a hybrid electric power system that integrates photovoltaic (PV) cells, autonomous soaring (AS) algorithms and fuel cell (FC) technologies. The PV array and AS algorithms support flight during the day by harvesting solar energy and by soaring in vertical winds generated by convection or topography. The FC system supports nighttime flight with a specific energy more than 5x that of Li-ion batteries.

These technologies were selected to minimize dependence on supply lines and maximize operational flexibility by exploiting abundant indigenous energy in the Pacific. The PV cells harvest solar energy directly, the AS algorithms harvest energy from rising air, and the hydrogen fuel could be produced locally using electricity from ground-based PV cells to electrolyze seawater.

Military Benefits: The military benefits of the Hybrid Tiger OECIF program include greater operational capability, improved energy efficiency, and reduced reliance on supply lines for fuel. Specifically:

- New CONOPS – A Group 2 UAS with multi-day endurance and long range enables new CONOPS options that have not been considered before. For example, continuous ISR coverage, uninterrupted radio communications relay, or tracking of a ship at sea are enabled by multi-day endurance and are currently only available with significantly larger and more expensive assets.

- Increased Endurance – High efficiency reduces average fuel consumption and enables significant increases in endurance/range. Hybrid power systems require complex controls, but the payoff is performance superior to that of any one contributing technology. Combining PV, FC, and AS will yield the most benefit when appropriate energy and powertrain management strategies are applied.

- Locally Sourced Fuel –There is an opportunity to generate fuel locally with native energy resources, eliminating fuel logistics burden: hydrogen gas can be produced locally using

solar power to electrolyze water. The ability to deploy and continuously re-deploy from a forward base obviates the logistics of moving hydrocarbon fuels.

Accomplishments/Status:

- Major accomplishments to date:
  - Energy-based performance simulation and analysis tool completed,
  - Vehicle airframe fabricated with co-molded solar wings and tail,
  - Software development and testing in hardware-in-loop benchtop setup, and
  - Integrated energy system bench testing.
- FY 2016 Accomplishments
  - Vehicle energy performance analysis tool written in Matlab to improve fidelity of endurance/range simulations and verify solar wing modifications.
  - Contracts let for the solar arrays, power management electronics, fuel cells, and hydrogen tanks; these constitute the bulk of COTS parts.
  - Onboard software architecture developed with Penn State and Naval Postgrad School
- FY2017 Accomplishments
  - Benchtop HIL setup (includes full aircraft wiring, energy system simulators, onboard processor, and autopilot simulation) for developmental testing of onboard software.
  - Simulation and refinement of the energy management strategy.
  - Propulsion system fabrication and testing in NRL's wind tunnel.
  - Solar array co-molding validation experiments in flight horizontal tail.
  - Delivery of composite wing tooling, in-house fuselage mold modifications and flight fuselage layup, and flight nose layup.
- FY 2018 Accomplishments and Ongoing
  - Co-molded solar wing fabrication, ground testing, and integration with airframe.
  - Simulated software trans-Pacific flights on HIL setup for debugging.
  - Integration power management electronics (done) and hydrogen system (ongoing).
  - Maiden flight of Hybrid Tiger and build-up flight tests (ongoing).
  - Evaluation of flight energy performance and revision of energy management (ongoing).
- FY 2019 Plans
  - Complete software in-flight testing/tuning
  - Max endurance flight test
  - Optional plus-up: Demonstration flight with sponsor's payload SWAP at sponsor's site.

HYDROTHERMAL VENT EXPLOITATION FOR UNDERSEA ENERGY (HTVE-UE)

Lead Organization: Sea Warfare and Weapons Department (Code 33), Office of NavalResearch (ONR)

Other Key Participants: Ocean Battlespace Sensing Department (Code 32), ONR; ONR Reserve Officer Component; Naval Surface Warfare Center – Carderock Division; Creare LLC; University of Washington Applied Physics Lab; Woods Hole Oceanographic Institute

OE Funding stream:

FY16 (M)	FY17 (M)	FY18 (M)	FY19 (M)	Total (M)
$1.3	$0.0	$0.4	$1.2	$2.9

Description: Energy harvesting is a key focus for the Energy and Power Community of Interest (EPCOI), a DoD-chartered multi-service organization constituted to provide technologies to enable intelligent power and energy management and enhance operational effectiveness. One of EPCOI's enduring S&T gaps is "Autonomous energy harvesting in operational environments." This project will extend and expand prior research in undersea energy harvesting by exploiting hydrothermal vents (HTV), oceanographic features where fissures occur on the sea floor, and from which geothermally-heated water flows. A recently-completed, ONR-sponsored, SBIR Phase II resulted in the design and testing of a heat exchanger component in a thermal-to-electric conversion system for use on an HTV, culminating with a one-year test period on an actual hydrothermal vent at almost 1500m ocean depth. The theoretical electrical power output for this full system - approximately 20 kW - portends significant increased potential for operational systems needing long undersea endurance. This OECIF effort will leverage the successful SBIR results by developing and demonstrating a fully operational system on an active hydrothermal vent in the July-September 2018 timeframe. Additional environmental and concept of operations (CONOPS) analyses are being conducted to further characterize the full potential and capabilities of this new and potentially game- changing technology advancement.

Military Benefit: The Deputy Assistant Secretary of Defense for Operational Energy (OE) solicited science & technology initiatives to improve the operational energy performance of unmanned systems that would be useful in the Pacific. "Improving operational energy performance" generally refers to increasing the military capabilities energy provides our forces and/or reducing the burdens and risks created by our energy supply lines. The HTVE-UE project responds directly to this OECIF "Unmanned Systems for the Pacific" solicitation. The project also responds to several Naval Undersea Warfare Science & Technology Objectives. One such example is USW-PE-03 "Develop the capability to harvest, obtain, store and transfer energy to undersea assets." Another, USW-PE-01, calls for development of safe, reliable, affordable and high efficiency generation for undersea platforms. The primary goal of the HTVE-UE project is to provide usable power and energy from a robust, affordable power system and virtually unlimited energy source, for operational use by unmanned undersea vehicles (UUVs) and other systems requiring power under the oceans.

Accomplishments/Status/Plans: Multiple contracts have been awarded and primary technology design efforts are underway; several studies and analyses have been completed addressing drilling for HTVs, HTVE-UE environmental impact, and various aspects of HTVs potential effect to undersea warfare operations. An HTV flow meter has been designed and built and will be tested in 2018; the HTVE-UE energy conversion device is approximately 60% complete (May 2018) and will be tested in 2019-2020. Electrical interoperability and interface design efforts with the Forward Deployed Energy and Communications Outpost (FDECO) project are underway and will be completed in 2020.

- FY 2016 Accomplishments (funding received Jun 2016)
  - Successfully worked with ONR SBIR office to award a "subsequent phase II SBIR" contract for HTVE-UE system development, design, fabrication and test (29 Sep 2016). Also, ONR SBIR office agreed to cost share on the HTVE-UE program in the amount of $1.5M.
  - Funding provided to NSWC-Carderock for technical support to the HTVE-UE project for electrical interface to and interoperability with FDECO
  - Presented at initial OECIF project kick-off conference
  - Initial drafts for HTVE-UE operational concepts, environmental considerations, and HTV characterization were developed by ONR Naval Reserve staff supporting the HTVE-UE project
  - Initial drafts were developed for the HTVE-UE Security Classification Guide (SCG) and Project Security Plan (PSP)
- FY 2017 Accomplishments (initial funding received November 2016 but adjusted multiple times through Jun 2017)
  - Two contracts (JHU-APL and Systems Planning & Analysis Inc.) were initiated for studying various aspects of HTVE-UE and undersea warfare operational concepts
  - Kick-off meeting conducted with prime contractor, Creare, and HTVE-UE government team; 3 subsequent quarterly reviews conducted
  - Preliminary Design Review conducted with contractor; device development and parts/component procurement initiated
  - HTV Flow Meter option exercised; flow meter design completed, in-water test planning initiated
  - Initiated coordination with the National Science Foundation (NSF) Ocean Observatories Initiative (OOI), where, through the Applied Physics Laboratory of the University of Washington (APL-UW), interoperation plans were undertaken to be able to demonstrate the HTVE-UE system while connected with the OOI cabled array power and communications undersea network
  - Several contract options were exercised to initiate two studies, one addressing of creating artificial hydrothermal vents, and one to conduct a detailed analysis of environmental considerations for the eventual HTVE-UE in-water experiment
  - Further pursued implementation of, and providing access to non-ONR personnel for, a master information data base for HTVE-UE information

- FY 2018 Accomplishments and Plans (ongoing; no FY18 funding received as of 24 May 2018)
  - HTVE-UE device development continued; parts procurement and component fabrication continued; breadboard design and assembly initiated
  - Evolved the program schedule to extend the period of development and testing by one year due to research vessel (RV) scheduling conflicts (extension estimated at no additional project cost); updated program plans to reflect extended schedule and spread out financial estimates
  - Final planning for 2018 cruise continued toward a July 2018 RV deployment, where the flow meter will be tested and the HTVE-UE device base (only) will be emplaced over the target HTV in international waters off the coast of Oregon
  - (Planned) Flow meter testing will be conducted and results analyzed and then applied to any flow meter and/or HTVE-UE device design changes
  - (Planned) HTVE-UE device breadboard will be completed; tank test planning will commence; two-vessel HTVE-UE design will be finalized and final component assembly and configuration refinements implemented
- FY 2019 Plans
  - HTVE-UE device assembly will be completed
  - Tank testing of HTVE-UE device will be conducted at Creare
  - Hydrostatic testing of HTVE-UE containment vessel will be conducted at Carderock.
  - Preparations for HTVE-UE device in-water test on the live HTV will be followed by the experiment itself in summer of 2019
  - Post-FY 2020 "transition" planning will commence for several possible user programs
- FY 2020 Plans
  - Final HTVE-UE/FDECO electrical interface development will be completed
  - HTVE-UE device will be retrieved and condition and performance analyzed
  - Operational concepts studies will be completed (for the OECIF-sponsored efforts)
  - Post-FY 2020 "transition" planning will be completed for several possible user programs

JP-8 BASED FUEL CELL POWER

Lead Organization: U.S. Army Tank Research, Development and Engineering Center (TARDEC) – Ground Vehicle Power and Mobility (GVPM)

Other Key Participants: Air Force Research Laboratory (Wright-Patterson)

OE Funding Stream:

FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	Total
$1.9	$2.4	$2.2	$1.6	$8.0

Description: Silent power is a critical enabler for robotic platforms to conduct extended missions with a low acoustic signature. This effort will develop a JP-8 based fuel cell power system that will meet the noise, range, and power requirements of the Squad Multi-purpose Equipment Transport (SMET) unmanned vehicle. The development of a power system for an SMET vehicle supports the reduction of soldier equipment burden and provides silent mobility, power generation, transportation, reconnaissance and autonomous resupply for dismounted infantry operations in the Pacific region. A JP-8 fuel cell power system integrated into an SMET representative vehicle will show the ability to meet both noise and range requirements. These systems can provide increased efficiency allowing the vehicle to go further before refueling is required. On-board power means reduced need for generators, battery chargers and additional batteries, further easing logistics. This project will integrate a JP-8 reformer and Sulfur absorption system with a Sulfur tolerant Solid Oxide Fuel Cell (SOFC) sized to provide 10 kW of electrical power. This 10 kW JP-8 fuel cell power system will then be integrated on an SMET representative vehicle for demonstration.

