Department of Defense

An Assessment of Operational Energy Capability Improvement Fund (OECIF) Programs

September 2017

EXECUTIVE SUMMARY

The Department of Defense (DoD) uses the Operational Energy Capability Improvement Fund (OECIF) to invest in science and technology (S&T) efforts that promote long-term improvements to military capabilities aligned to the Department's *Operational Energy Strategy*.

Since the fund's establishment in Fiscal Year (FY) 2012, OECIF has funded a total of 53 studies and programs through FY 2017. Annually, the Office of the Deputy Assistant Secretary of Defense for Operational Energy (ODASD(OE)) identifies one or more specific themes for each year to reflect Department priorities and focus the evaluation and management of S&T investments. Following a review of the most promising proposals submitted by the Services, OECIF provides programs with up to four years of funding.

This assessment evaluates the success of the 13 programs that began in FY 2012, FY 2013, and FY 2015 that are now largely concluded. Specifically, these programs were measured against their stated technical goals and the resulting activities, or transitions, following the end of OECIF funding. Twelve of the thirteen programs were successful, both from a technical and transition perspective, and their transition partners have either already funded or will continue to fund their efforts. Highlights of these programs and transitions include the following:

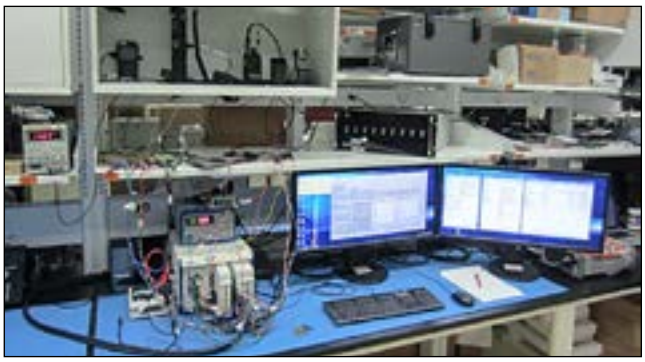
- The Super Energy Efficient Containerized Living Unit (SuperCLU) Design and Development program developed variants of living units, now being used by the Navy, with energy efficiency improvements up to 82 percent.

- The Advanced, Energy Efficient Shelter Systems (AEESS) for Contingency Basing and Other Applications program, continued by both the Army and Air Force, improved insulation efficiency by 50 percent.

- The Waste to Energy for Forward Operating Bases program developed a rotary kiln gasifier that provided an 81 percent liquid fuel savings and a peak efficiency of 75 percent to convert solid feedstock to fuel gas relative to burn pits.

- The Soldier and Small Unit Operational Energy (SSUOE) Consortium developed analysis tools that led to low-power consumption electronics, including software changes to a radio that reduced

SuperCLU folding structure with easy set up and tear down; transported as an International Standards Organization container



SSUOE Soldier System Operational Energy Test Bed

energy needs by 50 percent. These tools are transitioning to the Army.

- The Behavioral Energy Operations Demonstration program Phase I effort determined that savings of 9 to 20 percent may be possible at remote bases and up to 10 percent in vehicles in a tactical environment through behavior change interventions at little to no cost. The Navy is funding Phase II of this effort to test the recommended interventions.

These OECIF investments have yielded improved contingency base equipment and shelters that reduce the energy burden on deployed Warfighters. Building on these successes, the Department will continue to use OECIF to invest in opportunities that increase future warfighting capability and reduce operational risk in support of the Department's *Operational Energy Strategy*. This report is the first of what will become an annual assessment of OECIF programs.

SSUOE data collection for the Common Squad Capability Picture Tool, which evaluates the impacts of load versus mission performance for the Dismounted Warfighter.

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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 programs 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 was established in Fiscal Year (FY) 2012 and is overseen by the Office of the Deputy Assistant Secretary of Defense for Operational Energy (ODASD(OE)). 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, program 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).

OECIF programs are selected annually from Service and Combatant Command proposals that align with the Department's *Operational Energy Strategy* and support that fiscal year's OECIF theme. Since the inception of the OECIF, the ODASD(OE) annually identifies one or more specific themes to reflect Department priorities and focus science and technology (S&T) investments. For FY 2012, OECIF focused on reducing energy loads at expeditionary outposts, with an emphasis on energy efficient shelters and cooling. For FY 2013, OECIF funding was oriented around using consortia to involve a wide variety of organizations to persistently attack key operational energy problems. OECIF themes are summarized in Table 1, and Appendix A includes more detail on the programs within each theme.

Table 1. OECIF Programs, FY 2012-FY 2017

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	1. Thermal and power management technologies for high pulse power systems 2. Wireless transmission of energy in the far-field

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).

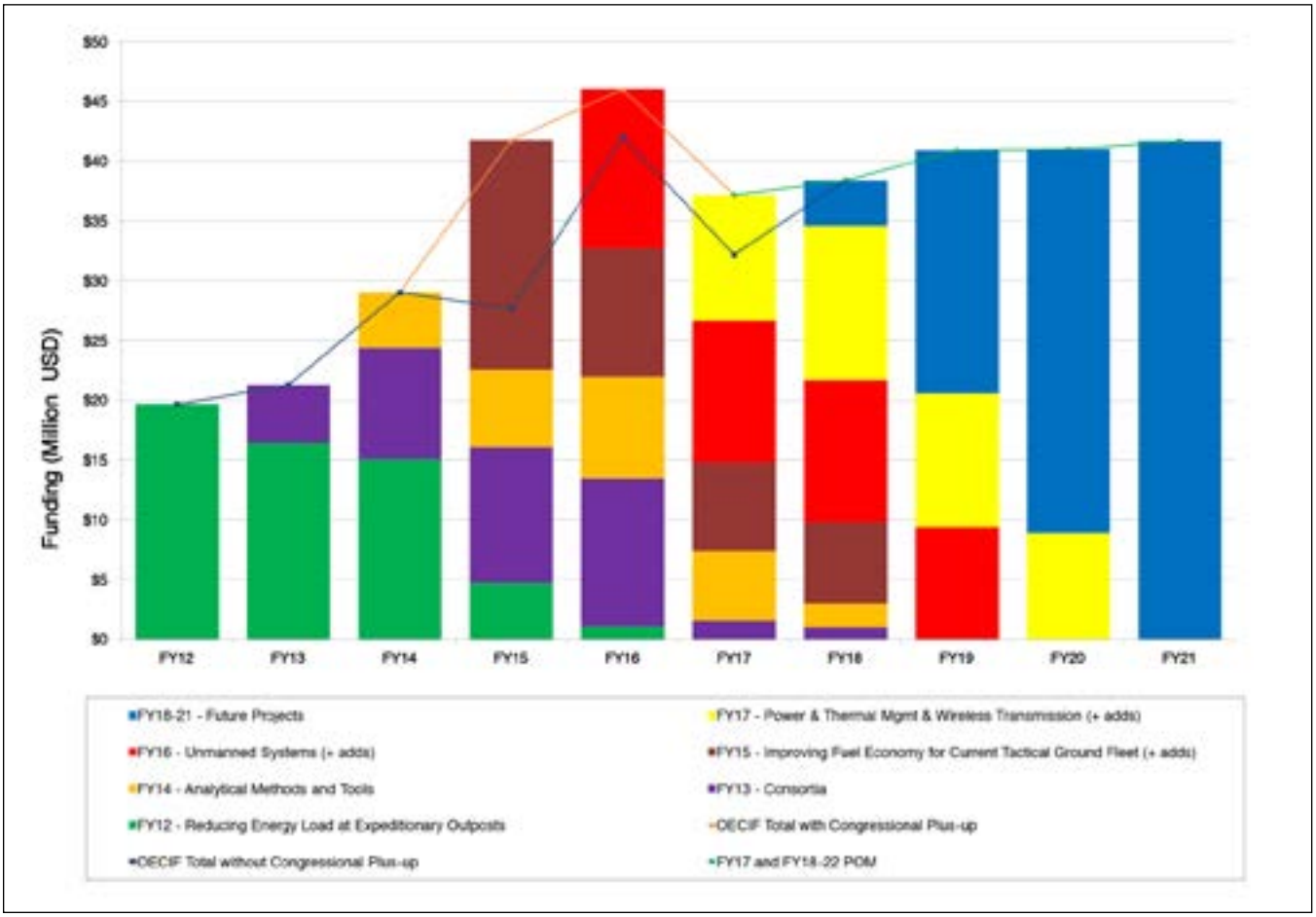
In 2016, the ODASD(OE) initiated a review of completed OECIF programs. These programs consist of all six of the FY 2012 programs, three of the four FY 2013 programs, and four of the ten FY 2015 short-term programs funded with a one-time Congressional plus-up. This report summarizes the results of that review, which will be conducted annually from here forward.

FUNDING

While the amount of OECIF dollars available has fluctuated year-to-year, historically $20-$40 million is appropriated each year. However, the ODASD(OE) typically receives about four times the number of program proposals than can be funded with available resources. OECIF programs typically receive four years of funding, but are managed, executed, and transitioned by the Services or Combatant Commands under ODASD(OE) 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 program objectives.

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

Figure 1. Overview of OECIF Program Funding from FY12 through FY21



BENEFITS

OECIF is designed to ensure that the Department benefits from energy technologies and concepts that would improve operational effectiveness today and in the future. The annual themes of the OECIF program align with the Department's *Operational Energy Strategy* and reflect Department priorities related to specific operational needs and risks. In some cases, programs are selected to fill an investment gap; in other cases, programs are selected to complement Service investments.

For example, in FY 2012, the Department was focused on risks transporting fuel around the battlefield in support of 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 programs for that year focused on reducing energy loads at expeditionary outposts, with an emphasis on energy efficient shelters and cooling.

