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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

A REPORT ON THE BENEFITS TO THE DEPARTMENT OF

NAVY OF THE IMPLEMENTATION OF AN ENERGY SYSTEMS

TECHNOLOGY EVALUATION PROGRAM

by

Brandon Naylor, Eva Regnier, Rabia Khan

January 2019

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ABSTRACT

This report summarizes the benefits the Energy Systems Technology Evaluation Program (ESTEP) has provided to the Department of Navy (DON). The ESTEP provides funding for investigators to carry out projects demonstrating the value or feasibility of a proven or emerging technology in the context of DON energy, using DON installations and DON personnel. ESTEP technologies contribute to assuring energy supply, and increasing energy resilience, while reducing costs and other resource requirements for installations and DON operations, enabling the DON to carry out and sustain its mission. This report documents the contributions of 55 ESTEP projects completed, or in progress, from fiscal year 2013 through fiscal year 2018.

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LIST OF ACRONYMS AND ABBREVIATIONS

ARL	Adoption Readiness Level	
COTS	commercial-off-the-shelf	
DOD	Department of Defense	
DON	Department of Navy	
ESTEP	Energy Systems Technology Evaluation Program	
EXWC	Engineering and Expeditionary Warfare Center	
FY	fiscal year	
HVAC	heating, ventilation and air conditioning	
IPR	Interim Program Review	
NPS	Naval Postgraduate School	
O&S	Operations & Support	
PI	principal investigator	
S&T	science and technology	
SPAWAR	Space and Naval Warfare Systems Command	
TRL	Technology Readiness Level	

I. INTRODUCTION

This report summarizes the benefits the Energy Systems Technology Evaluation Program (ESTEP) has provided to the Department of Navy (DON). Since 2013, the ESTEP provides funding for investigators to carry out projects demonstrating the value or feasibility of a proven or emerging technology in the context of DON energy, using DON installations and DON personnel.

As for any science and technology (S&T) effort, most of the value of ESTEP comes from the later implementation of the technological knowledge gained in the S&T phase. For late-stage S&T projects, such as demonstration projects, this value comes from learning whether and how to integrate the technology effectively and more broadly within the DON. Much of the value of a demonstration project will be realized in future adoption of the technology at a larger scale in the DON.

For ESTEP, this value is enhanced because each project includes DON civilians, service members, or veterans in key technical or business project roles. These personnel gain DON-energy-specific experience which stays within the organization after the completion of the project. Frequently, projects include new professionals in a DON S&T organization, such as Space and Naval Warfare Systems Command (SPAWAR) or Engineering and Expeditionary Warfare Center (EXWC), college student veteran interns via California State University San Marcos' Veterans to Energy Careers, and Naval Postgraduate School (NPS) students, providing real-world training and education opportunities for the future DON energy workforce. For example, as of 2017, over sixty student veterans had participated in ESTEP projects as interns, and over 80% of those went on to work in the Department of Defense (DOD) as contractors or civilian employees.

Most emerging energy technologies are targeted towards private industry and consumers whose requirements may be different from those within the DON. In ESTEP, technologies are demonstrated in DON-specific adaptations and applications. Consequently, project personnel develop DON-relevant workforce experience faster and/or more effectively, while working towards transition of the studied technology into the DON. Technologies studied in ESTEP become more adoption-ready, in terms of

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stakeholder support and alignment with organizational processes, as well as in terms of system readiness and the subsequent ease with which it can be integrated in the intended technology environment.

Once adopted and integrated operationally within DON energy systems, ESTEP technologies would provide benefits in operation (as distinct from adoption readiness and workforce development benefits). In operation, the technologies will contribute to national security by assuring energy supply, increasing energy resilience, and reducing costs and other resource requirements for DON operations, enabling the DON to carry out and sustain its mission.

In addition, ESTEP develops DON S&T personnel with experience in learning and applying skills in new energy technologies, as well as knowledge on how to navigate the challenges faced in integrating those new technologies into existing infrastructures and "ecosystems".

This report documents the contributions of 55 ESTEP projects, either completed or in progress from fiscal year (FY) 2013 through FY 2018. The report begins with a description of the research methodology in Chapter II, which is then followed by a discussion and categorization of projects into technology families in Chapter III. Chapters IV - VII follow, with a summary of ESTEP project contributions with respect to: benefits in operation, learning value, and workforce development. Finally, the report concludes with a discussion on adoption readiness levels and final notes on the value of ESTEP project implementation to the DON.

II. RESEARCH METHODOLOGY

Table 1 lists the ESTEP projects described in this report, along with each project's principal investigator (PI), period of performance, installation location, and a reference number that will be used to identify specific projects later in this report. Additionally, related or follow-on projects are also indicated by alternating color groupings.