Military Benefit: The JP-8 fuel cell power system enables a silent, efficient vehicle capable of transporting equipment at an increased range before refueling while simultaneously able to quietly export power for mission needs. Efficient power generation, especially at low electrical loads, enables exportable power capable of replacing conventional 10kW generators or water purification systems.

Technology enabler for long range Intelligence, Surveillance, and Reconnaissance (ISR) due to quiet extended power generation without any change in logistic fuels.

Technology common across DoD - Collaboration with Air Force, Navy, SOCOM, USMC, CERDEC

- Silent Mobility – The JP-8 fuel cell power system operates at very low noise level similar to a battery powered electric vehicle. The combination of JP-8 reformer and Solid Oxide Fuel Cell allows for this quiet operation fueled by JP-8.

- Extended Range – The JP-8 fuel cell power system augments the onboard battery to extend the range of the SMET vehicle. The system enables operation without lengthy battery recharges that would be very challenging in an operational field environment.

- Exportable Power – The JP-8 fuel cell power system is capable of quietly providing 10 kW of electrical power for either mobility or exportable power applications.

Accomplishments/Status:

- Accomplishments to date: An initial prototype JP-8 reformer system with sulfur absorption bed sized for 10 kW was successfully demonstrated during the first year and continues testing. A half size 24-cell Solid Oxide Fuel Cell (SOFC) was demonstrated and continues testing as well as design refinement for future mating with the JP-8 reformer. Full system process flow diagrams and designs have been developed and initial integration work has begun.

- FY 2016 Accomplishments (funding received August 2016)

  - 10 kW JP-8 prototype reformer completed with performance testing completed up to 1,000 ppm Sulfur.
  - 24 cell SOFC stack developed and tested.
  - Detailed process design completed for integrated JP-8 reformer and SOFC system with balance of plant components acquired.
  - Acquired SMET representative unmanned ground vehicle.

- FY2017 Accomplishments (Ongoing, funding received February 2018)

  - Improved SOFC manifold design confirmed to improve air flow and system operation, testing is ongoing
  - Continue JP-8 reformer performance testing of beta prototype up to 3,000 ppm Sulfur
  - Continue SOFC development and build of full scale 48 cell stack.
  - Initiate first iteration of JP-8 reformer and SOFC integration at a 10 kW fuel cell system size under laboratory supported conditions.

- FY 2018 Plans (Planning request of funds in August 2018)

  - Initiate second iteration of JP-8 reformer and SOFC integration at a 10 kW fuel cell system size but with all balance of plant components under laboratory supported conditions.
  - Characterization of SMET representative ground vehicle completed
  - Initiate third iteration of JP-8 reformer and SOFC integration at a 10 kW fuel cell system size with all balance of plant components transitioning from laboratory supported conditions to stand alone operation.

- FY 2019 Plans (Planning request of funds in August 2019)

  - Integrate the JP-8 fuel cell power system onto the SMET representative vehicle.
  - Demonstration of the JP-8 fuel cell powered SMET representative vehicle.

RELIABLE, EFFICIENT, TACTICAL UNMANNED AIRCRAFT SYSTEM (UAS) POWER SYSTEM

Lead Organization: Air Force Research Lab; US Army Research, Development and Engineering Command

OE Funding Stream:

FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$1.5	$0.8	$0.9	$3.1

Introduction: Current group 2-3 UAS have historically been developed using commercial-off-the-shelf engines, which has led to significant reliability issues and limited aircraft range/endurance. The Services are in the early stages of initiating science and technology research efforts to address this situation. Both the Army and Air Force have developed small engine test facilities to enable small engine development and validation. The Air Force has initiated a 1st iteration of technology development with an effort which is working towards the design and test of a turbo-generator and propulsor for integration into a representative group 3 fixed wing UAS. The Army has been monitoring the progress of the engine to serve as a development partner and possible transition partner for this technology.

Description: The objective of the proposed effort is to develop and validate propulsion technology for group 2/3 size UAS to significantly extend the operational endurance and payload capabilities of a small UAS while increasing reliability (increased availability, reduced O&S costs) and reducing vehicle noise.

The Army Aviation Development Directorate and Air Force Research Lab (AFRL) are forming a joint effort to design and build a "generation 2" engine based upon AFRL's first generation GHO engine (a recuperated micro-turbine with generator). The generation 2 engine's goals will be to maintain or shrink the current engine form factor while reducing the weight of the engine and enable running on heavy fuel. The improved Mean Time between Overhaul (MTBO) from 250 hours to 1000 hours will result in significantly higher availability rates while reducing the maintenance related costs and logistics footprint.

Engine Requirements Table

Weight	Power Output	Specific Fuel Consumption (SFC)	Mean Time Between Overhaul
11.5 pounds	5.5 kW – 6.0 kW	< 0.65 (lbs./hp-hr)	1000 hrs.

This will be a 20 month effort and will utilize an existing VATTE IDIQ contract to execute the next phase of work. Validation testing would include Army Small Engine Altitude Research Facility (SMEARF) testing.

Schedule: Award was completed in late 4th quarter FY 2016. The technical effort includes redesign of key components for improved performance and reliability, fabrication, and engine validation testing, which will be completed in 1st quarter FY 2019. Upon completion, two engines will be delivered.

Accomplishments: The contract has been awarded to Florida Turbine Technology (FTT) located in Jupiter, Florida. FTT has completed a 3-month study of the engine and has settled on a design configuration for the engine. Final design of the engine and procurement of the equipment is currently in process. Current estimates indicate that all of the engine requirements will be met, with the exception of the weight metric. Currently, the design of the engine places the weight of the engine at 14.3 pounds. This is nearly identical to the weight of the original working test engine designed by Azmark. However, the reliability of this unit will be substantially better than that of the original test engine. FTT will continue to work to improve the weight metric, but at this time the reliability of the engine is significantly more important to the program than the weight goal. Even if the weight is not improved, OECIF will have still developed a game changing engine that surpasses the performance of any engine in this class. Additionally, strong interest has been expressed for the engine by SOCOM and other government organizations. We are still planning on testing the engine at the Army SMEARF for altitude performance and ultimately a flight test of the engines in a representative testbed UAS platform.

JOINT OPERATIONAL ENERGY COMMAND AND CONTROL (JOEC2)

Lead Organization: Marine Corps Systems Command SPAWAR Systems Center, Pacific

Other Key Participants: Army

OE Funding Stream:

FY 2016 (M)	FY 2017 (M)	Total
$0.5	$1.2	$1.7

Description: The U.S. Marine Corps and Army must make deliberate and timely decisions that balance operational performance with energy consumption to win in a complex world. The 2024 Marine Expeditionary Brigade (MEB) will be 45% more energy intensive than in 2001, with no additional fuel storage or distribution capabilities. Current systems for operational units are inadequate to provide energy performance feedback in a timely manner. Uncertainty regarding energy awareness can lead to waste, but more importantly, it can limit commanders in their ability to execute missions on the battlefield. These capability gaps are addressed in the USMC - ICD for Expeditionary Energy, Water, and Waste, 14 Sep 2012, and the Army's Initial Capabilities Document (ICD) of Operational Energy for Sustained Ground Operations, 27 March 2012. JOEC2 will extend the operational reach and readiness of the Joint Warfighter by providing energy awareness and energy decision support for commanders in expeditionary operations throughout the Range of Military Operations (RoMO).

Military Benefit: This OECIF proposal for research will provide the following benefits to the

DoD. Operational demonstrations/experimental tests demonstrating energy decision support include:

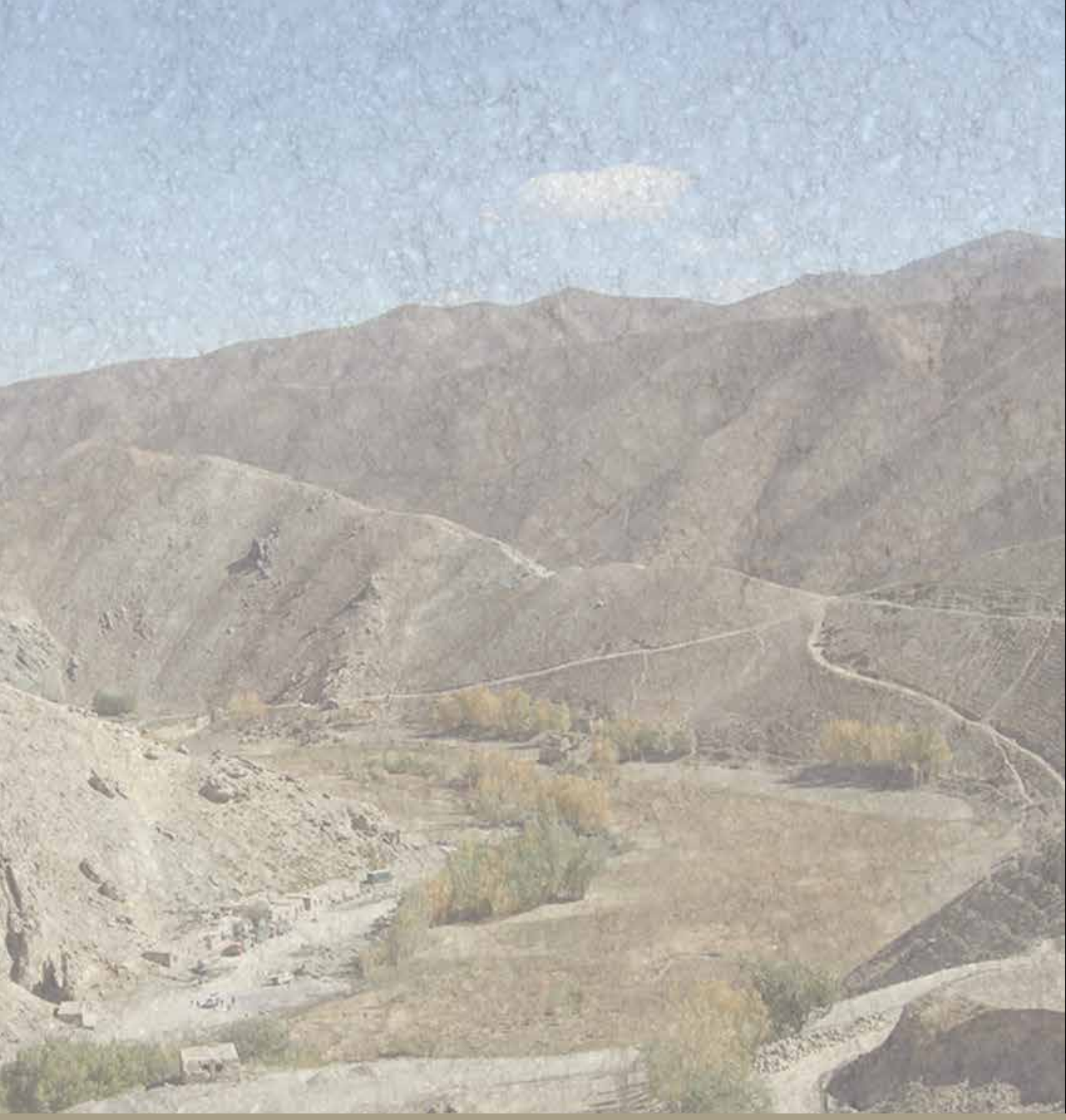
- Operational energy storage and distribution
- Operational energy power generation assets
- Operational energy maneuver assets
- Sustainable Test Bed at 29 Palms MCAGCC for continued advancement and adaptation of JOEC2 technologies for tactical environmental applications.

Accomplishments/Status:

- Stood Up Test Bed at Twenty-Nine Palms WARTEC facility
- Contract for Buildup of AWN modules complete
- ELT transition to government domain in process
- SIXCON Sensor Integration in process – Two units metered and communicating
- Initial purchase of AWN modules complete

Future Plans

- Focus on bulk fuel and build on current capability existing at 29 Palms
- Establish a semi-permanent JOEC2 bulk fuel operational test bed at MCAGCC 29 Palms CA to be used by operational units during Integrated Training Exercises
- Architecture supports real time decision support in forward command posts and to other stakeholders via NIPR
- All Marine Corps bulk fuel asset types (fuel bladders, MK970 tankers, Flatrack Refueler Capability (FRCs) and SIXCONs)
- Establishes a framework/testbed, including facilities, onsite personnel and baseline system hardware to support future development and testing of additional functionality



FY 2017 OECIF Project Summaries:

1. THERMAL AND POWER MANAGEMENT TECHNOLOGIES FOR HIGHPULSE POWER SYSTEMS
2. WIRELESS TRANSMISSION OF ENERGY IN THE FAR-FIELD

OPEN SYSTEMS FOR CONTROLS OF INTEGRATED PROPULSION, POWER, AND THERMAL (OSCIPPT)

Lead Organization: Air Force Research Laboratory/Aerospace Systems Directorate (AFRL/RQ)

Other Key Participants: Naval Surface Warfare Center Philadelphia Division (NSWCPD) (Code 321)

OE Funding Stream:

FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	FY 2020 (M)	Total (M)
$0.9	$0.7	$1.3	$0.7	$3.5

Description: Tighter integrated control strategies for propulsion, power, thermal and mission subsystems are absolutely critical to manage extreme pulsed loads within tough system footprint constraints in challenging and contested environments. At the expense of oversizing and large safety margins, the dominant design paradigm tends to minimize coupling among subsystems to mitigate costly complexity. A common systems control interface and control logic is being developed to overcome key integration challenges for dynamic allocation of energy resources among systems.

Military Benefit: This common interface and control logic is being jointly developed by the Air Force and Navy, with industry support. This work will provide a reference implementation of that interface and control logic for both a ship and aircraft platform. The expected outcomes, demonstrated in part via the reference implementation, include:

Increased Range – Integrated control of the propulsion and thermal systems strategically stores chilled fuel to reduce engine bleed air needed by the thermal system during the most fuel inefficient mission segments. Further, more efficient power generation is enabled by load sharing across multiple sources and storage units (i.e. batteries and generators), which allows engines and propulsion sets to operate at their combined optimal fuel efficient points.

Improved Capability – Next generation mission and weapon systems impose large, highly transient/dynamic loads on the power and thermal systems. Following the traditional approach of dedicating separate power and thermal systems for each weapon and mission system will lead to an infeasible weight and volume budget. Whereas, coordinating among propulsion, power, and thermal systems yields a transient power and thermal capability where the whole is greater than the sum of its parts.

Reduced Acquisition Costs – Future acquisitions are aiming to capture the benefits of an Open System Architecture (OSA) framework. In general, OSA is an organized decomposition using carefully defined boundaries and interfaces to enable several key objectives. These include modular design with loose coupling that allows for independent acquisition of system components across the life cycle; simplified system integration that isolates the effects of change; enterprise investment strategies that maximize reuse of proven designs; and, ability to keep pace with advances in technology.

Two follow on efforts, one within the Navy (Robust Combat Power Control Future Naval Capability) and one within the Air Force (Megawatt Tactical Aircraft), aim to further mature these concepts through hardware implementation.

Accomplishments/Status:

- Accomplishments to date: First overall architecture for OSCIPPT standard developed. Quantified opportunity for ~30% fuel savings on simulated aircraft for thermal system. Demonstrated on simulated aircraft a 20x improvement in faster response time for electrical system.
- FY 2017 Accomplishments (funding received July 2017)
  - Quantified opportunities for fuel savings (~30%) and faster response time (20x) on a notional Air Force architecture
  - FY2018 Plans (Ongoing) (funding received December 2017)
  - Develop power, thermal, and propulsion baseline controls including regulator logic.
  - Develop distributed coordination control and develop functional requirements.
  - Develop OSCIPPT architecture and develop functional requirements.
- FY 2019 Plans
  - Test initial integrated system of controllers on simulated aircraft mission.
  - Document version 1 of the OSCIPPT standard.
- FY 2020 Plans
  - Test integrated system of controllers on simulated ship.
  - Test integrate system of controllers with updates to standard over several aircraft missions.
  - Document version 2 of the OSCIPPT standard.

HIGH DENSITY HYBRID ENERGY STORAGE MODULE (HD-HESM)

Lead Organization: Office of Naval Research (ONR)

Other Key Participants: Air Force Research Laboratory (AFRL), Army Communications Electronics Research, Development and Engineering Center (CERDEC), Army Tank Automotive Research Development & Engineering Center (TARDEC), Naval Air Warfare Center (NAVAIR), Naval Surface Warfare Center Philadelphia Division (NSWCPD), USMC, and Pratt Whitney/ United Technologies

OE Funding Stream:

FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	FY 2020 (M)	Total
$0.7	$2.1	$2.5	$0.7	$5.9

Description: Hybrid Energy Storage Modules (HESM) with both high power and high energy densities, scalable to all power levels, will enhance fuel efficiency, improve reliability and enable future high power weapons and sensors on legacy and next generation vehicles and platforms. This OECIF project will develop a common HESM unit capable of buffering pulse Laser Weapons System (LWS)/Electronic Warfare (EW) loads in the 10's to 100's kW power scale. This leverages prior investment in this area, for all DoD platforms requiring an ultra-high density installation, including combat vehicles, aircraft, and Navy craft/Unmanned Surface Vessels (USV). The culmination of this effort will examine HESM-enabled LWS/EW operation in power hardware-in-the-loop (HIL) demonstrations. Two units will be delivered to the Air Force Research Laboratory (AFRL) and the Army's Tank Automotive Research, Development and Engineering Center (TARDEC), respectively for HESM-enabled LWS/EW operation in power hardware-in-the-loop (HIL) demonstrations. The Navy will conduct platform model analysis for small and unmanned surface vessels. Transition alignment is identified for all DoD services including Army Laser Weapon System Technology Roadmap Programs, Air Force Mega Watt Tactical Aircraft (MWTA) program, and Navy Multifunction Energy Storage FNC Program

Military Benefit: This OECIF proposal for research on High Density Hybrid Energy Storage Module (HD HESM) will provide the following benefits to DoD services.

- Enable continuous firing of pulse load capability
- Reduction of logistic and qualification cost through common platform application
- Enable fuel efficient platform configurations

Accomplishments/Status:

- Accomplishments to date: Contract awarded to Pratt Whitney/United Technologies (PW/ UTAS): Nov 17, DoD service common requirements established, PW/UTAS kickoff meeting completed: Jan 18, Breadboard 600VDC demonstration completed: Jan 18, Initial 2 Wire +/- 300VDC design completed, Initial packaging concept complete. Bi-Weekly OEM meetings w DoD team established.

- FY 2017 Accomplishments (funding received September 2017)
  - DoD Service Common Requirements Development Initiated
  - HD HESM Contract to Pratt Whitney/United Technologies Initiated
- FY2018 (Ongoing)
  - DoD Service Common Requirements Complete
  - HD HESM Contract to Pratt Whitney/United Technologies Complete
  - Kickoff Meeting Complete
  - HD HESM Detailed Design Initiated
- FY 2019 Plans
  - HD HESM Detailed Design Complete
  - Hardware Fabrication and Assembly Initiated
  - AFRL, TARDEC Power Hardware in Loop Test Prep Initiated
  - Navy Platform Analysis Initiated
- FY 2020 Plans
  - HD HESM Factory Acceptance Test
  - DoD Service Power Hardware in Loop Demonstration
  - Navy Platform Analysis Complete

THERMALLY ENABLING ARCHITECTURES FOR PULSE POWER SYSTEMS (TEAPPS)

Lead Organization: Office of Naval Research (ONR)

Other Key Participants: Air Force Research Laboratory (AFRL), Army Research Laboratory (ARL), Naval Surface Warfare Center, Philadelphia Division (NSWCPD), Johns Hopkins University Applied Physics Laboratory (JHU APL), PC Krause and Associates (PCKA), Raytheon, Colorado State University (CSU)

OE Funding Stream:

FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	FY 2020 (M)	Total
$1.8	$2.2	$2.7	$2.8	$9.5

Description: TEAPPS is developing advanced thermal architectures to reduce the size,

weight, and power (SWaP) of cooling systems associated with pulsed-power, directed energy weapons (DEW). This program will develop and employ advanced modeling tools; design and test innovative components and system prototypes; and perform comprehensive integration analysis.