For FY 2017, the OECIF call for proposals focused on filling a future investment gap. While the Services are funding the development of high pulse power systems, little funding is dedicated to the thermal and power management technologies that would help integrate these high pulse power systems onto existing platforms. OECIF programs initiated in FY 2017 are designed to remedy these shortfalls.

Ultimately, the true value of an OECIF program is dependent on a successful transition to the Warfighter after the end of OECIF funding. 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 programs aim to improve the operational effectiveness of the Joint Force. One to two-page summaries on each OECIF program are included as Appendix B.

ASSESSMENT

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

In FY 2012, six OECIF programs were initiated to reduce energy loads at expeditionary outposts. In FY 2013, four programs were initiated to take advantage of consortia to involve a variety of organizations to solve operational energy problems. In FY 2015, the OECIF program received a one-time $14.1M Congressional plus-up. This plus-up was used to start a number of shorter-term projects to complement existing OECIF programs or explore new directions. All six of the FY 2012 programs, three of the four FY 2013 programs, and four of the ten short-term FY 2015 programs have now concluded. Of these 13 programs, 12 were successful at achieving desired technical goals and have transition partners that have either funded or will continue to fund these efforts after the conclusion of OECIF funding.

TECHNICAL ASSESSMENT

The first part of the OECIF assessment reviewed the technical outcomes achieved by each program. To accomplish this, the ODASD(OE) evaluated the original goals proposed by the Service organization or Combatant Command, assessed results from recurring and close-out progress reviews, reviewed quarterly reports from the program managers, and discussed program outcomes with the program 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 program is not expected to succeed, the Department continuously reviews and improves the effectiveness of its investments, and makes adjustments when required to reflect shifting Department priorities and changing operational environments. This report provides specific changes to the program to identify failing programs as early as possible and redistribute the funds.

FY 2012 Technical Assessment

For FY 2012, the OECIF programs focused on reducing energy loads at expeditionary base camps, with an emphasis on energy efficient shelters and environmental control units (ECUs). Overall, these programs achieved their intended goals and realized significant improvements over current equipment. Table 2 provides a brief description of the technical achievements of all six completed programs. Appendix C contains a more detailed technical assessment.

Table 2. Technical Achievements of FY 2012 Programs

FY 2012 Program Name	Technical Achievement
Advanced, Energy Efficient Shelter Systems for Contingency Basing and Other Applications (AEESS)	Improved soft wall shelter insulation efficiency by 50 percent
Innovative Cooling Equipment Development/Demonstration Program (ICE)	Produced energy efficiency improvements of 56 percent for 9,000 (9K) British Thermal Units (BTU) units, 20 percent for 18K BTU units, 17 percent for 36K BTU units, and 14 percent for 60K BTU units
Navy Expeditionary Technology Transition Program (NETTP)	Successfully demonstrated a Stirling based ECU with an efficiency improvement of 18 percent and a membrane dehumidification system with energy savings of 10 percent
Super Energy Efficient Containerized Living Unit (SuperCLU) Design and Development	Developed an improved CLU with an energy efficiency improvement of 54 percent and a SuperCLU with an energy efficiency improvement of 82 percent
Transformation Reductions in Operational Energy Consumption (TROPEC)	Evaluated 61 technologies resulting in billeting shelter energy improvements of 47 percent and ECU savings of 91 percent
Waste to Energy for Forward Operating Bases (W2E)	Developed a rotary kiln gasifier that provided an 81 percent liquid fuel savings and a peak efficiency of approximately 75 percent to convert solid feedstock to fuel gas

FY 2013 Technical Assessment

For FY 2013, the OECIF programs focused on forming consortia of non-traditional organizations to address key operational energy challenges. Overall, these programs achieved their intended technical goals, realized significant improvements over current equipment, and developed software beneficial to the Warfighter. Table 3 provides a brief description of the technical achievements of the three nearly completed programs. Appendix C contains a more detailed technical assessment.

Table 3. Technical Achievements of FY 2013 Programs

FY 2013 Program Name	Technical Achievement
Energy Efficient Outpost Modeling Consortium (EEOMC)	Developed an Energy Resource Planning Tool to determine the optimal mix of power resources for a given operational scenario; developed the Energy Resource Dashboard and Control 'app' to provide outpost commanders real-time control of energy resources; and offered pilot courses on energy efficiency in expeditionary operations
Soldier and Small Unit Operational Energy (SSUOE) Consortium	Assembled Government Steering Committee, drafted policy for dismounted forces energy requirements, and developed analysis tools, test beds, and wearable measurement systems that led to low-power consumption electronics, including software changes to a radio that reduced energy needs by 50 percent
Engineered Surfaces, Materials, and Coatings for Drag Reduction (ESMC)	Design, analysis, and testing indicated improved fairings can reduce aircraft drag by 1 percent and ongoing research indicates skin friction drag can be reduced with skin surface treatments

FY 2015 Technical Assessment

For FY 2015, the OECIF program received a one-time $14.1M Congressional plus-up. This additional funding was used to start 10 shorter-term projects to complement existing OECIF programs or explore new directions. Overall, the four completed programs achieved their intended goals, evaluated new technologies to provide new capabilities, identified low or no cost energy saving behaviors, and identified gaps in cyber security. Table 4 provides a brief description of the technical achievements of the four completed programs. Appendix C contains a more detailed technical assessment.

Table 4. Technical Achievements of FY 2015 Programs

FY 2015 Program Name	Technical Achievement
Joint Infantry Company Prototype (JIC-P)	Performed small scale user evaluations with multiple units, conducted a human factors study on kinetic harvesters, and continued to improve M&S tools and data to evaluate a kinetic energy harvesting technology system
Behavioral Energy Operations Demonstration (BEyOnD)	Phase I effort determined that savings of 9-20 percent may be possible at remote bases and up to 10 percent in vehicles in a tactical environment through behavior change interventions at little to no cost; identified recommendations to test in Phase II

Table 4. Technical Achievements of FY 2015 Programs *(continued)*

FY 2015 Program Name	Technical Achievement
Advancing Cyber Security for Platform Information Technology (PIT) and Industrial Control Systems (ICS) (CYBER)	Three tasks were accomplished: 1) Analyzed key infrastructure at eleven DoD facilities for cybersecurity threats; 2) Performed gap analysis at the facilities to identify current and emerging technical solutions; and 3) Analyzed workforce skillsets to determine required cyber training to address malicious cyber-attacks; a standard assessment methodology was developed
Solar, Soaring, Cooperative Unmanned Aerial Vehicle (Persistent UAV)	Demonstrated cooperative soaring with two aircraft for over five hours by successfully integrating thermal soaring, photovoltaics, advanced power management, and command and control software

TRANSITION ASSESSMENT

In addition to evaluating the program's technical performance, ODASD(OE) assessed the continuation of the OECIF program with transition partner funding. Once the OECIF funding is exhausted, program funding switches to the identified transition partner, which is generally the Services, but can also be the Combatant Commands or OSD. Ensuring that OECIF advancements are sustained by the transition partner is a key measure of success; to be truly successful, OECIF-funded technologies must reach the Warfighter and improve military capability.

To accomplish this part of the assessment, the ODASD(OE) first determined the span of possible program transitions. Given the variety of different types of OECIF programs, transition outcomes were grouped into the following categories:

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

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

FY 2012 Transition Assessment

For FY 2012, the OECIF programs focused on reducing energy loads at expeditionary base camps, with an emphasis on energy efficient shelters and ECUs. Five of the six programs successfully transitioned and either have already been funded or will be funded. Table 5 provides a summary of the transition outcomes of the six programs.

Table 5. FY 2012 OECIF Programs: Transition Assessment Results

FY 2012 OECIF Program Name	Transition Partner	Transition Category
Advanced, Energy Efficient Shelter Systems for Contingency Basing and Other Applications (AEESS)	Army/Air Force	Equipment
Innovative Cooling Equipment Development/ Demonstration Program (ICE)	Army	None
Navy Expeditionary Technology Transition Program (NETTP)	Navy	S&T
Super Energy Efficient Containerized Living Unit (SuperCLU) Design and Development	Navy	Equipment
Transformation Reductions in Operational Energy Consumption (TROPEC)	USPACOM	Standards, Software, Service
Waste to Energy for Forward Operating Bases (W2E)	OSD[2]	S&T

Advanced, Energy Efficient Shelter Systems for Contingency Basing and Other Applications (AEESS). Three technology transition agreements have been signed with the Combined Arms Support Command, Product Manager Force Sustainment Systems, and Maneuver Support Center of Excellence to guide the transition of specific products. Additionally, the Army has provided $5.7M of follow-on funding for FY 2018-20 to advance shelter performance using the materials and prototypes developed under this program, and the Air Force has provided $14.98M for FY 2018-25 to field systems developed under this program.

Innovative Cooling Equipment Development/Demonstration Program (ICE). The ICE program was successful at achieving significant efficiency gains on existing ECU systems, but the Army chose not to continue funding because the program's technical approach did not follow the Army's acquisition process. 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). The Navy selected two of the technologies developed under this program to receive additional funding. An advanced heat pump project received $4.2M in FY 2016-17 to continue development to TRL 6/7, and two dehumidification membrane approaches received $3.2M in FY 2015-16 to develop prototypes.

Super Energy Efficient Containerized Living Unit (SuperCLU) Design and Development. The Navy Expeditionary Combat Command, Pacific, purchased three SuperCLUs for humanitarian support, and the Seabees purchased and deployed five SuperCLUs to the Philippines for Exercise Balikatan 2016. The program also received $856K from the Navy to finish development and testing of a net zero SuperCLU by incorporating renewable energy.