The research for this report was primarily carried out by reviewing Interim Program Review (IPR) materials and other documentation from 55 ESTEP projects completed between FY13 and FY18 and conducting interviews with the PIs when possible. The project IPR slides were reviewed first to gain a basic understanding of the technologies employed in each ESTEP project and to develop a taxonomy of technology families, as described in Chapter III.

Each project's IPR material and any other accompanying documents were reviewed in more detail to determine an applicable technology family, and to evaluate the type of benefits that could be achieved by said technologies. After establishing taxonomies for technology families and benefits of the technology in operation, the researchers then attempted to contact the project PIs to discuss the projects in more detail. The purpose of these discussions was to confirm our understanding of the technologies in use and review the progress made during each project. These discussions and the IPR reviews formed the basis of a further analysis of each demonstrated technology and its readiness for further adoption at other DON installations.

To facilitate the discussions with project PIs and standardize the project information used in this study, the authors of this report created a standard form for recording project information from the IPRs and PI interviews. Using their best judgement, the authors of this report first filled out these forms given the information available in the IPRs. The authors then reached out to key project personnel to conduct phone interviews in an effort to fill in any information gaps or make corrections to the authors' assessments. These key personnel were then sent a copy of the completed form to give their final approval of the contents and correct any misunderstandings. In the case where authors were not successful in contacting a knowledgeable representative for a project, assessment was documented based on the author's best judgement. For reference,

3

the complete set of final ESTEP project information forms is provided in Appendix B of this report.

Ref #	Project Title	FY Start	FY End	Principal Investigator	Performing
					Organization
2	Wind Powered Cooling with Thermal Storage	13 15	14 17	Anthony Gannon	NPS NPS
3	Uninterruptible, Renewable Augmented Building Power Circuits Building Scale Compressed Air Energy System (CAES)	15	17	Anthony Gannon Anthony Gannon	NPS
4	Self Contained Hydrogen to Electrical System	10	17	Garth Hobson	NPS
5	Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals	15	10	Eric Evans	SSC PAC
5	Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy	15	1/		SSC PAC
6	Goals	16	18	Eric Evans	SSC PAC
7	Real-Time Distribution Analysis for MCBP	16	17	Eric Evans	SSC PAC
8	Evaluation of Smart -Controllers for Distributed Energy Resources	16	17	Alan Williams	SSC PAC
9	Advance Power Electronics for PV Inverters	13	15	Ken Ho	EXWC
10	DC Micro-grid For Solid State Lighting	15	17	Ken Ho	EXWC
11	Networked Building Level Micro-grid	17	19	Bruce Garrett	EXWC
12	Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration	12	14	Jose Romero-Mariona	SSC PAC
13	Energy Efficient Cloud Computing Evaluationand Demonstration	14	17	Chris Chen	SSC PAC
14	RFID Reading Outlets for Device-level Granularity in Building Energy Control	14	18	WayneLie	SSC PAC
15	C-SEC On The Move	15	16	Jose Romero-Mariona	SSC PAC
16	Data Center Smart Metering Evaluation (DC Smart-E)	16	16	Chris Chen	SSC PAC
17	Building Energy Management Automation	16	16	Chris Chen	SSC PAC
18	Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)	16	17	Jose Romero-Mariona	SSC PAC
19	SCADA Deploy	16	18	Henry Au	SSC PAC
20	Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)	17	18	Jose Romero-Mariona	SSC PAC
21	Smart Plug Side Channel Analysis (SPAMSANDWICH)	17	18	Lawrence Kerr	SSC PAC
22	ENSURE (Ensuring Reliability and Efficiency)	17	18	Josiah Bryan	SSC PAC
23	Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)	17	19	Geancarlo Palavicini	SSC PAC
24	Passive and Active Cyber-Defense for Cyber-Physical Systems –Strategies, Implementation, and Evaluation	17	18	Roger Hallman	SSC PAC
25	Deep Subgrid-parity Solar	15	17	Randall Olsen	SSC PAC
26	Energy and Water Recovery by Microbial Fuel Cells	14	17	Lewis Hsu	SSC PAC
27	Ad-hoc Portable Power Systems (APPS)	17	19	Wayne Liu	SSC PAC
28	Energy Village: A Littoral Energy Test Facility	16	18	Wayne Liu	SSC PAC
29	Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study	16	18	Arthur Rubio	SSC PAC
30	Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage	14	16	Arthur Rubio	SSC PAC
31	Mobile EMS	15	16	Giovanna Oriti	NPS
32	Photovoltaic Power Conditioning System for an Energy Management System (EMS)	16	18	Giovanna Oriti	NPS
33	RTU Challenge	13	17	Max Hogan	EXWC
34	Improved Wind Load Design for Rooftop PV Systems	14	15	Fernand Marquis	NPS
35	Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-Manage) Seed	14	14	Tyler Chun	SSC PAC
36	Validate SIREN Computer Modeling	15	16	Ben Wilcox	EXWC
37	LIDAR Wind Measurement Experiments	15	16	Ben Wilcox	EXWC
38	Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind Turbine	15	17	Ben Wilcox	EXWC
39	Liquid Air Energy Storage (LAES)	15	17	Ken Ho	EXWC
40	Waste to Energy Hydrogen Generation	15	18	Ken Ho	EXWC
41	Adhered PV Reliability (Completed)	15	16	Robert Schoff	EXWC
42	Optimized Cooling for Concentrated Photovoltaic Systems	15	17	Sanjeez Sathe	NPS
43	Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion	16	20	Ben Wilcox	EXWC
43	Valuation and Financing for Energy Storage	16	18	Dustin Talley	EXWC
44	Transportable Micro-grid with Storage	16	19	Paul Kistler	EXWC
45	Modular Micro grid (M2G) System	16	19	Yutaka Sugiyama	EXWC
40	Wind Effects on Sun Tracking PV Cell Solar Panels	16	17	M. S. Chandrasekhara	NPS
48	Grid Stability in High Penetration Renewables	17	19	Bruce Garrett	EXWC
49	NanolubricantHVAC Refrigerant	17	19	Paul Kistler	EXWC
50	Tunable White LED	17	19	Paul Kistler	EXWC
51	Waste Heat Recovery From Gas Turbine Exhaust	17	19	Garth Hobson	NPS
52	Efficient Implementation of Solid State Transformers (SST)	17	19	Todd Weatherford	NPS
53	HVAC Control by Means of Predicted Percentage of Dissatisfied Method	17	19	Arthur Rubio	SSC PAC
54	Develop Energy Use Trends with Innovative Visualization/Analysis	17	18	Chris Chen	SSC PAC
55	Green Data Center Software Product Evaluation	17	19	Mamadou Diallo	SSC PAC
55		1/	15	Managou Diano	SSC FAC