Military Benefit: This OECIF program will provide the following benefits to the US military:

- Efficient thermal management systems (TMS) and control strategies yielding greater than 5% reduction in energy consumption.
- SWaP-reducing thermal technologies de-risked to bolster mission-success of DEW systems in a range of DoD applications.
- Validated government modeling capability to facilitate rapid assessment and optimization of TMS for DEW.

Accomplishments/Status:

- Accomplishments to date: Component models implemented in NavyHHF; model of two-phase pumped loop system; 3D model of diode packaging with PCM; design and testing of sub-scale thermal load emulator; detailed design of sub-scale PCM heat exchanger.
- FY 2017 Accomplishments (funding received June 2017)
  - Released an initial version of Navy High Heat Flux (NavyHHF) library within ATTMO tool containing component models to support pumped two-phase systems and substantially improved numerical robustness
  - Simulated the dynamic performance of two-phase pumped loop system using Navy HHF library
  - Developed initial control strategies using feedforward, instability-sensing scheme for two-phase pumped loop (TPPL) system
  - Completed three-dimensional PCM packaging analysis tool (Para PCM model)
  - Completed design and testing of sub-scale thermal load emulator (TLE)
  - Completed detailed design of full-scale PCM heat exchanger
  - Developed database to analyze integration risk for thermal management system
- FY 2018 Plans (funding received August 2018)
  - Simulate dynamic performance of low-lift vapor compression system (LLVCS) using Navy HHF library
  - Continue verification of physical correlations within the Navy HHF/ATTMO, including

ability to predict the onset of flow instabilities

- Develop PID control strategy for LLVCS
- Integrate Para PCM with ParaPower for full 3D module-scale analysis and study compatibility of metallic PCMs with laser diodes.
- Finalize 50 kW TLE design and fabricate modules
- Fabricate and test sub-scale prototype PCM heat exchangers
- Finalize design, fabricate, and test system performance of TPPL
- Populate database of integration risk for TMS
- Specify physical characteristics and identify shipboard interfaces for high energy

- FY 2019 Plans

  - Release of validated Navy HHF modeling tool within ATTMO
  - Complete testing of two-phase pumped loop control system
  - Integrate 3D PCM Modeling Tool into ATTMO
  - Fabricate and test full-scale PCM heat exchangers
  - Finalize design, fabricate prototype, and test low-lift VCS system performance
  - Develop technical data packages for prototype TMS installation

- FY 2020 Plans

  - Complete thermal system optimization study
  - Complete testing of LLVCS control system
  - Complete reduced order dynamic model of two-phase evaporator and integrate with ATTMO/Navy HHF
  - Test reliability of PCM embedded laser diode module
  - Test alternative components and system architectures
  - Deliver final integration risk database

POWER TRANSMITTED OVER LASER (PTROL)

Lead Organization: U.S. Naval Research Laboratory (NRL)

Other Key Participants: U.S. Army Communications-Electronics Research, Development and Engineering Center (CERDEC), Space and Naval Warfare Systems Center Pacific (SSCPAC), PowerLight Technologies

OE Funding Stream:

FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	FY 2020 (M)	Total
$1.5	$3.3	$1.8	$1.5	$8.1

Description: PTROL will provide a new means of power delivery that reduces the logistics tail, increases warfighter safety, and expands mission capabilities for unmanned and manned assets. The project objective is to deliver a safe, field-ready wireless power capability to provide time-shared power via laser to two sUAS in motion for a minimum of 12 hours at a distance of at least 0.5 km.

The project is structured as a series of technical demonstrations of increasing sophistication and capability to maximize the benefit to the sponsor. Each of the incremental development phases, ranging from TRL 4-6, culminates with a demonstration test for technology validation.

Military Benefit: This OECIF project will develop technology to unleash warfighters from the tethers of fuel, batteries, and power cabling for energy applications with scalable distances and a power levels that can be increased arbitrarily with parallel systems.

- This technology will allow warfighters to reduce risks and focus on the mission by minimizing or eliminating efforts associated with battery recharging, cable installations, small generator maintenance, and power resupply vulnerabilities.
- Lighting, communications relays, unattended sensors, sUASs, and UGVs could be powered indefinitely without risk to personnel use technology developed as part of PTROL.
- The technology directly supports UAV ISR missions: Over the horizon imaging, communications relays, area surveillance, convoy protection, target identification, and tracking.
- No other compelling solution exists to achieve indefinite UAV loiter time to meet mission requirements. Tech pull from CCMDs and services; directly addresses 6 CGA gaps.
- PTROL is a foundational technology for spinoffs that will give our forces an asymmetric capability with broad applicability: anywhere safe, fast, flexible power is needed.

Accomplishments/Status:

- FY2017 Accomplishments (funding received June 2017)
  - Completed successful on-time on-budget demonstration of Power Over Fiber (POF) system to an Uncrewed Underwater Vehicle, 70W over 100m
  - Stimulated transition engagement for POF and free-space Power Beaming from industry, CCMDs, and Services
  - Ordered nearly all hardware for free space power beaming demonstration
  - Extended operation of free space power beaming "safety box" to over 100m
- FY 2018 Plans (ongoing)
  - Demonstrate safe laser power beaming capabilities
  - Advance fine-tracking, FSP safety, and lay groundwork for future further range and coarse tracking
- FY 2019 Plans
  - Execute Free Space Power (FSP) point-to-point on ground 500W @ 300m
- FY 2020 Plans
  - Demonstrate laser power beaming capabilities to support the energy requirements of a quadcopter sUAS
  - Transition technology to JCTD, FNC, or put on GSA schedule

W-BAND POWER BEAMING

Lead Organization: Armament Research Development Engineering Center (ARDEC)

Other Key Participants: Air Force Research Lab (AFRL), Naval Research Lab (NRL)

OE Funding Stream:

FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	FY 2020 (M)	Total
$1.4	$1.4	$1.7	$1.7	$6.2

Description: The goal of this project is to demonstrate millimeter wave / w-band radio frequency (RF) far field wireless power transmission. Two prototypes will be developed each using different technologies to achieve the goal. The rectenna prototype utilizes advanced solid-state Gallium Nitride diodes to convert the 95 Gigahertz (GHz) RF transmission into Direct Current (DC) for storage or active use. The stirling engine prototype will focus on converting the heat generated from the RF into electrical energy.

Military Benefit:

- UAV / UGV Improved Capability – Rectenna's have the potential in removing the power line to UAVs for sustained operation. In addition, beaming power to these systems would allow for longer operational durations.
- Remote Station or Sensor Sustainment – Remote stations or sensors that do not have a direct line to power or lacking resources to generate power could receive power via Active Denial technology.
- Multirole capabilities – Active Denial Technology (ADT) uses 95 GHz as a means of achieving various effects. ADT was initially developed for personnel repel and can be used for concealed weapons detection. This project expands ADTs capabilities and allows for further utility.

Accomplishments/Status:

- FY 2017 / 2018 Accomplishments (funding received April and December of 2017)
  - Rectenna: Successful Rectenna Circuit Critical Design Review (CDR) with supporting analysis showing improved power handling and receiver circuit conversion efficiency over Commercial-On-The-Shelf (COTS) components.
  - Stirling Engine: Initiation of ceramic material synthesis
  - Modeling and Simulation (M&S): 1-D model developed and performed on measured ceramics.
- Planned Milestones (FY19-FY20)
  - Rectenna: Rectenna circuit characterization data to support an understanding of simulation results and at least one candidate device/design that advances the state of conversion efficiency and power handling capabilities of COTS assembled rectenna circuits identified in phase-1.
  - Stirling Engine: Millimeter wave power receiving and thermal conversion system demonstrated (calorimetry load) at ≥5 kW level –OR— Millimeter wave power receiving and thermal conversion system demonstrated with the Stirling Engine at ≥5 kW level (within laboratory enclosure).
  - M&S Thermal Model: Continue to refine the model. Start development of the 3D model.

SPACE SOLAR FOR FORWARD OPERATING BASES AND REMOTE INSTALLATIONS STUDY (S2FOB)

Lead Organization: U.S. Naval Research Laboratory (NRL)

Other Key Participants: U.S. Army Communications-Electronics Research, Development and Engineering Center (CERDEC), U.S. Air Force Air University, The Raytheon Company, Mankins Space Technology, SDP Space Systems, Renaissance Strategic Advisors

OE Funding Stream:

FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	FY 2020 (M)	Total
$0.3	$0.4	$0.4	$0.4	$1.5

Description: This study investigates a potentially remarkable opportunity to develop space-based energy collection and transmission systems for providing clean, constant, globally transmissible energy to support military operations with dramatically increased flexibility and resilience, and with potentially decreased risks and costs.

The study's objective is to determine if it does or does not make sense to pursue a coordinated development effort for a FOB and remote installation energy resupply capability via space solar within the next ten years.

Military Benefit: This OECIF project study will provide the following benefit to the DOD:

- Asymmetric advantage - Illuminates a potentially compelling technology that supports the ongoing transition away from fossil fuels, provides a global transmission energy architecture for resilience and flexibility, employs direct energy delivery to reduce logistics burden and minimize energy resupply risks, and unlocks new and novel operational concepts.

Accomplishments/Status:

- FY2017 Accomplishments (funding received June 2017)
  - Identified applicable installation classes and baselined critical metrics (leveling electricity cost, fully burdened fuel cost, others)
  - Performed orbits, architectures, CONOPS, challenges, benefits, and vulnerabilities assessments
- FY 2018 Plans (ongoing)
  - Incorporate end-user feedback into CONOPS and apply thresholds for feasibility versus alternatives
  - Deliver final study report and brief to Operational Energy office and transition sponsors

APPLIED RESEARCH FOR INSTALLATIONS AND BASE OPERATIONS (ARIBO) MIRAMAR

Lead Organization: Marine Corps Installations Command, Marine Corps Air Station (MCAS), San Diego California

Other Key Participants: Army Tank Automotive Research and Development Engineering Center (TARDEC) and Robotic Research

OE Funding Stream:

FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$0.4	$0.1	$0.1	$0.6

Description: The Marines partnered with TARDEC and Robotic Research to develop an Autonomous Vehicle Proving Grounds at MCAS consisting of (1) Development of an on-base autonomous shuttle, (2) Demonstration of vehicle to grid power network, and (3) Developing a testing grounds (both on-road and off-road) for various industry and Government partners to test and demonstrate their technologies. The proving grounds will allow industry and other Government agencies the ability to test Autonomous Vehicle technologies in a standardized method and allows the military to understand the current state of technology to enhance current and future military developments related to Operational Energy Capability.