Transformation Reductions in Operational Energy Consumption (TROPEC). 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 continues to provide testing services at the sole cost to the user.

2. This program was a joint OSD Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) effort partially funded by OECIF.

Waste to Energy for Forward Operating Bases (W2E). The most promising technology from this program was submitted as an FY 2017 proposal under the OSD Environmental Security Technology Certification Program (ESTCP); however, final selections have not been made at the time of this assessment.

FY 2013 Transition Assessment

For FY 2013, the OECIF programs focused on forming consortia of non-traditional organizations to address key operational energy challenges. While these programs are still executing, they are very near the end of their OECIF funding cycle. Three of these programs have transition pathways identified and have continued transition partner funding or product use. Table 6 provides a summary of the expected transition outcome of the three nearly complete programs.

Table 6. FY 2013 OECIF Programs: Transition Assessment Results

FY 2013 OECIF Program Name	Transition Partner	Transition Category
Energy Efficient Outpost Modeling Consortium (EEOMC)	Army	Standards, Software, Service
Soldier and Small Unit Operational Energy (SSUOE)	Army	Equipment / Standards, Software, Service
Engineered Surfaces, Materials, and Coatings for Drag Reduction (ESMC)	Air Force	Equipment

Energy Efficient Outpost Modeling Consortium (EEOMC). Although EEOMC is a Navy-led program, the Navy has not provided any follow-on funding. However, the Army has programmed $1.5M in FY 2017 for continued development of the Energy Resource Dashboard and Control Tool and may continue funding the Energy Resource Planning Tool.

Soldier and Small Unit Operational Energy (SSUOE). The tools and software developed within the SSUOE program will transition within the Army as enduring capabilities; however, the Army has not approved any additional funding to sustain the SSUOE consortium or their efforts. The SSUOE will continue to build the community and exploit collaboration opportunities.

Engineered Surfaces, Materials, and Coatings for Drag Reduction (ESMC). The Air Force has programmed $500K in FY 2017-18, along with $1M per year for FY 2019-21 for drag reduction technologies. While encouraging, this funding level is low compared to the $6.3M total cost of the program, and consequently will not fully capitalize on the technology identified by the OECIF program.

FY 2015 Transition Assessment

For FY 2015, OECIF applied one-year Congressional plus-up funding to short-term programs that would complement existing OECIF programs or explore new OE relevant technologies. The four completed programs have continued through transition partner funding. Table 7 provides a summary of the transition outcomes of these programs.

Table 7. FY 2015 OECIF Programs: Transition Assessment Results

FY 2015 OECIF Program Name	Transition Partner	Transition Category
Joint Infantry Company Prototype (JIC-P)	Army/USMC	Equipment
Behavioral Energy Operations Demonstration (BEyOnD)	Navy	TTPs
Advancing Cyber Security for Platform Information Technology (PIT) and Industrial Control Systems (ICS) (CYBER)	OSD	TTPs
Solar, Soaring, Cooperative Unmanned Aerial Vehicle (Persistent UAV)	OSD	S&T

Joint Infantry Company Prototype (JIC-P). The Army is planning a user evaluation of the selected energy harvesting technologies in August 2017, and the USMC will do the same in September 2017. The Army and USMC have provided approximately $600K and $300K, respectively, for these efforts. The Army and USMC also are funding continued development of M&S tools to evaluate the effects of dismounted Warfighter operational energy technologies 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.

Behavioral Energy Operations Demonstration (BEyOnD). The Navy has funded the BEyOnD Phase 2 effort at $1.7M for FY 2017-18. Phase 2 consists of analyzing the data from Phase 1 to generate a list of interventions, which will be experimentally measured to determine their impact. The fuel savings are targeted at improvements in vehicle operations and the efficient employment of diesel generators and ECUs.

Advancing Cyber Security for Platform Information Technology (PIT) and Industrial Control Systems (ICS) (CYBER). The findings 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 2016-20. Additionally, the assessment procedure was standardized and recommended for Joint Mission Assurance Assessments and integrated into FY16 NDAA sections 1647 and 1650, which require the evaluation of cyber vulnerabilities of all major DoD weapons systems and critical infrastructure, respectively.

Solar, Soaring, Cooperative Unmanned Aerial Vehicle (Persistent UAV). The Persistent UAV technologies transitioned directly into the 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 2016-19.

OECIF IMPROVEMENTS

The ODASD(OE) is committed to ensuring that OECIF programs align with the Department's *Operational Energy Strategy* and Department priorities, are managed effectively and with proper oversight, and successfully transition to the Warfighters. To that extent, the ODASD(OE) is implementing a series of changes to improve overall OECIF outcomes.

First, the ODASD(OE) will focus additional attention on program transitions. A letter of intent from the transition partner(s) is now required with all OECIF proposals. All OECIF proposals also must include a transition plan, which will be reviewed annually to encourage transition planning from the beginning of the program and regularly confirm commitment.

Second, the ODASD(OE) is using lessons learned to refine oversight of OECIF programs. Specifically, regularly scheduled program updates and reviews will ensure proper program execution and management, and will allow any issues to be resolved early and quickly. Also being introduced is a new "go, no-go" program review decision that allows funding from failing programs to be redistributed to other successful ongoing programs or fund new initiatives.

Third, an OECIF Technical Advisory Committee (TAC) was established for the FY 2017 proposal selection and oversight process. Subject matter experts from the Office of the ASD for Research & Engineering, National Aeronautics and Space Administration, and the Department of Energy's Advanced Research Projects Agency-Energy participated in the proposal selection and will remain actively involved over the life of these programs. The TAC will be used in future selections to facilitate OECIF investments across a broader spectrum of technologies, and encourage partnering and sharing of technologies and S&T investments across Federal departments.

Fourth, the Service energy offices will become more directly involved in the management of their respective programs. The level of program involvement would entail determining Service gaps, providing input for annual themes, attending annual reviews, ranking their respective proposals, and providing assessments and recommendations for their respective programs. This increased involvement will help ensure a successful program transition into one of the categories listed in the Transition Assessment section above.

Finally, the OECIF annual call for proposals and review process will commence earlier in the fiscal year to ensure the programs stay within their four-year schedule. These timeline changes better enable ODASD(OE) to align resources year-to-year, allow for programs to start work nearly a quarter earlier than previous years, and should reduce financial management burdens on program managers. Accordingly, the OECIF cycle will now have the following timelines:

- By 3rd quarter of the prior fiscal year, select annual theme and post call for proposals;
- By 4th quarter of the prior fiscal year, select the winning proposals; and
- By 1st quarter of the execution fiscal year, fund the selected programs.

Together, these changes improve overall program management, strengthen ODASD(OE) oversight, and, most importantly, ensure that OECIF programs deliver increased military capabilities to the Warfighter.

CONCLUSION

This assessment is the first of what will be a recurring annual review of the OECIF program. 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 programs, the ODASD(OE) will continue to invest in opportunities that align with the Department's *Operational Energy Strategy* and support Department-wide priorities.

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	6
2013	Using consortia to involve a wide variety of organizations to persistently attack key operational energy problems	4
2014	Analytical methods and tools for considering operational energy in Department planning and decision processes	6
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	10*
2016	Increasing the operational energy performance of unmanned systems for the Pacific including air, surface, undersea, and ground systems	6
	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***

*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 Program Summaries

1. Two short-term studies were funded in FY 2012; however, at the time of this assessment, program summaries have not been completed. These program summaries will be included in the FY 2018 OECIF Assessment.

2. One short-term study was funded in FY 2013; however, at the time of this assessment, a program summary has not been completed. The program summary will be included in the FY 2018 OECIF Assessment.

3. At the time of this assessment, program summaries have not been completed. These program summaries will be included in the FY 2018 OECIF Assessment.

4. At the time of this assessment, kickoffs have not taken place and program summaries have not been completed. These program summaries will be included in the FY 2018 OECIF Assessment.

Financial Summary Table

Start Year	Program Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	Total
FY12	Advanced, Energy Efficient Shelter Systems for Contingency Basing and Other Applications	$6.0	$5.9	$4.4	$1.0						$17.3
FY12	Innovative Cooling Equipment Development/ Demonstration Program	$2.5	$4.5	$1.5	$1.5						$10.0
FY12	Navy Expeditionary Technology Transition Program	$3.2	$1.2	$3.3	$1.6						$9.3
FY12	Super Energy Efficient Containerized Living Unit Design and Development	$1.0	$1.5	$0.6							$3.1
FY12	Transformation Reductions in Operational Energy Consumption	$3.9	$2.5	$4.2	$0.5	$0.9					$11.9
FY12	Waste to Energy for Forward Operating Bases	$1.5	$0.8	$1.1							$3.4
FY13	Tactical Microgrids Standards Consortium		$1.2	$2.3	$2.9	$2.1	$1.3	$1.0			$10.7
FY13	Energy Efficient Outpost Modeling Consortium		$1.4	$2.7	$2.8	$2.7					$9.4
FY13	Engineered Surfaces and Materials for Drag Reduction		$0.4	$1.6	$1.0	$3.0					$5.9
FY13	Soldier and Small Unit Operational Energy		$1.4	$2.8	$4.5	$4.7					$13.4
FY14	Capability Assessment & Modeling for Energy Logistics			$1.0	$1.4	$1.5	$1.4				$5.3
FY14	A Comprehensive Operational Energy Toolkit			$0.2	$0.9	$0.4					$1.4
FY14	Joint Deployment Energy Planning and Logistics Optimization Initiative			$0.4	$0.9	$1.0	$1.2	$1.4			$4.9
FY14	Developing an OE Theater Supportability Analysis Toolkit, Operational Energy Analysis Task Force			$1.0	$2.2	$2.6	$2.0				$7.8