Table 1.ESTEP projects

Note: Follow-on or related projects are shown below the preceding project, in the same color.

III. OVERVIEW OF TECHNOLOGY DEMONSTRATION FAMILIES

As explained in Chapter II, the technologies used in the ESTEP demonstration projects were categorized into technology families (defined in Table 2). This taxonomy was developed for the purposes of this report, to allow for easier comparison among projects, by highlighting the most significant ways in which ESTEP projects are intended to help reduce costs and improve DON installation energy assurance.

Table 3 indicates to which family each ESTEP project belongs. In many cases, the demonstrated technologies or systems used can be grouped under multiple technology families. An 'X' is used to indicate that a project belongs in that technology family, while an 'XXX' indicates the project's primary technology family. Figure 1 shows the distribution of projects by technology family.

Over half of the technology demonstration projects (N=29) are secondarily associated with the *Modeling, Optimization and Decision Support* family. Yet, a small number of the technology demonstration projects (N=7) fall within the *Modeling, Optimization and Decision Support* group as a primary technology family.

Technology Family	Description
Energy Production	Technologies that generate usable energy or covert other energy into a more usable form.
Energy Storage	Technologies that create independent supplies of stored energy that can be used later.
Management, Monitoring	Technologies that improve situational awareness and/or control capabilities of energy (usually electrical power) systems.
Cyber & Physical Security	Technologies that provide detection of, defense against, or minimize potential damage caused by malicious actions, attacks, natural events, or human error affecting the operation of energy systems or, via energy systems, affecting other systems they support.
Modeling, Optimization, Decision Support	Technologies that can be used to model energy (usually electrical power) systems to determine if systems are behaving as expected and analyze the expected impact of potential changes or events to inform future decisions ¹
Microgrids, Islanding, Isolation	Technologies that improve a facility's ability to function independently of the commercial electrical power grid or provide a greater degree of resilience against disturbances on the commercial grid
Other	Technologies that provide a significant energy-related capability outside of those categories listed above

Table 2.Technology family definitions

¹ For more examples and detailed explanation of Modeling, Optimization and Decision Support Capability, see Seals (2017).