Military Benefit: This effort provides the following benefits:

- The Army and Marine Corp gain valuable insight into autonomous vehicle technology advancements that can be leveraged for efficient base transportation and new battlefield capabilities.
- Government and Industry gain access to local driving test routes covering complex urban environments to high speed roadways with the flexibility that facilitates accelerated development of technology essential for enabling autonomous vehicles.
- Demonstration of vehicle to grid power and how that technology can be used to support troops in combat during high power demands.
- Creation of an on base autonomous shuttle system that augments the current transportation system and advances the current state of autonomy needed for base operations with vehicular and solider traffic.

Accomplishments/Status:

FY18 Accomplishments to date:

- Development of the Standard Operating Procedures necessary for the establishment of

the proving grounds. The SOPs ensure safe and productive testing of industry and military vehicles at Miramar. Testing has already begun utilizing these SOPs.

- Enhancements were made to the current ARIBO data recorder and analysis software allowing greater universal connectivity and additional capabilities. Data recorders will be utilized at Miramar's Autonomous Proving Grounds. The data recorders provide a standardized method to compare vehicles and performance improvements and allow data to be easily shared and understood in the engineering community.

- 3D mapping of Miramar's autonomous routes was performed. This 3D map can be shared with potential test partners allowing them to simulate their vehicles and identify issues before exposing the vehicles to pedestrian and vehicular traffic thus creating a safer transition from development to operation.

- Various meeting were held with the stake holders involved in the proving grounds, the vehicle to grid power network, and the autonomous shuttle effort. These meetings are helping to define this military leading effort at Miramar and serve as the direction forward as technologies begin to be developed and demonstrated.

AUTONOMOUS AND ROBOTIC REMOTE REFUELING POINT (AR3P) PROJECT

Lead Organization: U.S. Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC) Aviation Development Directorate (ADD) & Engineering Directorate's (ED) Operational Energy Lab (OpEn Lab)

Other Key Participants: U.S. Army Program Executive Office (PEO) Aviation: Aviation Systems (AS), Aviation Ground Support Equipment (AGSE), the Apache Attack Helicopter (AH)-64E Product Office, Aviation Advanced Technology Directorate (AATD); U.S. Army Tank, Automotive, Research, Development and Engineering Center (TARDEC), Robotic Systems Joint Project Office (JPO), and the Aviation Manuever Battle Labratory (AMBL)

FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	Total
$0.4	$0.1	$0.6	$0.6	$1.7

Description: The Autonomous and Robotic Remote Refueling Point (AR3P) system delivers ground based autonomous unmanned refueling capability. This project addresses the range and on-station time limitations and mission risks faced by current military Rotary Wing (RW) aircraft. Current RW and unmanned aircraft systems are challenged to meet emerging endurance and range profile requirements. Within the Department of Defense (DoD), several disparate capabilities exist and can assist as an interim and long-term solution increasing the resiliency of our systems and providing significant fuel savings coupled with increased tactical time on station.

Military Benefit: The AR3P program goals are to re-introduce the Forward Arming and Refueling Point (FARP) concept using autonomous capabilities in order to a) reduced soldier exposure and b) improve combat radius/increase the range of key existing rotary wing Army aircraft, c) support "Demand reduction" of associated log support on the battlefield, d) improved "On-station time" for Reconnaissance, e) reduced refueling time translates to crew survivability.

Accomplishments/Future Plans:

- Identified three configurations (A, B1 and B2) with subsystems and solution sets for autonomous refueling. During our efforts we identified the three viable paths as: a containerized robotic arm (Configuration B1), UGV mounted robotic arm (Configuration B2), and a "Bump-n-Run" (BnR) fuel tank and carriage (Configuration A) along with common elements for each.

- Designed Small Mount Manifold (SMM) system and cap-less fuel nozzle to reduce fueling time.

- Identified, demonstrated, and analyzed Technical Readiness Levels (TRLs).

- Conducted Limited Initial Capabilities Demonstration (LICD) of Configuration B solution using two robotic systems with machine vision to execute autonomous refueling of an AH-64 static fuselage. Potential to reduce refueling time by 50% when both robotic systems demonstrated auto-fueling concurrently on the same aircraft.

- Defined a project Work Breakdown Structure (WBS) and associated cost model for Configuration B1 and B2 and part of Configuration A (still a work in progress).

- An Operational View (OV1) and Force-on-Force Model was developed by the ABML. AMRDEC and AMBL also developed a draft Command and Control (C2) Plan. A Technology Transfer Agreement and Plan (TTA and TTP) with PdO AGSE is going final in February 2081.

The current 2018/2019 plan forward reflects the original plan to execute Phase 3 to demonstrate two viable approaches for Configuration B and further research into the Bump-and-Run (BnR) concept and benefits of Configuration A. As a roll-up for Phase 3:

- Continued development of Configuration B1/B2 and Configuration A. We submitted for 4 Small Business Technology Transfer proposals relating to autonomous fuel certification/ agitation, bonding, and blind-find methods.

- Initial testing using Configuration B1 and B2 refueling of the Mosquito Unmanned RW helicopter planned for Sep/Oct 2018. This will define the electro-static environment and safety envelopes prior to AH-64 testing in May 2019.

- Continued development and maturity of the Performance Parameter Model (PPM) interface between our technical/physics based models and the AMBL Force-on-Force Operation model.

- Development/improvement of the alternate path of the solution dendritic using path A: 1-3-1-3 (an aerial delivery approach) will also be studied with specific focus on AR3P's BnR approach.

SPACE SOLAR

Lead Organization: Air Force Research Laboratory (AFRL)

Other Key Participants: Northrop Grumman in collaboration with Caltech.

OE Funding Stream:

FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	FY 2020 (M)	Total
$2.4	$2.2	$2.0	$2.0	$8.6

Description: Space Solar is a multi-year research effort in the field of space solar power conducted by Northrop Grumman in collaboration with Caltech.

- Goal is to develop affordable, 24/7 available solar power collected in space and beamed to points of interest – space, air, or land
- Mature and accelerate fielding technology to harvest solar energy in space
- Wirelessly beaming energy in the form of RF wave
- Collect the RF energy convert into electrical energy
- Directly support the Air Force's distributed basing concept with enabling agile operational energy

Military Benefit: This OECIF proposal for research on space solar power will provide the following benefits to DoD.

- Energy Distribution – provide power where and when needed anywhere on or above earth
  - Power for austere bases/denied areas
  - Power to UAVs/Airships extending time on station
  - Power to remote systems reducing need for servicing or replacement
  - Power to unmanned marine vehicles

- New Solar Cell Technology for Satellites - Eliminates wiring and reduces weight
- Satellite Propulsion
- Disaster Relief Capabilities
- Operational energy available more than 20 hours a day
- Independent of weather
- Rectennas can be incorporated into FOB structures (tents, shelters, and temporary structures) reducing the amount and weight of equipment needed to provide expeditionary power
- Eliminates or reduces the need to transport generators into the field for expeditionary power
- Reduced the need for a logistics chain of fuel, lubricants, and spare parts for the generators
- Reduces the amount of people and material that must be moved from a receiving base or port to a forward area in support of combat operations

Accomplishments/Status:

- Clean, inexpensive power available 365/24/7 providing a major impact to military/security operations
- Provide new capabilities to military systems and missions
- Prevent technological surprise for US
  - Chinese announced intent to have a SSP prototype on-orbit by 2030
  - UAE planning to undertake a new SSP initiative
  - Japan actively developing SSP capability, demonstrated ground-based wireless power transmission, series of demos planned through 2020s
- Identified thermal lead, analysis and assessment plan developed
- Evolved metrology correction process & developed near-term demonstration plan
- OECIF FY17 and FY18 funding focused on advancing metrology
  - Demo 1 (FY17) Objective: Demonstrate effectiveness of sun-sensor based metrology process using a 60m flexible structure

- Demo 2 (FY18) Objective: Demonstrate practical, self-contained implementation of metrology process leading to corrected beam-patterns

OE WATSON

Lead Organization: Air Force Research Laboratory

Other Key Participants: University of Dayton, SAF AQ (AFMC/A4)

OE Funding Stream:

FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	FY 2020 (M)	Total
$2.2	$1.7	$3.1	$2.0	$9.0

Description: AI approaches have emerged as powerful tools for analyzing unstructured data

- Opportunity to improve decision making across the OE R&D enterprise by applying AI-based tools, for example:
  - alignment to strategy
  - gaps in resources, knowledge or capability
  - understand patterns / results of past investment
  - evidence-based common understanding across enterprise is the goal