Financial Summary Table *(continued)*

Start Year	Program Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	Total
FY14	Synthetic Theater Operations Research Model-Energy			$1.4	$0.4	$3.0	$1.3	$0.6			$6.6
FY15	Autonomy-Enabled Fuel Savings for Military Vehicles				$0.8	$1.8	$1.4	$2.3			$6.2
FY15	Tactical Vehicle Electrification Kit				$3.0	$2.9	$4.6	$1.7			$12.2
FY15	Thermal Barrier Coating and Heat Transfer in Engines				$0.6	$2.0	$1.6	$0.9			$5.1
FY15	Vehicle Lightweighting Using Modeling & Simulation				$0.5	$0.5	$0.5				$1.5
FY15	Waste Heat Recovery Solutions in Military Applications				$2.6						$2.6
FY15	Small Unit Power and Battery Eliminator				$2.9						$2.9
FY15	Solar, Soaring, Cooperative UAV (Persistent UAV)				$0.6						$0.6
FY15	Marine Prescreening Assessment of Conservation Technology				$2.5						$2.5
FY15	Joint Infantry Company Prototype				$1.8	$1.6					$3.4
FY15	Joint Deployable Waste to Energy Working Group				$0.4						$0.4
FY15	Dehumidification Membrane & Cooling Systems				$1.1						$1.1
FY15	Advancing Cyber Security for Platform Information Technology and Industrial Control Systems				$1.5	$0.2					$1.7
FY15	Behavioral Energy Operations Demonstration				$1.0						$1.0

Financial Summary Table *(continued)*

Start Year	Program Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	Total
FY15	Energy-Integrated Modeling & Simulation Federations					$2.0					$2.0
FY16	MQ-9 Improved Performance Technology Engine					$2.0	$2.0	$2.0	$2.0		$8.0
FY16	Operational Energy Capabilities Improvement Fund for Aluminum-Water Power for Unmanned Undersea Vehicles					$1.8	$2.8	$4.1	$3.4		$12.1
FY16	Multi-Day Endurance of Group 2 Unmanned Aircraft System using Pacific Energy Sources (Hybrid Tiger)					$1.4	$1.4	$1.8	$1.7		$6.2
FY16	Hydrothermal Vent Exploitation for Undersea Energy					$1.3	$0.0	$0.8	$0.5		$2.7
FY16	JP-8 Based Fuel Cell Power					$1.9	$2.4	$2.4	$1.9		$8.5
FY16	Reliable, Efficient, Tactical Unmanned Aircraft System Power System					$1.5	$0.8	$0.9			$3.1
FY16	Army Training and Education Projects					$0.9					$0.9
FY16	Navy Training and Education Projects					$1.0					$1.0
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	$1.8	$0.7	$0.3	$3.6
FY17	Ultra-High Density Hybrid Energy Storage Module for Laser Weapon System and Electronic Warfare Operations						$0.7	$2.9	$1.6	$0.7	$5.9
FY17	Thermally Enabling Architectures for Pulse Power Systems						$1.8	$2.9	$2.7	$2.1	$9.5

Financial Summary Table *(continued)*

Start Year	Program Name	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	Total
FY17	Power Transmitted Over Laser						$1.5	$2.6	$2.6	$1.5	$8.1
FY17	Millimeter Wave Ground-to-Ground Power Beaming Demonstration and Far-Field Wireless Power Transmission						$1.1	$1.4	$1.7	$1.7	$6.0
FY17	Space Solar for Forward Operating Bases and Remote Installations						$0.3				$0.3
FY17	Space Solar Power						$2.0	$2.0	$2.0	$2.0	$8.0
FY17	Joint Operational Energy Command and Control						$0.9	$0.7			$1.6
FY17	Operational Energy Watson						$1.3				$1.3
FY17	Autonomous and Robotic Remote Refueling Point						$0.4				$0.4
Total		**$19.7**	**$21.3**	**$29.0**	**$41.3**	**$45.6**	**$23.0**	**$22.2**	**$9.5**	**$8.2**	**$211.6**

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	$4.4	$1.0	$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
$2.5	$4.5	$1.5	$1.5	$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	$1.2	$3.3	$1.6	$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 Thermodevices (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.[1] 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 125°F ambient temperature.
  - Plan to optimize several system components and controls to reach the targeted project efficiency and cooling output targets.

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

- **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:
  - 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 Lemonnier, 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 Lemonnier 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	$4.2	$0.5	$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) microgrid.

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 Program Summaries:
CONSORTIA

TACTICAL MICROGRIDS STANDARDS CONSORTIUM (TMSC)

Lead Organization: U.S. Army Engineer Research and Development Center

Other Key Participants: U.S. Army Communications-Electronics Research Development and Engineering Center (CERDEC) and U.S. Army Research Laboratory

OECIF Funding Stream:

FY 2013 (M)	FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$1.2	$2.3	$2.9	$2.1	$1.3	$1.0	$10.7

Description: Energy availability is a major concern on today's battlefield. Reducing the need for fuel resupply in operations reduces combat risk and cuts costs associated with moving and protecting convoys. Microgrids network battlefield generators and renewable energy sources together and control their outputs as one system, which is significantly more effective than running individual generators that power separate electrical loads. For instance, when demand is low, the microgrid system turns off unneeded generators to optimize overall efficiency. Notably, tactical microgrids differ from microgrids used at large DoD installations in that they must be deployable, rugged, and able to be set up with maximum safety.

Because of their utility, there has been great interest in tactical microgrid designs in recent years. Standards for tactical microgrid communication and control are needed to enable the systems and their components to be interoperable, compatible, and easily integrated into a variety of systems.

TMSC organized a variety of organizations inside and outside the government to:

- Develop, test, publish and maintain military standards for tactical, deployable microgrids, including communications and control standards that leverage existing or emerging microgrid standards to the greatest extent possible.
- Develop standards to fill gaps for resilient energy system implementation for tactical microgrids, such as (a) interconnection and islanding and (b) safety and grounding.

Military Benefit: The final military standard will be non-proprietary, universal set of standards enabling interoperability of tactical microgrid components, resolving the most significant impediment to widespread microgrid implementation. Benefits will include:

- Potential reduction of fuel consumption by 30% within an operational environment.
- Ability to configure power resources according to mission needs.
- More reliable and resilient energy network for increased energy availability.
- Improved cross-platform compatibility of microgrids and their components for simplified logistics and sustainment.

Initiate discussions for international standards to game change integrative leverage gained by coupling microgrids from different partner systems.

Accomplishments/Status:

Established group consisting of over 85 participants from Government, Industry, standardization organizations, and research and development organizations.

Published multiple drafts of the Tactical Microgrid Standard with extensive reviews by Industry and government subject matter experts (SMEs) through active discussions with military and private sector SMEs to address the technical, operational, human safety and interface aspects of the Tactical Microgrid Military Standard.

Conducting initial laboratory testing of the draft military standard.

Leading a North Atlantic Treaty Organization (NATO) task force to investigate the need for a Standardization Agreement for tactical power.

Developed a future concept for Advanced Power for military and civilian use in remote areas where utility power is unreliable or unavailable.

Transition: Project Manager Expeditionary Energy and Sustainment Systems (PM E2S2) and CERDEC have incorporated the emerging tactical microgrid interoperability standards into their future plans and will continue to maintain the standards. TMSC is also working towards the adoption of portions of the tactical microgrid interoperability standards into existing industry standards. They are in discussions with and influencing future standards maintained by the Institute of Electrical and Electronics Engineers, Electrical Generating Systems Association, SunSpec, and Open Field Message Bus. Additionally, TMSC prepared a proposal, Remote Area Autonomous Power System, which would develop a certified family of microgrid components; however, this proposal has not secured funding at this time.

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	$1.0	$3.0	$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	$2.8	$4.5	$4.7	$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 Program 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)

OE Funding Stream:

FY 2014 (M)	FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	Total
$1.0	$1.4	$1.5	$1.4	$5.3

Description: The overall goal for the CAMEL program is to inform operational energy (OE) decisions that can positively affect future warfighting capability. The main objectives of CAMEL are to assess the effects of energy logistics within a contested operational environment, develop materiel and non-materiel strategies to mitigate threats, and estimate the costs of these mitigation strategies. CAMEL will investigate Joint operational capabilities within the context of maritime delivery, strategic and tactical airlift, and aerial refueling. The cost effectiveness of various solutions to mitigate counter-energy threats and reduce OE also will be considered.

AFRL/RQ will investigate both mid and far-term technology improvements to the mobility fleet and their impact on OE consumption, concept of operations changes, and ability to mitigate threats to the energy logistics chain. Specifically, CAMEL work will: 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: Identifying technology improvements and behavioral changes that reduce OE consumption and mitigate threats to the energy supply chain will inform decision makers regarding future investments on how to reduce cost and improve operational capability.

- **Joint Force:** Provide the OE risk implications from a system-of-system perspective to appropriately increase Warfighter capability.
- **Air Mobility Command (AMC):** Highlight logistics requirements based on a full understanding of OE challenges and Joint implications.
- **Air Force Life Cycle Management Center (AFLCMC):** Utilize a tool suite that measures OE impact to aircraft life cycle costs.
- **Pacific Air Forces (PACAF):** Within a contested environment, inform decisions regarding basing and aircraft capabilities to meet extended range requirements.
- **United States Transportation Command (USTRANSCOM):** Joint mobility planning to mirror operations.
- Air Force Research Lab (AFRL) - Increased knowledge regarding science and technology investment priorities.