	4		Evber & Phy & Monitorin & XXX		Ni Pling, Optim Support			
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	Energy Production	nergy Storag	\$ NI. Phy	sical	Su, Optin	lari Brids		
	roducti	Stor	Vonitori	Secur	opport in	izatio	nding, Oth	
Ref. #	Project Title		se "	8	le la	~ <i>n,</i>		er
1	wind Powered Cooling with Thermal Storage		~~~					
2	Uninterruptible, Renewable Augmented Building Power Circuits Building Scale Compressed Air Energy System (CAES)		X XXX				XXX X	
4	Self Contained Hydrogen to Electrical System	х	XXX				~	x
5	Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals	~	7001	х		XXX		~
	Seamless Integration of GIS and Electrical Architecture Models for							
6	Smart Grids and Net-Zero Energy Goals			XXX	Х	Х		
7	Real-Time Distribution Analysis for MCBP			XXX	Х	Х		
8	Evaluation of Smart -Controllers for Distributed Energy Resources	2007		XXX		Х	Х	
9 10	Advance Power Electronics for PV Inverters DC Micro-grid For Solid State Lighting	XXX X	x	х			XXX	
10	Networked Building Level Micro-grid	X	X	Λ			XXX	
	Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development,							
12	and Demonstration			х	XXX	х		
13	Energy Efficient Cloud Computing Evaluationand Demonstration			Х		Х		XX
	RFID Reading Outlets for Device-level Granularity in Building Energy							
14	Control			XXX	X	X		
15 16	C-SEC On The Move Data Center Smart Metering Evaluation (DC Smart-E)			XXX	XXX	X X		
16	Building Energy Management Automation			XXX	x	X		
	Resilient Critical Infrastructures through Secure and Efficient Micro					~		
18	Grids (ReClst)				ххх	х	х	
19	SCADA Deploy			Х	XXX	Х		
	Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and							
20	UHWO)				XXX	Х		Х
21 22	Smart Plug Side Channel Analysis (SPAMSANDWICH) ENSURE (Ensuring Reliability and Efficiency)			X X	XXX XXX			
22	Hypercritical Operational Technology Mitigation of Embedded			~				
23	SploitSyndrome (HOTMESS)			х	xxx	х		×
	Passive and Active Cyber-Defense for Cyber-Physical Systems							
24	-Strategies, Implementation, and Evaluation			х	XXX	Х		
25	Deep Subgrid-parity Solar	XXX						
26	Energy and Water Recovery by Microbial Fuel Cells	Х	Х					XX
27	Energy Village: A Littoral Energy Test Facility	X	X				X X	XX
28	Ad-hoc Portable Power Systems (APPS) Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility	X	Х				X	XX
29	Study	х	x			х	xxx	
	Optimization of a Decentralized Micro-grid with PEM Fuel Cell,							
30	Electrolyzer and H2 Storage	Х	х			Х	XXX	
31	Mobile EMS	Х	Х	Х			XXX	
	Photovoltaic Power Conditioning System for an Energy Management							
32 33	System (EMS)	XXX	Х	X X		X X	Х	XX
34	RTU Challenge Improved Wind Load Design for Rooftop PV Systems	XXX		~		X		
34	Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-	~~~				^		
35	Manage) Seed			xxx		х		
35	Validate SIREN Computer Modeling			х		XXX	х	
37	LIDAR Wind Measurement Experiments	Х				XXX		Х
	Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind							
38	Turbine	Х	100	V				XX
39 40	Liquid Air Energy Storage (LAES) Waste to Energy Hydrogen Generation	XXX	XXX X	Х		x		×
40	Adhered PV Reliability (Completed)	XXX	~			X		,
41	Optimized Cooling for Concentrated Photovoltaic Systems	XXX				~		
	Shore Based Test of X-Band Radar Hardware on Mast for Real Time							
43	Hydrodynamic Control of Wave Energy Conversion	XXX				х		
44	Valuation and Financing for Energy Storage		Х			XXX		Х
45	Transportable Micro-grid with Storage	X	X	X		X	XXX	
46	Modular Micro grid (M2G) System Wind Effects on Sun Tracking PV Cell Solar Panels	X	Х	Х		X	XXX	
47 48	Grid Stability in High Penetration Renewables	XXX X	x	XXX		X		>
40	NanolubricantHVAC Refrigerant	~	^	777		Х		XX
50	Tunable White LED					X		XX
51	Waste Heat Recovery From Gas Turbine Exhaust	XXX						×
52	Efficient Implementation of Solid State Transformers (SST)	Х				Х	Х	XX
	HVAC Control by Means of Predicted Percentage of Dissatisfied							
53	Method			Х		XXX		x
54	Develop Energy Use Trends with Innovative Visualization/Analysis					XXX		

Table 3.List of projects and their technology families



Figure 1. Distribution of ESTEP projects by technology family

IV. TECHNOLOGY BENEFTIS IN OPERATION

Once adopted and operational, ESTEP technologies would provide benefits in operation – as distinct from benefits the demonstration provides via learning value, workforce development, or by improving a technology's adoption readiness.