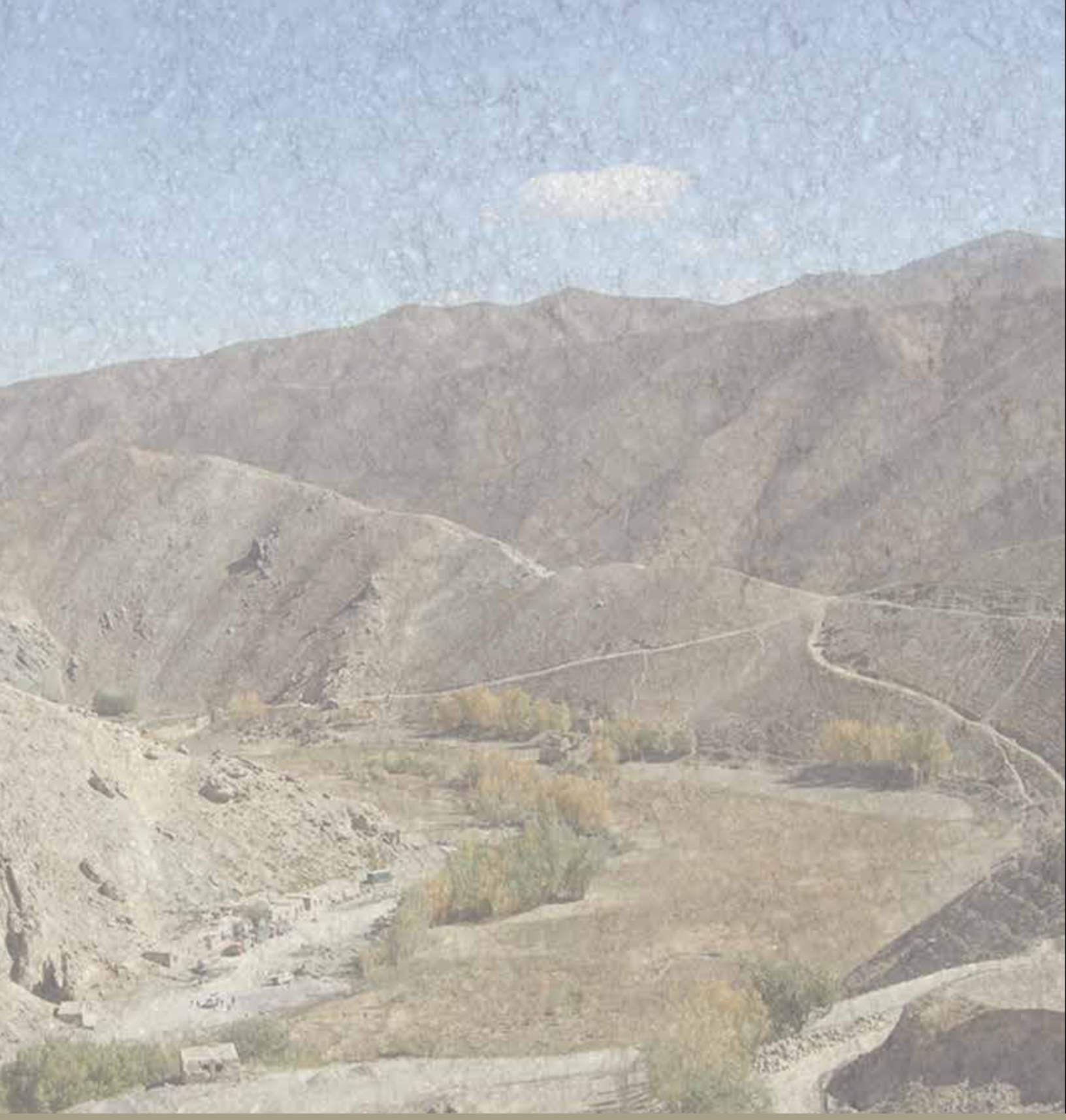
Effective engineering analysis is outpaced by (a) too much "generated data" (data is not knowledge), (b) human inability to assess the data, and (c) modern warfare logistics complexity. Depot industrial output and the effects/impacts to the warfighter can only be performed using a side by side human/cognitive assistant. The combination succeeds because humans and or machines cannot be successful individually. The latest studies show a human/machine combination cannot lose in a contest or armed conflict. This program will utilize an instantiation of the IBM's cognitive computing platform known as Watson as the central hub of a learning decision support process to better inform the Air Force industrial base on the most effective implementation on depot and supply chain options to meet current and future contested environments. This process will leverage current work at UDRI/AFRL and by bringing qualitative warfighter logistics support and insight into the operational viability and flexibility of new industrial base investment areas. To accomplish this, the Watson system will be trained using relevant LIMS-EV and other depot data, documentation on industry trends, war plans, CONOPS, supply chain parameters, etc. In this way, a depot operations knowledge repository is established. Once trained, Watson can be used to investigate the most effective warfighter industrial production and supply chain approach to meet current and future scenario needs.

Military Benefit: This OECIF proposal will provide the following benefits:

- Utilizing advanced computing techniques will provide better information to decision makers
- Better information supports decision making across the enterprise and improves stakeholder communications (e.g. w/Congress)
- Decision making results in improved R&D outcomes and military capabilities
- Communication with stakeholders results in better resourcing for DoD priorities

Accomplishments/Status:

- Developed AI-enhanced portfolio management "Discovery" tool
  - Implemented with "out of the box" Watson AI
  - Non-ITAR, cloud implementation for proof of concept
- Developed AI-enhanced technology development tool
  - Enriched performance with custom Type-system
  - ~200 hours of training language model
  - Focused on hypersonic technology area
- Established OE-metrics to guide portfolio management approach
- Continue development of portfolio management (PM) tool analytics for connecting technologies to systems and missions (1-N, 1-mission problem)
- Transition technology discovery tool to AFRL/RQ for trials



FY 2018 OECIF Project Summaries:

STUDIES TO IDENTIFY OPERATIONAL ENERGY SCIENCE & TECHNOLOGY GAPS IN THE NEAR-, MID-, AND FAR-TERM

ADVANCED UNMANNED VEHICLE REMOTE AUTONOMOUS SUSTAINMENT (AURAS)

Lead Organization: Naval Surface Warfare Center, Carderock Division

Other Key Participants: Naval Research Laboratory (NRL); Sandia National Labs (SNL); National Renewable Energy Labs (NREL); Marine Corps Expeditionary Energy Office (E2O); Army Communications-Electronics Research, Development and Engineering Center (CERDEC)

FY 2018 (M)	Total
$1.2	$1.2

Description: The proposed AURAS study is a one-year effort with the goals of identifying operational energy-related capability gaps and providing a methodology to identify S&T investments needed in the field of remote, autonomous refueling and recharging of unmanned vehicles. Without careful study, a limiting factor in transitioning advanced unmanned combat capabilities to the Operating Forces in high threat environments will simply be the logistics and manpower required to sustain them.

The technical approach for this study will be broken into three broad categories: energy management and optimization, energy generation, storage, and transportation, and energy transfer. Each section will identify relevant capability gaps with assessments of the near-, mid-, and far-term challenges and provide methodologies to identify S&T investments required to overcome them. A technology and investment roadmap will be developed to help decision makers identify and prioritize S&T investments. This roadmap will follow an anticipated progression in autonomous capabilities, beginning with the OE logistics of today which require energy to be transported to the operating area, manual refueling (typically only performed in non-hostile areas), and little to no system-level energy management or optimization.

Military Benefit: The 2016 Operational Energy Strategy highlights that area-denial practices such as improvised explosive devices (IEDs), mines, and anti-aircraft defenses will limit the feasibility of "logistically intensive future concepts" required to maintain military superiority.

1. Identification of operational energy capability gaps in the near-, mid-, and far-term

2. Improved UXV persistence can lead to improved battlespace control, reduced combat risk, improved logistics, reduced manpower burden, and force multiplication.

3. Helps DoD identify S&T technology investments to improve energy generation, storage, management, and transfer in order to achieve autonomous sustainment of UXVs.

Status/Accomplishments:

- Organized diverse team of SMEs with broad range of energy generation, management, and storage expertise needed to tackle the AURAS study.
- Conducted preliminary consultation with Carderock S&T Investment Roadmap lead for their input and recommendations on the AURAS effort.
- Conducted preliminary consultation with Carderock Unmanned Vehicles / Autonomous Systems (UV/AS) working group co-chair for their input and recommendations on the AURAS effort.
- Developing financial and management plans and an execution schedule.
- Finalized the technical approach plan and methodology.

PACIFIC OPERATIONAL ENERGY SURVEY, EXPLORATION, INVESTIGATION, AND DEVELOPMENT TO MEET OPERATIONAL NEEDS (POSEIDON)

Lead Organization: U.S. Pacific Command

Other Key Participants: Institute for Defense Analysis; Gartner Group

FY 2018 (M)	Total
$0.9	$0.9

Description: This joint study addresses energy-related capability gaps associated with plan execution in the US Pacific Command area of responsibility (AOR). This include theater campaign plans (steady state), contingency (CONPLAN), and operations plans (OPLAN). Additionally, the USPACOM 2016 Base Resiliency Strategy creates certain operational energy requirements that will be exceptionally difficult to meet. USPACOM has noted these deficiencies in various requirements documents since 2012. This study will serve as a comprehensive technology roadmap to address these challenges.

Military Benefit: The resulting technology strategy will inform a path forward to close the identified capability gaps through an integrated and future-looking investment program. This will improve our "tooth to tail" ratio, make our forces more expeditionary and nimble, and reduce our vulnerabilities associated with long, exposed supply lines.

Accomplishments/Future Plans:

US Pacific Command has executed a campaign of experiments designed to address specific theater operational energy challenges:

- FY 11-15—Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) –illustrated the utility of single integrated circuits using multiple power generation techniques, particularly renewables—critical to a high-renewable density and small grid environment, such as the many small bases on small, isolated islands that we have in this AOR.

- FY12-16–-Transformative Reductions in Operational Energy Consumption (TROPEC). Created a test bed for industry to bring a broad range of energy-saving technologies.

- FY13-16—Joint Deployable Waste to Energy (JDW2E). Solved two problems at once for small, isolated bases—what to do with trash and how to generate electricity.

- FY14-18—Joint Deployment Energy Planning and Logistics Optimization (J-DEPLOI) Modified the Joint Operational Planning Process and the Joint Operational Planning Execution System.

Future plans focus on a holistic, systems approach to the USPACOM plans, scheme of maneuver, and mobility requirements in order to conduct operations. Rather than attempting to solve each energy challenge in a one-off manner, a thoughtful approach (driven by data analysis) may provide greater and quicker successes. POSEIDON provides the resources and relationships to approach our operational energy challenges in this manner.

NAVY AND USMC BULK FUEL STORAGE AND DISTRIBUTION STUDY

Lead Organization: Naval Surface Warfare Center Carderock Division (NSWCCD)

Other Key Participants: Marine Corps Expeditionary Energy Office (E2O), US PACOM J4, US Army Petroleum Center (USAPC), OPNAV N42, OPNAV N45, Naval Postgraduate School and Military Sealift Command (MSC)

OE Funding Stream:

FY 2018 (M)	Total (M)
$0.3	$0.3

Description: Our Navy's current fuel storage and distribution systems were designed and built with objectives for low cost and to support well-defined lines of supply. Therefore, these systems cannot provide the proper level of support to Joint Forces operating in contested environments. Our team, led by the Naval Surface Warfare Center, Carderock Division (NSWCCD), in collaboration with the Marine Corps Expeditionary Energy Office (E2O), US PACOM J4, US Army Petroleum Center (USAPC), and Military Sealift Command (MSC), as well

as subject matter experts from within DoD and industry, will conduct a 12-month study to assess the capability of current and developmental technologies to operate outside, as well as inside, a threat arc to distribute fuel to Marine Corps and other Joint Forces in multiple locations ashore.