Accomplishments/Status:

- Completed analysis of impact of AETD in combination with a Directed Energy Weapon (DEW) on aircraft performance.
- Completed analysis of existing and future Strategic Airlift concepts in permissive and constrained Integrated Security Construct-B (ISC-B) scenarios, allowing for robust evaluation of advanced OE technologies.
- Developing methodology to investigate the theater-wide MILCON requirements needed to support the desired tempo of tanker operations in a select theater.
- Assessing the ability of the current baseline aircraft tanker fleet to meet aerial refueling requirements, and evaluating concept technologies to mitigate any gaps.
- Upgrading the Analysis of Mobility Platform (AMP) model, which provides automated and distributed execution of AMP, to facilitate large Designs of Experiments.
- Integrating AMP with Synthetic Theater Operations Research Model (STORM) to include the effects of mission level engagements at the campaign level.
- Continuing to evaluate advanced technologies for countering energy constraints within the ISC-A scenario.

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	$0.9	$0.4	$1.4

Description: Currently, a comprehensive way of examining the effectiveness and impact of enemy attacks against airbase infrastructure does not exist. The COE Toolkit will assist with the development of a comprehensive modeling and simulation toolkit to help examine the vulnerabilities of airbases and the effect of these vulnerabilities on both energy use and combat operations. This program will not only look at operational energy (aviation fuel, vehicle fuel, electricity, etc) at a base, but also include the forces and infrastructure needed to deliver energy to the base. The toolkit will consider the interactions of the force "tooth" and "tail" in a contested environment. The decision-quality results could 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 (STORM) or the Bayesian Enterprise Analysis Model military enterprise level examination tool. The designed tools will be "side agnostic," which means such tools will allow for not just a defensive look at operational energy, but also could be used to assess the effects of denying operational energy to potential adversaries.

The program will follow a three phase approach. Phase 1 will develop a tool to examine current and projected future "red" 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. Finally, Phase 3 will build an analytic tool to examine the effects of interdicting operational energy prior to it getting to an air base.

Military Benefit: This program will fill existing gaps in DoD analysis capability and provide a standard methodology for examining the use of energy at air bases and how energy is delivered 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, modeling, and simulation techniques and should be viable and modifiable for the next 10-20 years.

Accomplishments/Status:

- Completed first stage of development, which applied current/forecast adversary weapons capability to attacks on energy-related airfield infrastructure.
- Completed second stage of 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	$0.9	$1.0	$1.2	$1.4	$4.9

Problem Description: Warfighter operational planning courses of action (COAs) are traditionally created in a multi-dimensional environment that has not been able to incorporate logistics feasibility, particularly for energy, early enough in the planning process to affect planning outcomes. Many plans still hold assumptions of ubiquitous and invulnerable supplies of energy. The USPACOM warfighting command is challenged by an Area of Responsibility (AOR) that encompasses over 51% of the Earth's surface and the Guidance for Employment of the Force (GEF) requirement for resource-informed planning. Joint logistics planners currently lack user friendly tools to estimate fuel demand, supply, and risk across the battlespace and communicate those plans in an interactive manner with the Services.

Military Benefit: J-DEPLOI will address these gaps via policies, procedures, and a collaborative information technology tool which draws upon authoritative joint databases. Combined, these steps will facilitate the consideration of operational energy during planning and visualize potential fuel supply chain vulnerabilities earlier in the Joint Operational Planning Process (JOPP). Tools developed and refined for USPACOM's fuel logistics planners will be 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:

FY 2016: Completed Phase I, Discovery & Requirements Prioritization and began Phase II, Solutions Development

- Evaluated over sixty (60) information technology tools and modeling and simulation programs against the priority functions and capability gaps identified in the process map
- Selected one information technology COA from six COAs
- Identified non-material solutions to address within the scope of J-DEPLOI and PACOM J4; requested assistance from DLA-E
- Initiated tools development and awarded contract to Group W
- Drafted Implementation Directive and finalized Phase 1 report

FY 2017: Will continue to execute Phase II, Solutions Development:

1. Implementation Directive, Program Requirements and Conceptual Model Document
2. Begin agile development cycles, collect and incorporate user feedback and prototype technology tool to achieve Increment 1, Visualization of Fuel Logistics Network
3. Policy, tactics, procedural change requests to enhance fuel logistics planning capability
4. Continued discussion with users, partners, policy makers, and stakeholders

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	$2.0	$7.8

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.
- Completed several enhancements to the core supply distribution and costing models. This effort will continue through FY 2017.

CREATING A CAMPAIGN-LEVEL OPERATIONAL ENERGY ANALYSIS CAPABILITY USING THE SYNTHETIC THEATER OPERATIONS RESEARCH MODEL-ENERGY (STORM-E)

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

Other Key Participants: Deputy Commandant, Combat Development and Integration/Futures Division/Ellis Group; Deputy Commandant, Combat Development and Integration/Capabilities Development Directorate/Expeditionary Energy Office

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	$0.6	$6.6

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 with accurate and credible insights into the implications of operational energy (OE) for force effectiveness and operational risk above the tactical level. Expeditionary Force 21 (EF 21) 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 STORM campaign model to produce actionable insights; and,
- Informs decision-making processes in time to influence operational planning and program budget cycles.

Military Benefit: Developing a coherent, campaign-level OE analytic capability will provide the Marine Corps a rigorous method for exploring the relationship between energy supply and demand and force effectiveness. The ultimate goal is the institutionalization of an authoritative and accepted way to evaluate the implications of energy supply and demand for the employment and effectiveness of systems, concepts and capabilities. In turn, this will allow assessment of the effects of energy availability and use on higher level military outcomes.

Accomplishments/Status:

- Created first draft of campaign-level OE insight requirements and established requirements identification panel
- Continued the acquisition, incorporation, sharing, and formatting of data between STORM and the Marine Air-Ground Task Force Power & Energy Model (MPEM) and Logistic Analytical & Wargame Support Tool (LAWST) (mission-level energy models)
- Completed development of theater logistics system in support of USMC operations
- Completed initial development of the Marine Expeditionary Force / Marine Expeditionary Brigade (MEF/MEB) logistics systems
- Created new energy data sets and performed STORM test runs
- Created, and prepared for implementation in STORM version 2.6, the following near-term enhancements: (1) fuel consumption by landing boats and amphibious fighting vehicles; (2) withdrawal by sea connector; (3) enhanced bulk commodity tracking visualization; and (4) enhanced forward operating base model.

FY 2015 OECIF Program Summaries:

IMPROVING FUEL ECONOMY FOR THE CURRENT TACTICAL GROUND FLEET

IMPROVING FUEL ECONOMY FOR THE CURRENT GROUND TACTICAL FLEET PROGRAM: AUTONOMY-ENABLED FUEL SAVINGS FOR MILITARY VEHICLES

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

Other Key Participants: Department of Energy Vehicle Technologies Office (DOE-VTO); U.S. Army Program Executive Office (PEO) - Combat Support & Combat Service Support - Project Manager Transportation Systems; U.S. Marines Corps PEO Land Systems; Office of Naval Research

OE Funding Stream:

FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$0.8	$1.8	$1.4	$2.3	$6.2

Description: This program is developing a smart adaptive cruise control to optimize fuel economy during military missions, as well as for commercial driving applications. The smart adaptive cruise control will take into account such things as vehicle capabilities and configurations, terrain profiles, surface conditions, and mission requirements. Best practice applications for implementation in military and commercial vehicles will be developed during this effort along with system architecture and design documents. A final test report validating reduction of fuel consumption also will be completed.

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. In addition, the tactical fleet is unique across military ground platforms because of the significant overlap with the commercial trucking industry. This program will leverage significant recent investment by the DOE-VTO to improve the efficiency of the DoD legacy tactical fleet while positioning technology for future tactical vehicle procurements with significantly improved fuel economy. Through partnering across the Army, Marine Corp, and DOE, the program intends to deliver a technology that will reduce fuel consumption, increase the range of the vehicles and time on station, and decrease the number of fuel convoys in harm's way.

Military Benefit: The Autonomy-Enabled Fuel Savings for Military Vehicles will maintain the current combat effectiveness of the platform. The estimated reduction in fuel consumption will be greater than 5% with potential of greater than 20% on certain duty cycles according to existing research. This reduction in fuel economy will allow convoys to extend their range before needing to be refueled. Convoys will see smoother operations and not have the severe accelerations and decelerations typically seen in convoys also. As a result brakes will last longer with less down time needed.

Status/Plans: The Autonomy-Enabled Fuel Savings for Military Vehicles program was started in fourth quarter FY 2015 and has made great progress to date. In Phase I of the program, modeling and simulation of the military M915 was completed, which is based on a commercial Freightliner Class 8 tractor. Analysis of data from Soldiers using driving simulators was completed and further work was done with data from operations in Afghanistan in

regards to driver aggressiveness. Phase I was completed at the end of FY 2016 where a single vehicle convoy was conducted to test the performance of the developed smart adaptive cruise control. Phase II started in FY 2017 using the information gathered in Phase I to conduct modeling and simulation of a three vehicle convoy using M915A3 and M915A5 vehicles. Phase II will roll into FY 2018 where testing will be completed on a three vehicle convoy to determine the results of the effort smart adaptive cruise control and provide a report of the findings along with the technology that will be developed.