ESTEP technologies provide different kinds of benefits in operation. Based on a review of ESTEP project documents, PI interviews, and a review of DOD and DON guidance on energy priorities (Simon et al., 2014; Whitney et al., 2013) we identified energy systems' benefits in operation that are most important to DOD and DON leadership, as detailed in Table 4.

The most fundamental benefits of investing in new DON energy technologies are that they can provide enhancements to energy resilience and energy assurance.² Energy is a requirement of almost every activity – both in support and operational roles in the DON – and making sure energy is available in the form usable (when and where required), is essential to the mission. "Assured access to reliable energy is critical to the DON's ability to accomplish its mission. Optimizing energy use by increasing energy efficiency and diversifying sources of supply enhances combat capability and operational flexibility, while reducing risk and logistical demands" (Department of the Navy, 2017).

The technologies demonstrated in ESTEP projects offer ways to ensure that DON installations are able to provide a supply of energy that meets the demands of mission assurance. In some cases, technologies provide resilience by providing services, or otherwise allow continued functionality if energy supplies are cut off. Other technologies, such as renewable energy generation, can generate usable energy independent of outside sources. Some technologies work to protect the infrastructure that distributes energy, by reducing risk or the frequency of disruptions. While it is difficult in some cases to assess the full operational impact of any given technology during the S&T stage, ESTEP

² Energy assurance is making sure mission-demanded energy is available, while energy resilience emphasizes recovery from a disruption---it is defined in the U.S. Federal code as "the ability to avoid, prepare for, minimize, adapt to, and recover from anticipated and unanticipated energy disruptions". (U.S.C. Title 10 Section 101(e)(6).

projects have shown that many of these technologies have the potential to provide significant benefits when adopted and implemented on a larger scale. For example, the building-scale solid state lighting microgrid demonstration (Project 10) has made significant progress towards the development of a technology template and process roadmap to easily convert other buildings into standalone microgrids without the need to invest in a lengthy design process.

In addition to identifying the general categories of potential benefits that could be provided by demonstrated installation energy technology projects, the research conducted by the NPS team also broke out several sub-categories of benefits, for the general benefit categories described in Table 4. A breakdown of the sub-categories, mapped to the general benefit categories they are associated with, is also provided in Table 4.

Table 4.	Benefit cate	gories
----------	--------------	--------

Benefit Category	Description	Sub-categories
Introduce / Integrate New Energy Generation	Capability to generate electrical power on DON installations. This could take many forms such as capturing waste energy, new PV generation, technology that makes other power sources on installations more efficient, etc.	•Added renewable energy generation capability •Improved efficiency or effectiveness of existing renewable generation •Improved capability to integrate renewables into larger grid •Integrated alternative-powered backup power systems
Introduce / Integrate New Energy Storage	Capability for energy to be stored for later use. This could take many forms such as battery storage, compressed air energy storage, fuel cell systems, technology that makes existing storage more efficient, etc.	 Integrated or expanded renewable energy storage Improved efficiency or effectiveness of existing renewable energy storage Incorporated energy storage to reduce peak power demand Increased energy storage capability for independent operation
Reduce Energy Demand on Bases	Capabilities that reduce base energy resource requirements without compromising operational capability. These could take many forms such as efficiency improvements at point-of-use or in the distribution infrastructure, reducing waste, or shifting to alternative sources of energy.	 Reduced installation power consumption through improved distribution efficiency Reduced installation power consumption through building control automation Reduced installation power consumption through improved end-user efficiency Reduced natural gas needed for heating or installation operations Improved efficiency or alternative fueled vehicles on installation

Table 4, Benefit Categories, continued:

Benefit Category	Description	Sub-categories
Reduced O&S Requirements	Reduction in the operation, maintenance, and support requirements for energy systems. This could take many forms such as technologies that reduce maintenance requirements on a heating, ventilation and air conditioning (HVAC) system, technologies that aid energy managers in diagnosing power grid problems, reduce failure rate, etc.	 Reduced contractor support required to install, maintain, or operate technology Technology requires less maintenance labor than alternative systems Technology requires fewer or less costly replacement components that alternative systems Technology is easier to operate than alternative systems Technology reduces need for specialized training Reduced reliance on systems with expensive replacement parts Increased ability to diagnose need for preventative maintenance Reduced wear and tear on mechanical systems
Physical or Cyber Security, Resiliency, Redundancy	Capabilities that help safeguard energy supply or distribution resources. These could take many forms such as identifying vulnerabilities within critical systems, improving monitoring of electrical systems to detect abnormal activity, implementing measures to limit the potential damage of catastrophic events, improving ability to restore operations following a power failure, etc.	 Improved monitoring and detection of potential cyber threats Improved capability to isolate potential vectors for cyber-attacks Improved fail-safes or system logic to limit potential damage from cyber-attacks Improved capability to restore operation after successful cyber-attacks Improved islanding capability to isolate and protect critical systems Improved fault isolation to prevent cascading blackouts Automated backup systems for critical systems Reduced reliance on outside energy suppliers Improved diagnostic capabilities for energy infrastructure components Improved metering and monitoring of installation energy use Real-time monitoring of energy systems Improved documentation of infrastructure Reduced frequency of backup generator use Reduced requirement for backup generators to assure power