Military Benefit: The Navy has the Service-level responsibility for delivering bulk fuel to the high water mark for further distribution in a Joint Operating Environment. The results of this study will support the Navy, USMC and Joint Force Commanders by providing flexible options to refuel Army, Navy, USMC, USAF and coalition forces in theater as well as providing petroleum product delivery for an over-the-shore connection to inland distribution points/hubs. This study will:

- Enhance the understanding of bulk fuel storage and distribution impacts on the Joint Force.
- Identify capability and capacity gaps to drive S&T and RDT&E budgetary decisions and future force composition.

Accomplishments/Status:

- Accomplishments to date: Kick-Off meeting held with Ms. RuthAnne Darling, Director of Innovation, OASD EI&E and team on 4 May 2018 outlining the plan for the performance, schedule and cost of the study.
- FY 2018 Plans (funding to be received June 2018)
  - Research existing information and works pertinent to this subject including, but not limited to joint and service doctrinal publications, past studies and analyses about bulk fuel requirements, ground and air transportation and capacity, operational requirements, war games, and lessons learned. Review current and planned future naval bulk fuel capabilities, capacities and delivery systems.
  - Develop an analytic framework for the study that includes several key elements:
    - The mission tasks and functional objectives (FOs) that the portfolios of systems must satisfy.
    - The Measures of Effectiveness (MOEs) and Measures of Performance (MOPs) that are used to evaluate the portfolios of alternatives.
    - The methodology by which the MOEs and MOPs are quantified.
- FY 2019 Plans
  - Define and choose scenarios in collaboration with the FY18 OECIF awarded USPACOM POSEIDON Study team.
  - Map the Naval & Joint Bulk Fuel Storage & Distribution Network using the Bulk Fuel Distribution model (BF-DiST), incorporating:
  - The results of the 2017 MAGTF Bulk Fuel Study
  - The littoral (Permissive/Contested) and blue water operating areas

- Identify emerging and new technology solutions within the trade space from academia, industry and government.
- Provide modeling and analysis of portfolios of systems in multiple scenarios in the near, mid- and far-term.
- Baseline to determine weaknesses, vulnerabilities and chokepoints.
- Perform excursion analysis by incorporating new technology solutions to determine impacts to the Naval & Joint Bulk Fuel Network.
- Develop a near, mid and far-term technology roadmap.

OPERATIONALLY RELEVANT FUEL CONSUMPTION AND RANGE ESTIMATION

Lead Organization: US Army Materiel Systems Analysis Activity (AMSAA)

Other Key Participants: Army Centers of Excellence (CoEs), TRADOC Analysis Center (TRAC)

OE Funding Stream:

FY 2018 (M)	Total
$0.1	$0.1

Description: For Army and Joint operations, the capability to predict operationally relevant ground vehicle fuel consumption and range is limited. Current fuel estimates are sustainment focused and lack the geospecific fidelity to capture Area of Interest (AOI) specific (terrain, path) information. Operators, logisticians, and analysts need better fuel and range estimates at their disposal to support mission planning activities, readiness, and acquisition decisions.

These Capability Improvement Funds (CIF) will be used by AMSAA to achieve to primary goals, 1) Assess gap between sustainment focused fuel estimates and geospecific estimates, and 2) Socialize concept with potential end-users to establish need(s) and develop potential end-user requirements. In order to support activities related to the efforts two primary goals, AMSAA will integrate proven geospatial/mobility/fuel modeling capabilities to estimate fuel (and range) based on operationally relevant conditions.

Military Benefit: This effort represents a paradigm shift from low fidelity sustainment based fuel and range estimates to "real-world" geospecific estimates that directly impact mission planning activities and potentially impact the entire acquisition spectrum:

- Capability to shape/inform requirements development
- Capability to reduce acquisition risk because operational impact of new technologies can be assessed prior to development/production

- Capability to address materiel "what if" scenarios during Research and Development (R&D) and Engineering Change Proposals (ECPs)
- Capability to forecast/plan Operations and Sustainment (O&S) fuel consumption/cost

In addition, new methods explored will impact information provided to decision makers regarding fuel consumption and range estimates. The analytical measurement space will be extended to include operationally relevant metrics (e.g. path specific range, Number of FOB-to-COP refuels, Total Accessible Area on a Single Tank) far beyond the current capability (total fuel based on limited conditions).

Accomplishments/Status:

- GAP ASSESSMENT (Goal #1)
  - Identified two CONUS sources of information and currently processing data sets to verify gaps between sustainment based estimates and geospecific estimates
  - Identified OCONUS source of information (June 2018 Operation Saber Strike) to validate fuel estimation approach and capture/assess gap
- NEED EXPLORATION (Goal #2)
  - Identified various Army and USMC stakeholders who requires fuel estimates for planning and/or analysis?
  - Identified relevant Army fuel planning tools what tools are being used for fuel planning and/or analysis?
  - Coordinated upcoming participation in Army Logistics University (ALU) Logistics Captain's Career Course (LOG C3) with intent to audit the Class III (B) fuel block portion of the course and Army CoE Simulation Exercise (SIMEX) how are operators taught to plan for fuel, and how do they plan for fuel?
- FY 2018 Plans (ongoing)
  - Complete fuel estimate verification process using CONUS data sets
  - Complete fuel estimate validation process using OCONUS data set
  - Apply geospecific fuel modeling techniques (range estimation) in support to EHET AoA
  - Participate in LOG C3 fuel block training and SIMEX
  - Document User needs/requirements based on interaction with Army and USMC stakeholders to include analysts, operators, and instructors

TACTICAL PHOTOVOLTAIC (PV) TEST METHODOLOGY DEVELOPMENT

Lead Organization: US Army Aberdeen Test Center (USAATC)

Other Key Participants: Naval Surface Warfare Center - Carderock Division; Communication-Electronics, Research Development and Engineering Center; Navy Research Lab; and Natick Soldier Research, Development and Engineering Center, National Renewable Energy Lab, Redstone Test Center, Sandia National Lab

OE Funding Stream:

FY 2016 (M)	FY 2018 (M)	Total (M)
$0.5	$0.2	$0.7

Description: Renewable energy technologies (e.g. photovoltaics for expeditionary energy) must be subjected to a wide range of environmental and use conditions to properly characterize performance across the full range expected under warfighter usage. Due to the relatively recent injection of these technologies into the Department of Defense (DOD) inventory, no applicable standard exists which can be referenced by test and evaluation or acquisition entities. For this reason, a number of DOD agencies have gathered together to merge best practices and standardize evaluation methodology.

U.S. Army Aberdeen Test Center personnel will lead this multi-agency effort to finalize and publish the developed methodologies as a formal an Army Test and Evaluation Command (ATEC) Test Operating Procedure (TOP) as TOP 09-2-291, Environmental and Performance Testing of Photovoltaic Systems. A general scope of the test methodologies that will be included in the TOP will be for Performance, Safety, Environmental and Durability.

Military Benefit: This OECIF proposal to develop a published DOD standard for Test Operating Procedures for the testing of tactical photovoltaic systems will provide the following benefits to the Department of Defense.

- Consistency – When testing is conducted to the published standard it shall allow DOD test agencies, research and development labs, and program managers to compare test data conducted at each lab with confidence

- Open Standard – The published test standard will be published for public release, allowing open access to the standard to anyone with industry. This shall eliminate the need for DOD personnel or industry to purchase a commercial test standard.

Accomplishments/Status:

- Accomplishments to date: A draft TOP has been authored and is undergoing initial technical editing within Army Test & Evaluation Command's formal TOP publishing process.

- FY2017 Accomplishments (funding received June 2017)

- Coordinate between supporting organizations in the authoring of 22 unique test methods for DOD PV technologies.
- Conducted round-robin Current-Voltage (IV) curve testing on sample PV panels at each supporting test lab to ensure consistency in measurement techniques

- FY 2018 Plans (funding received in July 2018)
  - Analyze round-robin test data
  - Adapt and modify authored standards based off round-robin test results
  - Conduct the environmental performance test methodologies as written in the draft TOP and compare test results to expect on a subset of tactical PV technologies

- FY 2019 Plans
  - Release to the DOD's Joint Standardization Board (JSB) for Mobile Electric Power (MEP) for formal review.
  - Formally publish as TOP 09-2-291, Environmental and Performance Testing of Photovoltaic Systems through ATEC's TOP publishing process.

POWER & ENERGY STUDY FOR DIRECTED ENERGY/ELECTRONIC WARFARE CAPABILITIES (DE EW)

Lead Organization: U.S. Army's Communication-Electronics, Research Development and Engineering Center (CERDEC)

Other Key Participants: U.S. Army's Tank Automotive Research, Development and Engineering Center (TARDEC), Air Force Research Laboratory (AFRL)

OE Funding Stream:

FY 2018 (M)	Total
$0.7	$0.7

Description: The one-year study is to identify operational energy related capability gaps in near, mid-term and far term DE and EW capabilities, and to identify the associated S&T investments to bridge the gaps.

The proposed study includes the following tasks:

1. Power Requirements Trace: This task will provide the Power and Energy Data for different DE / EW capabilities and identification of any gaps.

2. Thermal Systems Requirements Trace: In conjunction with Task 1, this task will provide the thermal data required for different EW / DE capabilities and identification of any gaps.

3. Data from the requirements trace will be analyzed to evaluate performance with different technologies for different mission capabilities.

4. Power, Energy and Thermal Systems Roadmap: A road map to identify technology investments in Power, Energy and Thermal technologies to enable EW / DE capabilities.

Military Benefit: The Roadmap will inform future investments in S&T to enable:

- Increased Survivability – The use of DE and EW Counter Measures (CM) systems will potentially enable increased survivability of military platforms as multiple CMs can be more effectively employed to defeat threats.

- Increased Lethality – The DE and EW offensive weapon systems will potentially enable increased lethality as these systems are precise, cost-effective and offer almost unlimited firing capacity.

Accomplishments/Status:

Accomplishments to date: Power, Energy and Thermal Requirements have been identified for Counter UAVs systems.