IMPROVING FUEL ECONOMY FOR THE CURRENT GROUND TACTICAL FLEET PROGRAM: TACTICAL VEHICLE ELECTRIFICATION KIT (TVEK)

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

Other Key Participants: Department of Energy Vehicle Technologies Office (DOE-VTO); U.S. Army Program Executive Office (PEO) - Combat Support & Combat Service Support - Project Manager Heavy Tactical Vehicles; U.S. Marines Corps PEO Land Systems; Office of Naval Research; and TARDEC GVPM

OE Funding Stream:

FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$3.0	$2.9	$4.6	$1.7	$12.2

Description: The goal of the Improving Fuel Economy for the Current Tactical Ground Vehicle Fleet (IFECGTF) effort is to develop and demonstrate an affordable truck auxiliary system electrification kit on one or more existing Tactical Wheeled Vehicle (TWV) platforms to significantly improve vehicle operational energy, range, and future electrical warfighting system growth potential. The program vision is to reduce fuel usage by 15% to 25%, improve vehicle mobility performance, enhance silent watch capability, a shore power connection for export power capability, and possess the future electrical capability to support large electrical loads.

The Tactical Vehicle Electrification Kit (TVEK) project will be demonstrating on an Oshkosh built Army Heavy Expanded Mobility Tactical Truck (HEMTT) and the Marines Logistics Vehicle System Replacement (LVSR). To accomplish this program vision, the following components will be investigated for inclusion in the electrification kit: an integrated starter generator (ISG), ISG controller, LI-Ion 6T batteries, electrified steering, electrified HVAC, electrified engine cooling, electrified pumps, electrified air brake compressor, and a shore power connection. The intent of the program is to develop capabilities for the warfighters while the electrification kit must also be lightweight, robust, compact, and affordable.

Military Benefit: The TVEK project will focus on improving the current heavy tactical vehicle fleets' effectiveness and efficiencies. The thrust areas are described as follows:

- Intelligent start/stop strategy, auxiliary system electrifications and smart system controls to Demonstrate (minThreshold) 15%/ (Objective) 25% fuel use reduction.
- Capability to support future electrical needs for jamming, communications, e-weapons, and e-armor.
- Affordable auxiliary system electrification kit for tactical vehicles. Project directly supports HEMTT and LVSR.
- Shore power connection for base power or vehicle auxiliary functions.
- Reduced maintenance burden and elimination of hydraulic systems.
- Achieving safe integration of high voltage power generation.
- No impact to constrained space, weight, and cooling – neutral.
- Specifications and evaluation of TRL at auxiliary systems and system level.
- Universal (platform agnostic)
- Common M&S model architecture and supervisory software
- Increasing TARDEC core competency in high voltage power generation and growth in Vehicle Electrification technical knowledge (tactical vehicle anti-idle technology, fuel reduction) within an affordable positive ROI. The estimated total combined fuel economy savings applying all the thrust areas is in the range of 15-25% over current platform performance (dependent upon individual vehicle drive cycle and other operational parameters).

Status/Plans:

The TVEK project is currently executing and implementing the following activities:

- Completing market research for electrified auxiliary systems, DC/DC converters and Power Distribution Units
- Obtaining OEM's vehicle baseline auxiliary system information for component sizing and analysis of alternatives
- Ordering long lead items for System Integration Labs (SIL) testing activities in FY 2016 and FY 2017-2020 and 75kW inverter controllers and others
- Ordered HEMTT engine and preparing Engine fuel map testing in SIL
- Completed System Needs Review (SNR) and TARGET GATE 1 Review as part of System Engineering processes
- Conducted System Requirement Review (SRR) in 4QTR FY 2016
- Conducted System Functional Review (SFR) in 1QTR FY 2017

The TVEK project is currently planning the following activities:

- Complete Trade Studies and technical analysis of electrified system and subsystem components
- Award OSHKOSH Baseline technical information gathering Effort – SWAPC and component sizing information
- Obtain CAT15 Engine (MILSTRIP) for Engine fuel Map test
- Initiate CAT 15 Engine Cell Set-up, Instrumentation, and Testing
- Execute Technical Analysis of Subsystems Electrification
- Initiate Purchase of Subsystem Electrification Hardware
- SIL set up for electrified component testing, integrated with CAT15 engine in dyno
- Test and record baseline auxiliary system performance of HEMTT – FY 2017

IMPROVING FUEL ECONOMY FOR THE CURRENT GROUND TACTICAL FLEET PROGRAM: 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); U.S. Army Program Executive Office (PEO) - Combat Support & Combat Service Support - Project Manager Transportation Systems; Office of Naval Research

OE Funding Stream:

FY 2015 (M)	FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$0.6	$2.0	$1.6	$0.9	$5.1

Description: This program will leverage DOE's SuperTruck Program to take advantage of advancements in commercial powertrain systems. Specifically, the program focuses development of an engine Thermal Barrier Coating (TBC) 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 will develop engine wall heat transfer models, which are important 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:

- Projected fuel economy benefit of 5% (threshold) and 10% (objective)
- 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

Status/Plans: Currently, the program has begun reconfiguring a single-cylinder engine test cell for efficiency and heat rejection measurements. The single-cylinder engine being used as part of this project is setup to represent one cylinder of heavy duty truck engine. The single-cylinder engine allows for high accuracy measurements to be made relatively quickly on a prototype coating applied to the combustion chamber surface. Initial testing is planned on the single-cylinder engine to evaluate both the uncoated and coated version of the combustion chamber. Testing and modeling and simulation will provide feedback to the coating supplier allowing the coating thickness, thermal properties, mechanical properties and spray pattern to be adjusted. After an optimized coating is found though single-cylinder testing, the coating will be applied to a military relevant multi-cylinder engine. The multi-cylinder engine will be tested on a standard NATO cycle dynamometer durability cycle.

IMPROVING FUEL ECONOMY FOR THE CURRENT GROUND TACTICAL FLEET PROGRAM: VEHICLE LIGHTWEIGHTING USING MODELING & SIMULATION

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

Other Key Participants: Department of Energy Vehicle Technologies Office (DOE-VTO); U.S. Army Program Executive Office (PEO) - Combat Support & Combat Service Support - Project Manager Transportation Systems; U.S. Marines Corps PEO Land Systems; Office of Naval Research; Army Research Laboratory

OE Funding Stream:

FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	Total
$0.5	$0.5	$0.5	$1.5

Description: 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. The tactical fleet is unique across military ground platforms because of the significant overlap with the commercial trucking industry. This program will leverage significant recent investment by the DOE-VTO to lightweight commercial trucks and apply it to military vehicles.

Military Benefit: This program will use modeling and simulation to reduce and optimize the weight of an FMTV 6X6 Cargo vehicle platform design to the lowest point, while allowing the design to satisfy all threshold performance measures from the FMTV requirements document. Once this process is established, it can be used on other vehicles. The decreased weight could lead to a 5% to 10% increase in fuel economy.

Status/Plans: After reviewing all Army vehicles, the program chose FMTV as the target vehicle because of its large fleet size and 3D CAD data is available for model development.

The 3D CAD geometry is used to develop the baseline Finite Element Analysis (FEA) M&S model for the FMTV platform. The Vehicle Dynamics model is being used to identify candidate components for weight reduction. This loading will be applied on the target component / sub-system to reduce the weight using optimization and compare it to the current baseline design to meet or exceed the current performance. The lightweight component will then be replaced in the original system model and compared to the baseline system model to meet or exceed the threshold performance measures. This process will be repeated with other "target" components and sub-systems, for achieving light-weighting for this vehicle which will lead to improving the fuel economy of this platform.

FY 2015 OECIF Program 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)

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)

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:

1. RPA eliminates the need to carry and recharge ~90 PRC154 batteries/platoon/day
2. RPA reduces individual Soldier load by ~1.7 lbs/day
3. RPA ultra-capacitor technology provides >100,000 cycles vs 100s in the PRC154
4. Supports Intelligent Power Management architectures and improves peripheral electronics
5. 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 - $0.6M (short-term program funded by FY 2015 Congressional plus-up)

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 - $2.5M (short-term program funded by FY 2015 Congressional plus-up)

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
$1.8	$1.6	$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:*

1. Provide sufficient statistical sample opportunity to demonstrate the value of renewable tactical energy harvesting in lightening the load and increasing self-sustainability.

2. Leverage ongoing efforts within the Army and Marine Corps regarding kinetic energy harvesting development.

3. Measure the power usage for the Army and Marine Corps squad, platoon, and company to capture energy requirements in a tactical environment.

4. 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).

5. Inform future energy harvesting acquisition by understanding performance and logistical implications.

6. 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) WORKING GROUP

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

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 - $0.4M (short-term program funded by FY 2015 Congressional plus-up)

Description: The Joint Deployable Waste to Energy (JDW2E) Working Group (WG) aids in the coordination of DoD efforts to holistically develop deployable systems and necessary non-material information needed to address the issues identified in:

- 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.

- 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

- 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

- 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

JDW2E WG will aid in the development of Joint Tactics, Techniques, and Procedures (TTPs), Joint Requirements, Joint Standardized Testing Protocols, and Joint Testing & Evaluation (JT&E) of waste-elimination and W2E systems.

Military Benefit: JDW2E Working Group will aid in synchronizing 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 more safe and 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
- Reviewed several technologies including the Battalion-Scale Waste to Energy Converter, Solid Waste Destruction System, and Expeditionary Waste Destruction Box
- 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 - $1.1M (short-term program funded by FY 2015

Congressional plus-up)

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, Installations and Environment)

OE Funding Stream: Short-term program funded by FY 2015 Congressional plus-up

FY 2015 (M)	FY 2016 (M)	Total
$1.5	$0.2	$1.7

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.

1. 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.

2. 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.

3. 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.