Table 4, Benefit Categories, continued:

Benefit Category	Description	Sub-categories
Improved Modeling or Decision Support	Capabilities that allow facility decision makers to optimize grid operations, estimate returns on infrastructure projects, or otherwise provide valuable insight when considering installation energy projects. These could include improving ROI estimates of infrastructure improvements, properly sizing new infrastructure components, identifying power quality issues, etc.	 Improved decision support capability for sizing backup generators Improved capability to estimate ROI of renewable systems Improved decision support capabilities for investing in renewable systems Power modeling used to optimize grid configuration or expansion Modeling and simulation to inform energy infrastructure investments Improved decision support tools to inform future investments or funding requirements
Mobile / Remote Power	Capabilities that lend themselves to improving energy access or reliability at remote outposts, in the field, remote locations on bases, or other areas where reliable power sources are limited or unavailable.	 Improved decision support capability for sizing backup generators Improved energy capabilities at remote locations without energy infrastructure access Improved energy capabilities on mobile platforms or temporary facilities

Estimating the magnitude of these benefits – e.g., how much can we improve wave energy generator output (Project 43), or how much energy can we save with improved heating, ventilation and air conditioning (HVAC) units (Project 33) – is one of the valuable contributions of some ESTEP demonstration projects. The magnitude of benefits provided by the technologies may be difficult to estimate because they will depend on the details of specific future adoption. In addition, estimating the value of many of the above-described benefits can be challenging, as many of the most important benefits are non-financial, such as assuring the supply of power to mission-critical capabilities.

Many of these benefits are indirect. For example, a capability may enable enduser behavioral changes such as conservation by providing feedback to the end user regarding local power consumption or prices. The technology and its capability create benefits indirectly by enabling better downstream decisions, not directly as a result of the technology's implementation. It could enable changes in operational choices by providing system operational data or control capability. It could also improve infrastructure choices by providing information to inform design choices, e.g., sizing electrical equipment, and providing justification for use in procurement requests.

Energy technologies can also improve mission capability by reducing operating costs – either financial, or via the use of resources such as labor required for operating the energy system. While reducing operating costs associated with installation energy does not directly affect operational effectiveness, if a command can reduce its total energy costs, that potentially frees up funding for other programs, or for further energy improvements. Reductions in the total cost of energy from outside sources can also make an installation more financially resilient against changes in fuel or energy prices. A graphical representation of how operational DOD energy-related objectives, including reducing costs as discussed here, contribute to defense and national strategic objectives is shown in Figure 2.

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Figure 2. Network of DOD energy-related objectives (adapted from Whitney et al., 2013)

of ESTEP. For this reason, we have used three different designations to classify the observed or potential benefits each project had/has to offer. A benefit was considered a "realized" benefit if it was observed at an operational scale during the demonstration projects. If not realized, a benefit could be classified as "demonstrated" if the ESTEP project had shown all of the capabilities needed to provide a given benefit, but was not yet functioning so as to provide this benefit at an operational capacity. Finally, a benefit would be considered a "potential" benefit if the technology provided most of the capabilities necessary to achieve a certain benefit, but would need to be further developed or integrated with a complementary system. A graphical summary depicting the total

count of realized, demonstrated and potential benefits across the ESTEP projects is shown in Figure 3.



Figure 3. Distribution of ESTEP projects by benefit category

Table 5 provides a summary of the observed or expected benefits of the different ESTEP projects. Appendix A contains a series of figures [Figures A-1 to A-7], showing the *realized*, *demonstrated*, and *potential* benefits of each technology, for each benefit category, broken down by specific ways they provide benefits in each category described in Table 4.