DISMOUNTED WARFIGHTER OPERATIONAL ENERGY S&T GAPS STUDY

Lead Organization: Natick Soldier Research, Development and Engineering Center (NSRDEC)

Other Key Participants: CERDEC, ARL, NSWCCD, NRL, USMC, ARCIC, MCoE, TARDEC, PEO Soldier, MITRE Corp, AMSSA

OE Funding Stream:

FY 2018 (M)	Total
$1.2	$1.2

Description: Conduct a study that identifies Dismounted Warfighter operational energy Science and Technology (S&T) gaps over the near, mid, and far terms and documents the findings with recommendations to support alignment and prioritization considerations to inform future operational energy research and investment decision to enable Dismounted Warfighter operational effectiveness and overmatch to support Multi-Domain objectives in the Future Operating Environment.

Develop and execute a formalized and repeatable analytic process identifying technical challenges throughout the phases of preparation, planning and execution of future tactical level mission in the context of a likely future operational environment and tactical level maneuver concepts. Conduct a tactical level review of the operational energy demands and technical challenges in terms of the operational system capabilities required to assess the tactical level operational energy sufficiency, suitability, efficiency and risks associated with maintaining a significant tactical advantage over threat and adversarial capabilities and provide recommendations for the near, mid and far term priorities. Showcase findings in a technology investment roadmap informed through collaboration across the OE community, addressing operational energy capability gaps, technology opportunities, operational opportunities and risks. This approach will document OE related research and development and operational employment goals and objectives for the near, mid and far term to enable operational overmatch of the Tactical Small Unit in the future multi-domain operating environment.

The methodology will consist of five phases: front end analysis, technology assessments, potential technical solution activities, integration analysis and deliverable development.

Military Benefit: This OECIF effort will provide the following benefits to the Warfighter:

- Provide a compiled representative listing of the Dismounted Warfighter Capability Sets for the near, mid and far-term.
- Provide a compiled objective assessment of the Operational Energy technologies in the near, mid and far term.
- Provide an alignment between the planned and desired Warfighter Capabilities, system-level power demands in the near, mid and far term as well as findings and insights related to the sufficiency, efficiency, suitability and risks associated with various operational energy technologies and approaches.
- The results of this effort will help to inform the OSD OE strategy for FY 19 to enable Dismount Warfighter operational effectiveness and overmatch in Multi-domain battle in future operating environments.

Accomplishments/Status:

- FY 2018 Accomplishments (funding received May 2018)
  - Established a collaborative working group composed of those agencies who have a stake in identifying Science and Technology Gaps in Power and Energy.
  - Organized the working group into three Lines of Effort (LOE), each focused on a particular activity: LOE 1- Future Operational Energy Missions, Systems and Equipment Demands, LOE 2 – Operational Energy Systems and Technology Assessments, LOE 3 – Data Development, Modeling and Analysis.

- Developed a draft Systems Book that lists for the baseline and near terms, technology options and their key characteristics, organized by the RDECOM Power and Energy Taxonomy: Generation & Conversion, Storage, Distribution, and Management & Control.
- Developed a tool for modeling at the Platoon and below level the tactical impacts of baseline and optional near-term capability sets.
- Developed an Emerging Insights deliverable

- FY 2019 Plans (ends May 2019)
  - Finalize the Systems Book, extending the time frames into the mid and far term.
  - Exercise the existing and potentially new models to examine mid and far-term capabilities to assist with evaluating sufficiency, efficiency, suitability and the risks associated with various operational energy technologies and approaches.
  - Develop a final deliverable that builds on and expands upon the Emerging Insights deliverable.

APPENDIX C

Technical Assessment of FY 2014, FY 2015 and FY 2016 Completed OECIF Programs

The FY 2014 programs focused on designing analytical methods and tools to model operational energy requirements and inform decision making.

- Joint Deployment Energy Planning & Logistics Optimization Initiative (J-DEPLOI): The program was led by US Indo-Pacific Command (USINDOPACOM) to delivery an analytic tool and policy to allow planners to evaluate vulnerabilities in fuel logistics. The evaluations are used to refine and inform the Commander's course of action selection. User demonstrations were conducted and feedback was used to continue tool development. Verification and Validation roadmap was published and two feature requirements specifications were completed.

- Synthetic Theater Operations Research Model-Energy (STORM-E): Three lines of effort for the USMC effort included result integration, analysis and modeling and simulation. The team created a STORM supported energy focused analytic framework in Joint campaign analysis. The result was a credible and accurate examination of operational energy from the campaign perspective is available as the new standard across the community.

- Operational Energy Analysis Task Force (OEATF): The Army project was designed to establish a foundational operational energy (OE) analytic capability and analysis architecture capable of informing OE decisions and impact on organization, materiel, and operations. Data Management and Validation included a functioning web-based database available to analytical community. Model enhancement was defined by 3 tools – Fully Burdened Cost tool (FBC) and System of Systems Analysis Toolset (SoSAT) and Infantry Warrior Simulation (IWARS).

- Comprehensive Operational Energy Toolkit (COE Toolkit): The project was led by the Air Force to examine in a comprehensive way the impact of attacks on airbase infrastructure through modeling and simulation. The toolkit provides a holistic look at operational energy (aviation fuel, vehicle fuel, electricity, etc.), not only at a base but also the delivery of energy to a base. The methodology allows the analyst to determine various attack options/effects on the infrastructure. The transition partners will continue the evaluation of development to examine the effect of attacks on sortie generation at multiple locations.

- Mission Engineering Analytical Method for Operational Energy (MEAM): The Navy led project designed to analyze the readiness and effects of energy demand and delivery in a contested environment was terminated.

- Capability Assessment & Modeling for Energy Logistics (CAMEL): CAMEL developed a robust methodology and holistically evaluated the OE impacts and military utility of advanced air refueling, airlift, and alternative basing technologies/CONOPS at both

mission and campaign levels. The strengths/functionalities of GOTS, COTS, and purpose-made MS&A tools were leveraged to identify OE vulnerabilities of our logistics/combat fleets in A2/AD environments and the cost of mitigating (via technology and behaviors) these threats to warfighting capability.

- COE Toolkit was an Air Force led effort to take a holistic look at operational energy (aviation fuel, vehicle fuel, electricity) at bases as well as the delivery of these OE assets to a base. The results of this process to take a comprehensive look from the engagement level of modeling up to the campaign level to inform Senior Leaders of the potential vulnerabilities and solutions.

The FY 2015 programs focused on improving fuel economy for the current tactical ground fleet. In addition, Congressional short-term projects were chosen to complement existing OECIF programs or explore new directions.

- Joint Deployable Waste to Energy (JDW2E): USINDOPACOM and ONR led the effort to develop deployable systems and the necessary non-material information to synchronize development of Tactics, Techniques, and Procedures (TTPs), Joint Requirements, Joint Standardized Testing Protocols, and Joint Testing & Evaluation (JT&E) of waste-elimination and waste to energy (W2E).

- Membrane Dehumidification: This project partnered with ARPA-E and NAVFAC to demonstrate that a dehumidification system can selectively allow water vapor to pass, but not air. The evaporative coolers can reduce fuel use for expeditionary cooling and the water produced by dehumidifier can be used.

- Tactical Vehicle Electrification Kit (TVEK): The project was Army led to develop and demonstrate an affordable truck auxiliary system electrification kit to significantly improve vehicle operational energy efficiency. The project will leverage current DOE, ONR, and USMC kit development. The estimated fuel savings is 15-25% over the current performance. The project will validate the capability and provide a business case for transition.

- Autonomy Enabled Fuel Savings for Military Vehicles (Autonomy): The Army led program intended to leverage expertise to develop and test autonomy-enabled technologies to reduce fuel consumption for military vehicles through a smart adaptive cruise control to optimize fuel economy during military missions. The project was terminated, but the knowledge and simulation methods learned will transfer to future work. Additionally, DOT collaboration brings a commercial application for fuel savings in vehicle convoys.

- Thermal Barrier Coatings (TBC): The Army led project focused on the development of a coating for pistons on high power density engines to allow higher in-cylinder gas temperatures while lowering heat rejection without compromising the piston integrity. The program was terminated, but the knowledge and data will continue to be used internally by Tank Automotive Research, Development &Engineering Center.

- Vehicle Light weighting Using Modeling & Simulation (Light weighting): The Army led project was designed to be part of the core competency modeling and simulation capability to develop an analytic framework for structural and topology optimization

through use of novel materials to lessen the structural weight of vehicles. The program was terminated, but the knowledge and data will continue to be used internally by Tank Automotive Research, Development &Engineering Center.

- M-PACT: This multi-agency partnership between the Naval Sea Warfare Centers, DOT, and DOE/NREL demonstrated commercial off the shelf energy technologies at sea. Variable Refrigerant Flow technology and magnetic bearing, variable speed compressor were installed on the ship and demonstrated.

- Waste Heat Recover: This collaboration between Naval Surface Warfare Center, USNA, and Army Research Laboratory and Construction Engineering Research Laboratory to evaluate the efficacy of recovering waste heat to save fuel in various military systems. The recovered energy is integrated into the platform to reduce fuel consumption and improve capability.

- Persistent UAV: The USMC, NRL and industry developed high efficiency, lightweight, and flexible PV solar arrays which were incorporated into UAV wings and provided power to on-board electronics and propulsion systems. The two year project demonstrated cooperative soaring with two aircraft for over five hours by successfully integrating thermal soaring, PV, advanced power management, and command and control software. The goal of this effort was a persistent tactical UAV which utilized thermal soaring and solar energy to complete its mission without the need for fuel. This effort targeted the development of high efficiency, lightweight, and flexible photovoltaic (PV) solar arrays that are incorporated into UAV wings and provided power to on-board electronics and propulsion systems. The optimization of autonomous soaring and cooperation algorithms allow multiple autonomous UAVs to identify and communicate the locations of thermal updrafts to remain aloft without expending energy for propulsion. This transitioned into an FY16 OECIF program.

- Federated Models: OASD (EI&E) led this project to identify which operational energy related analysis tools offered the better utility than manual modeling and what approach would best ensure enduring capability. The Energy-Integrated Modeling and Simulation (M&S) Federations program will utilize integration methods to facilitate multi-resolution war gaming, analysis, and requirements development.

- Cyber: The project led by OASD (EI&E) with support from Johns Hopkins University/Applied Physics Laboratory focused on cybersecurity threats that affect the ability of asset owners to perform their missions. The holistic system and networking enabled analysis of casualties like loss of power, loss of cooling, and communications or security failures impact the control systems.

FY 2016

- Education & Training: A one year study by the Marines, Army, and Air Force to study ways to use energy more efficiently in operations.

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