BEHAVIORAL ENERGY OPERATIONS DEMONSTRATION (BEYOND)

Lead Organization: Naval Surface Warfare Center, Carderock Division

Other Key Participants: Office of Naval Research; Marine Corps Expeditionary Energy Office; Department of Energy Federal Energy Management Program; Army Engineer Research and Development Center-Construction Engineering Research Laboratory; Navy Engineering and Expeditionary Warfare Center; JPID Consulting, LLC

OE Funding Stream: FY 2015 - $1.0M (short-term program funded by FY 2015 Congressional plus-up)

Description: Despite the recent push to reduce energy and fuel consumption on the battlefield through training and material solutions, Warfighters do not appreciate how their behavior and energy use impacts combat effectiveness. Non-material energy training efforts have failed to make enduring change in the past due to some of the following challenges:

- Modifying training programs takes significant time and effort;
- Training programs only impact the Warfighters rotating through them;
- A significant amount of training is required to make permanent changes to behavior; and
- Warfighters have no tools or ability to make more energy efficient choices in the field.

BEyOnD consists of three phases: 1) Centralize all previously executed human behavior work (government and academic research), and seek out any missing data during a field exercise; 2) Use energy-focused human behavior experts to analyze the comprehensive data set, develop a validation and verification plan, and then experimentally measure the impact of those solutions; and 3) Transition those solutions to the acquisition, training, and operations

communities. The Operational Energy Capability Improvement Fund portion of this program includes Phase 1 only.

Military Benefit: BEyOnD seeks to reduce ground-based Marine Corps fuel consumption in austere environments by at least 10% by leveraging modern human behavior modification techniques, currently applied in the commercial world, at little to no cost. Our four focus areas include: 1) Vehicle idling, 2) Vehicle operations, 3) Environmental control unit interface, and 4) Electrical equipment usage.

Accomplishments/Future Plans:

- Conducted a comprehensive literature review of academic and government research.
- Provided insights gained from the research to Utility, Motor Transport (Marine Corps) and Power Generation (Army) communities.
- From 21-28 May 2016, executed observational data collection plan and conducted interviews during an annual Marine Corps capstone training exercise, Integrated Training Exercise 3-16, Marine Corps Air Ground Combat Center, Twentynine Palms, California.
- Prepared a report summarizing all human behavior energy related efforts to date, and propose a set of justified human behavior experiments that indicate at least 10% energy savings.
- On 26 July 2016, briefed results and insights to the Office of the Deputy Assistant Secretary of Defense for Operational Energy.

Transition: The Navy and Army will independently fund Phase 2. The Navy is funding the Marine Corps at $1.7M for FY 2017/2018; however, the Army has not provided funding at this time. Currently, the team has analyzed the data from Phase 1 and generated a draft list of interventions, which will be experimentally measured to determine their impact.

ENERGY-INTEGRATED MODELING & SIMULATION FEDERATIONS

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

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 - $2.0M (short-term program funded by FY 2015 Congressional plus-up)

Description: The Energy-Integrated Modeling and Simulation (M&S) Federations program will utilize integration methods to facilitate multi-resolution wargaming, 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 Wargames. Rendering and integrating energy into wargames rarely occurs. "Stochastic wargaming" 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(OE) 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 wargaming.

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 wargame 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 wargaming and analysis with DARPA; and
  - energy integrated, stochastic wargaming with A9.

FY 2017/2018 Plan

- Kickoff program and establish working groups.

FY 2016 OECIF Program Summaries:
UNMANNED SYSTEMS

MQ-9 IMPROVED PERFORMANCE TECHNOLOGY ENGINE (IPTE)

Lead Organization: Air Force Research Laboratory, Turbine Engine Division

Other Key Participants: Air Force Life Cycle Management Center ISR and Special Operations Forces SPO (AFLCMC/WI); PACOM TROPEC Office, Honeywell Aerospace, and Booz Allen Hamilton

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 project will demonstrate 15% specific fuel burn reduction and 25% increase in takeoff and cruise horsepower for the MQ-9 TPE 331-10 YGD engine. The goals will be realized by achieving increases in compressor and turbine efficiency through improved aerodynamic design, increasing the pressure ratio of the engine and by increasing the cycle temperature of the engine by 220F. Cycle temperature goals will be realized through material changes in the combustor and turbine of the engine that have increased strength at higher temperatures. The project will culminate in a TRL 6 (i.e., system/subsystem model or prototype demonstration in a relevant environment) demonstration of the integrated engine technologies and materials. The engine will be flight weight and can quickly transition to flight testing.

After successful ground demonstration of this project in 2020, Honeywell plans to pursue FAA Certification of the improved TPE331-10 IPTE engine, pending a business case analysis at the time of demonstration. The FAA Certification will prove airworthiness of the engine. FAA certification will significantly reduce the military certification requirements and reduce the resources required to flight test the TPE331-10 IPTE in an MQ-9 Reaper for use by the military. FAA Certification by Honeywell significantly enhances the transition opportunity for the new engine technology to the AFLCMC/WI SPO.

Military Benefit: The fuel burn reductions will result in approximately 1,000 nm increased maximum range or 6 hours increased maximum loiter time for the MQ-9 Extended Range (ER) configuration. Increased takeoff power also will eliminate the need for alcohol/distilled water injection for the ER, reducing logistics burden in theater, and will provide up to 80 kW power at cruise altitude for all MQ-9 configurations.

Accomplishments/Future Plans:

- The Operational Benefits Analysis (OBA) of the IPTE is complete. This analysis "flew" the MQ-9 with the new engine through a series of classified real-world Reaper mission scenarios and compared it to the existing/baseline engine. Preliminary results show the IPTE engine will provide a 785nm increase in maximum range or a 4 hours increase in mean time on station and an 11% increase in time sensitive target responsiveness. In addition, recent optimization of the engine cycle suggests even greater benefits. As the program progresses, the design team will continue to focus on increasing the range and loiter time of the engine to meet/exceed the 1000nm and 6 hour goals.
- This S&T contract was awarded in mid-May 2017.

OPERATIONAL ENERGY CAPABILITIES IMPROVEMENT FUND FOR 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	$4.1	$3.4	$12.1

Description: The Applied Research Laboratory (ARL) of the Pennsylvania State University has demonstrated proof-of-concept operation 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, depending on the configuration of the vehicle on which it is used. The Navy's 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 components (combustor, steam generator, heat exchanger, and start system), cold components (solid product separator and solid product removal system), 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/electric 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; three laboratory tests executed; and laboratory hardware design improvements implemented to support future breadboard component testing.

- FY 2016 Accomplishments (funding received Aug 2016):
  - Initial version of the Aluminum-Water system model was translated into the Simulink modeling environment. Various component models were created which can be assembled to form various system configurations for trade study evaluations.
  - Existing reactant cart / combustor setup mobilized and updated in preparation for testing.
  - Drawings of the existing laboratory combustor hardware updated and design improvements considered.
- FY 2017 Plans (ongoing): Component fabrication and testing; evaluate alternatives for fuel treatment scale-up; laboratory 10" fuel feed system design review and testing; breadboard component design reviews and tests (heat exchanger, steam generator, start system, combustor); Computational Fluid Dynamics (CFD) modeling final report
- FY 2018 Plans: Breadboard combustor design review; breadboard hot-side testing; product removal hardware down-select and testing; water replenishment hardware down-select and testing.
- FY 2019 Plans: Breadboard hot-component test readiness review and testing; Breadboard System test readiness review and test.

MULTI-DAY ENDURANCE OF GROUP 2 UNMANNED AIRCRAFT SYSTEM (UAS) USING PACIFIC ENERGY SOURCES (HYBRID TIGER)

Lead Organization: Naval Research Laboratory

Other Key Participants: Pennsylvania State University, Naval Postgraduate School, NRL- Marine Meteorological Division Monterey

OE Funding Stream:

FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	Total
$1.4	$1.4	$1.8	$1.7	$6.2

Description: The goal of this program is to develop and demonstrate a multi-day, Group 2 UAS at TRL 6. The proposed hybrid power system leverages DoD funded research in photovoltaic (PV) cells, autonomous soaring (AS) algorithms and fuel cell (FC) technologies. These technologies exploit abundant indigenous energy in the Pacific to minimize dependence on supply lines and maximize operational flexibility. The PV cells and AS algorithm harvests solar energy directly, while the hydrogen fuel could be produced locally using electricity from ground-based PV cells to electrolyze seawater. Together, these technologies are projected to enable flights of 4+ days and/or 3,000 nmi.

Military Benefit: The military benefits of this program include greater operational capability, improved energy efficiency, and reduced reliance on supply lines for fuel. Specifically:

- Group 2 UAS with multi-day endurance and long range will open new CONOPS options.
- High efficiency to reduce average fuel consumption per km traveled or hour in the air.
- Opportunity to generate fuel locally, eliminating fuel logistics burden.

Extended range capability is advantageous and critical in the Pacific, where aircraft may have to travel long distances from the launch point to support a mission on a remote island or ocean location. Extended endurance is almost universally advantageous, providing uninterrupted coverage using a single asset. Multi-day and low altitude operation capability improves effectiveness at many missions, including SAR, ISR, ELINT/SIGINT, and dark-ship tracking.

Accomplishments/Status:

- Hybrid Tiger airframe design was completed
- Tooling was delivered, and the first flight parts were fabricated
- The propulsion system was refined in NRL's wind tunnel
- Hydrogen tank liners were fabricated and shipped for carbon overwrapping
- Solar arrays, fuel cells, and power management hardware were ordered and/or contracts let
- The alpha and beta software builds were completed, uniting aircraft control with energy-awareness algorithms, and underwent testing in a custom hardware-in-the-loop benchtop system

HYDROTHERMAL VENT EXPLOITATION FOR UNDERSEA ENERGY (HTVE-UE)

Lead Organization: Sea Warfare and Weapons Department (Code 33), Office of Naval Research (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:

FY 2016 (M)	FY 2017 (M)	FY 2018 (M)	FY 2019 (M)	Total
$1.3	$0.0	$0.8	$0.5	$2.7

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), an oceanographic feature where a fissure occurs 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 initiated for environmental considerations and CONOPS development. Current efforts are on track for laboratory testing in late 2017, followed by full design and build of a test system for at-sea deployment for testing in September 2018.