Table 5.Summarized project benefits

	Introduce interview Beneration Project Title	Inn, Cintegrate new Beenergy	Redu	re energy demand at	Physical or cyte redundant Does requireme point of				
	^{Urod} uce/i	Im,	Reduc orove efficienc istribution 'energy XXX	e energy Reduce	^{ITVSICAT} OF CVC redundant O&S requirement Point of	inproved	Mobile A modeling or c port iliency,	ile / Remote Po	
	storestion	ntegrate -	istributi	Use demand	ORS re-	CV Security	nodeling	ile Ren	
	in thew	ener	ener	V of ener	Point	y, reg	iliene or c	lecisio	W.
Ref. #	Project Title Wind Powered Cooling with Thermal Storage	"By	XXX	-''8y	X	The states	·''',	"On	ver
1	Uninterruptible, Renewable Augmented Building Power Circuits		XXX	x	^	х	х		
3	Building Scale Compressed Air Energy System (CAES)		XXX		Х	Х	Х		
4	Self Contained Hydrogen to Electrical System Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals		XXX	х		X	X X	XXX	Х
	Seamless Integration of GIS and Electrical Architecture Models for			^			~	7000	
6	Smart Grids and Net-Zero Energy Goals			X		X	X	XXX	
7 8	Real-Time Distribution Analysis for MCBP Evaluation of Smart -Controllers for Distributed Energy Resources			Х		X X	XXX	X XXX	
9	Advance Power Electronics for PV Inverters	XXX		х					
10 11	DC Micro-grid For Solid State Lighting Networked Building Level Micro-grid	X X	XXX XXX	X X	X	Х	X X		
11	Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development,		~~~~	^					
12	and Demonstration					Х	XXX		
13	Energy Efficient Cloud Computing Evaluation and Demonstration RFID Reading Outlets for Device-level Granularity in Building Energy				XXX				
14	Control				х	х		ххх	
15 16	C-SEC On The Move Data Center Smart Metering Evaluation (DC Smart-E)				XXX	X X	XXX X	x	
16	Building Energy Management Automation				XXX XXX	X	X	^	
	Resilient Critical Infrastructures through Secure and Efficient Micro						10.7		
18 19	Grids (ReClst) SCADA Deploy			X X		X X	XXX XXX	x	
	Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and								
20				х			XXX		
21 22	Smart Plug Side Channel Analysis (SPAMSANDWICH) ENSURE (Ensuring Reliability and Efficiency)			x		X X	XXX XXX	X X	
	Hypercritical Operational Technology Mitigation of Embedded								
23	SploitSyndrome (HOTMESS) Passive and Active Cyber-Defense for Cyber-Physical Systems					Х	XXX	Х	
24	-Strategies, Implementation, and Evaluation						XXX	x	
25	Deep Subgrid-parity Solar	XXX				Х			
26 27	Energy and Water Recovery by Microbial Fuel Cells Ad-hoc Portable Power Systems (APPS)	X X	X X			х			XXX XXX
28	Energy Village: A Littoral Energy Test Facility	X	X			X			XXX
29	Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study	х	x				xxx		
29	Optimization of a Decentralized Micro-grid with PEM Fuel Cell,	~	^				~~~		
30	Electrolyzer and H2 Storage								
31	Mobile EMS Photovoltaic Power Conditioning System for an Energy Management							х	XXX
32	System (EMS)	х						х	ххх
33	RTU Challenge	NVA/			XXX	X			
34	Improved Wind Load Design for Rooftop PV Systems Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-	XXX				Х			
35	Manage) Seed				ххх	х	х	х	
35 37	Validate SIREN Computer Modeling LIDAR Wind Measurement Experiments	х		X		Х	Х	XXX XXX	х
57	Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind	^						~~~	^
38	Turbine	XXX	100			X	x	х	
39 40	Liquid Air Energy Storage (LAES) Waste to Energy Hydrogen Generation	х	XXX X		X	Х	X		
40	Adhered PV Reliability (Completed)	XXX	~		~	Х			
42	Optimized Cooling for Concentrated Photovoltaic Systems Shore Based Test of X-Band Radar Hardware on Mast for Real Time	XXX							
43	Hydrodynamic Control of Wave Energy Conversion	xxx				х		x	
44	Valuation and Financing for Energy Storage		X			Х	Х	XXX	
45 46	Transportable Micro-grid with Storage Modular Micro grid (M2G) System	X X	X X	X		X X	X XXX		XXX
40	Wind Effects on Sun Tracking PV Cell Solar Panels	XXX	~	~		Х	Х		
48	Grid Stability in High Penetration Renewables			XXX	Vi Vi	X	Х	Х	
49 50	NanolubricantHVAC Refrigerant Tunable White LED				XXX XXX	X X		x	
51	Waste Heat Recovery From Gas Turbine Exhaust	XXX			X				
52	Efficient Implementation of Solid State Transformers (SST) HVAC Control by Means of Predicted Percentage of Dissatisfied	XXX				Х			
53	HVAC Control by Means of Predicted Percentage of Dissatisfied Method				ххх	х		x	
54	Develop Energy Use Trends with Innovative Visualization/Analysis					Х		XXX	
55	Green Data Center Software Product Evaluation				XXX	Х	Х	Х	
V. LEARNING VALUE OF TECHNOLOGY DEMONSTRATION