JP-8 BASED FUEL CELL POWER

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

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	$2.4	$1.9	$8.5

Description: Silent power is a critical enabler for robotic platforms to conduct extended missions with low acoustic and thermal signatures. 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, designed to provide soldier equipment off-loading, power, transportation, reconnaissance and autonomous resupply, is essential for operations in the Pacific regions. A JP-8 fuel cell power system integrated into an SMET representative vehicle will show the ability to meet both noise and range requirements identified within the SMET CDD. These systems can provide efficiencies over 35%, which means the vehicle can go further before refueling is required, increasing the operational efficiency overall. On-board power means reduced need for generators, battery chargers and additional batteries, further easing logistics.

Military Benefit: Availability of a silent vehicle capable of transporting equipment and conducting autonomous resupply missions with increased quiet range before refueling. Demonstration of an SMET Unmanned robotic platform able to meet requirement attributes outlined in the Capability Development Document (CDD). Efficient power generation, especially at low electrical loads, with 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. Relevant across DoD, including USAF, Navy, Army, SOCOM, USMC.

Accomplishments & Plans:

FY 2016: Accomplishments

- Scope of Work Development and Concept Refinement

FY 2017: Plans

- JP-8 Reformer Maturation
- Solid Oxide Fuel Cell (SOFC) Enhancement
- Initial Design Review

FY 2018: Plans

- System Integration and Initial Testing (Iteration 1)

FY 2019: Plans

- Additional System Testing (Iteration 2 & 3)
- Begin Final Packaging

FY 2020: Plans

- Vehicle Installation and Calibration
- Vehicle Testing and Demonstrations

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.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Appendix C

TECHNICAL ASSESSMENT OF FY 2012, FY 2013, AND FY 2015 COMPLETED OECIF PROGRAMS

The FY 2012 programs focused on improving the operational effectiveness of contingency bases through improvements to shelters and environmental control units (ECUs).

- Advanced Energy Efficient Shelter Systems (AEESS): This program was led by the Army, who partnered with the Air Force. It received the largest funding and focused heavily on soft wall shelter insulation efficiency improvements. The program was proposed to develop incremental shelter improvements followed by testing to evaluate those improvements. A series of five tests were conducted in both hot and cold climates and indicated shelter insulation efficiency improvements of 50 percent over baseline designs. The program also focused a small effort on improvements to shelter interior lighting, solar shades, and radiant barriers, which produced additional energy savings in these areas.

- Innovative Cooling Equipment (ICE): This program was led by the Army, and focused on incremental (evolutionary) energy efficiency improvements to existing ECU designs. The program proposed to use manufacturers of current ECU systems to incorporate state of the art technologies into the current product line to achieve efficiency improvements of 10 percent threshold and 30 percent objective. The program successfully introduced improvements, such as variable speed fans, micro-channel heat exchanger, variable speed compressor technologies, electronic expansion valves, and super hydrophobic surface treatments to produce energy efficiency improvements of 56 percent for 9,000 (9K) British thermal units (BTU) units, 20 percent for 18K BTU units, 17 percent for 36K BTU units, and 14 percent for 60K BTU units.

- Navy Expeditionary Technology Transition Program (NETTP): This program focused on developing disruptive (revolutionary) energy efficient ECU designs. The program proposed to further develop four basic cooling concepts that were the result of an Advanced Research Project Agency-Energy (ARPA-E) program on radical cooling concepts to achieve energy savings of 20-50 percent. The concepts chosen were membrane dehumidification; two compact, efficient absorption and adsorption coolers that could run on waste heat; and one highly efficient cooler that uses a Stirling cycle instead of a typical vapor compression cycle. The program successfully demonstrated a Stirling based ECU with an efficiency improvement of 18 percent and a membrane dehumidification system with energy savings of 10 percent.

- Super Energy Efficient Containerized Living Unit (SuperCLU): This program was led by the Navy and developed an improved CLU with an energy efficiency improvement of 54 percent and a SuperCLU with an energy efficiency improvement of 82 percent. This program incorporated advancements in CLU design using, improved ECUs, insulation, radiant barriers and air distribution. The additional energy efficiency improvements proposed for the SuperCLU were highly efficient split pack ECUs and high R-value (thermal resistance) insulations. These efficiency improvements were successfully realized for several hard wall shelter designs.

- Transformative Reductions in Operational Energy Consumption (TROPEC): This program was led by the Pacific Command (PACOM) and funded as an assessment program to evaluate new and existing energy demand reducing technologies, capabilities, tactics, techniques and procedures in tropical environments. The program successfully evaluated 61 technologies in both lab and field assessments on a cost share basis indicating realizable billeting shelter energy improvements of 47 percent and ECU savings of 91 percent.

- Waste to Energy (W2E): This program was a joint Office of the Secretary of Defense (OSD) Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) effort partially funded by OECIF. The program proposed to investigate four concepts for incinerating camp solid waste and providing the required electricity to operate the system. Three design concepts were explored for the incineration process: down draft, updraft, and rotary kiln. The rotary kiln process proved to be the most successful and provided 81 percent liquid fuel savings and a peak efficiency of approximately 75 percent to convert solid feedstock to fuel gas. In addition, generator exhaust emissions when operating dual fueled (diesel and syngas) are significantly lower than when operating on 100 percent liquid diesel fuel.

The FY 2013 programs focused on forming consortia to investigate various energy capability improvements.

- Energy Efficient Outpost Modeling Consortium (EEOMC): This program was led by the Navy and focused on developing new system-level energy modeling tools to determine the proper balance of energy resources and optimizing their integration into a tactical microgrid. The program consisted of three pillars: 1) developed tools for planning energy efficient contingency bases, 2) developed a battlefield energy resource dashboard and controls, and 3) developed education and training to highlight the importance of battlefield fuel consumption and conservation.

- Soldier/Small Unit Operational Energy (SSUOE) Consortium: This program was led by the Army and funded to reduce the battlefield Soldier's power system burden by reducing power demand of the electronic load. The team's major achievements included building the Government Steering Committee; drafting a policy for implementation of dismounted forces energy requirements; and developing analysis tools, test beds, and wearable measurement systems to successfully influence electronics manufacturers on the importance of low power draw electronics. One of the software changes to a radio will reduce energy needs by 50 percent.

- Engineered Surfaces, Materials, and Coatings (ESMC) for Drag Reduction: This program was led by the Air Force and funded to reduce aircraft skin friction drag by achieving practical laminar flow. The program proposed focusing on wing drag and developing outer mold line flow control techniques to reduce drag without having to modify existing aircraft skin or the underlying structure. Design, analysis, and testing indicate improved fairings can reduce aircraft drag by 1 percent and ongoing research indicates skin friction drag can be reduced with skin surface treatments.

The FY 2015 Congressional plus-up programs were short-term programs chosen to complement existing OECIF programs or explore new directions.

- Joint Infantry Company Prototype (JIC-P): The program was led by USMC and funded to evaluate a fully integrated state-of-the-art energy harvesting system comprised of a bionic knee harvester, packable solar, Lightning Pack (electricity-generating backpack), and wearable power managers. The program performed small scale user evaluations with multiple units, conducted a human factors study on the kinetic harvesters, and continued to improve M&S tools and data.

- Behavioral Energy Operations Demonstration (BEyOnD): The program was led by USMC to reduce operational fuel consumption by ground forces in the Army and USMC by 10 percent or greater through behavior change at little to no cost. This program targeted improvements in vehicle operations and the efficient employment of diesel generators and ECUs at contingency bases. The BEyOnD Phase I effort determined that savings of 9-20 percent may be possible at remote bases through more efficient use of generators and ECUs and savings up to 10 percent may be achievable through vehicle behavior interventions in the tactical environment. The team identified several interventions - institutional, informational, and materiel - that may reach the projected goals. Phase II consists of testing how effective the behavioral interventions are at reducing fuel use. Data from those experiments will then be used in Phase III to make recommendations for institutional changes.

- Advancing Cyber Security for Platform Information Technology (PIT) and Industrial Control Systems (ICS) (CYBER): The program was led by the Office of the Deputy Assistant Secretary of Defense for Installation Energy and funded to analyze the cyber security of operational energy infrastructure that is critical to DoD missions. Three tasks were accomplished: 1) Analyzed key infrastructure at eleven DoD facilities for cybersecurity threats; 2) Performed a gap analysis at the facilities to identify current and emerging technical solutions; and 3) Analyzed workforce skillsets to determine required cyber training to address malicious cyber-attacks. The CYBER program developed a series of recommendations for each of the three tasks and the assessment process was standardized and recommended for Joint Mission Assurance Assessments and integrated into FY16 NDAA sections 1647 and 1650, which require the evaluation of cyber vulnerabilities of all major DoD weapons systems and critical infrastructure, respectively.

- Solar, Soaring, Cooperative Unmanned Aerial Vehicle (Persistent UAV): The program was led by the Navy and funded to develop a persistent intelligence, surveillance, and reconnaissance UAV that utilizes solar thermal soaring algorithms, wing integrated high efficiency photovoltaics, advanced power management hardware, and cooperative swarming software to allow up to five Group I UAVs to complete their mission without the need for fuel. The program conducted multiple two-vehicle flight tests demonstrating over five hours of endurance based on cooperative autonomous soaring algorithms. The two aircraft shared soaring data in real-time and built a memory map of probable thermal locations. Additionally, the team published a Navy Research Lab formal report and a Journal of Aircraft paper on autonomous soaring and solar modelling.

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