As first-of-their-kind efforts, often small-scale and requiring substantial engineering and technical labor, few ESTEP projects will have positive net financial benefits if evaluated in isolation. In other words, evaluating the projects based only on the demonstration projects' direct impacts would undervalue these efforts' value to the DON. While many successful technology demonstration projects provide demonstrated benefits to their host installations, as for any research and development effort, the greatest value of ESTEP projects is in learning about technologies, and therefore will be realized in future adoption of the technology at a larger scale at installations. The learning gained from demonstration projects can add value in several different ways.

One of the key ways ESTEP projects add value is by S&T personnel learning how to integrate emerging technologies within a DON environment. Historically, the DOD was the developer and owner of the most advanced technologies in the world, but increasingly the DOD and DON are adopting technologies largely developed in the commercial sector. Even for the technologies that are in use operationally in private industry, in many cases the challenge is to integrate the technology in a DON context. The technology requires military-specific or even DON-specific adaptations, or perhaps may require experience in procuring, installing, and using a technology effectively. In DOD applications with more intensive system resiliency or cyber security requirements, special considerations are needed to integrate a system or technology that wasn't designed with these requirements in mind. To meet those requirements, DON engineers must find clever ways to add in safeguards or demonstrate that a new technology meets a given requirement that may have been written with a different technology in mind. Learning how to use energy management software across DON installation applications can help other installations adopt the technologies more effectively and rapidly, as similar technology is adopted and relevant learning occurs. For example, DON engineers can develop templates for integrated power conditioning systems for adding new alternative energy generation or backup sources to a base power grid, or develop a suite of tools to probe power distribution systems for various cyber security vulnerabilities.

A second way ESTEP projects add value through learning arises if an evaluation project compares multiple instances of a technology (e.g., equipment from multiple manufacturers, or comparing a new technology with the existing technology it would replace). Then, it provides information that helps the DON determine which is the better choice for future adoption and increases the likelihood that the DON will adopt the most effective and efficient technology in future investments. For example, comparing multiple photovoltaic roof-mounting technologies helps the DON acquire the one that is best-suited for widespread adoption or most appropriate for a specific climate or building type. In other cases, a project might demonstrate the potential applications and unique benefits of new applications such as using supercapacitors or chilled water as efficient forms of energy storage. In such instances, the demonstration project may help inform future decisions on which types of technologies to pursue further, even if the project doesn't evaluate products from specific vendors.

A third way ESTEP projects add value through learning is by speeding adoption of promising technologies. The processes within the DOD to certify a technology for use can create significant obstacles when integrating new technologies. The defense industry has very stringent requirements for vetting a new product and technology before accepting a system for wider use. Meeting these requirements often requires visibility into the inner workings of a system that is not required by the technology developer's main target market. Evaluating these products for acceptance often requires close coordination between defense personnel and technology developers. Implementing new technologies may also require the creation of a support mechanism, contract, or agreement that falls outside of the technology developers' primary business model. Add in mandates such as those that give preference to certain businesses, impose environmental constraints, and require multiple safety certifications, and it becomes clear that even purchasing a new technology can become a daunting task.

Technologies that have been demonstrated in a DON installation may fare better in competition for limited funds in the DON project selection processes. In addition, they may pass more quickly through the specification and contracting processes. In some cases, demonstration projects and the identification of new requirements as discussed above has even led to DON engineers having to draft and justify new requirements for

their specific systems because existing mandates were poorly matched to the context of new technology applications. For example, many of these ESTEP projects required researchers to draft or otherwise identify an information security accreditation for their demonstration projects in order to collect energy use data through different automated systems. Setting a precedent could speed the process of getting accreditation for wider adoption. In this way, learning can accelerate the adoption of more efficient and effective installation energy technology, thus providing its benefit sooner.

In some cases, a desired capability is not available as a prepackaged commercially available system, but clever DON engineers can develop these capabilities by combining different commercial-off-the-shelf (COTS) products. Although an ESTEP project of this nature is unlikely to result in a fully mature technology solution, the demonstrated capabilities of the resulting systems can inform future efforts to collaborate with industry partners to develop a mature system, or demonstrate the application for a particular technology composed of already mature systems. For example, several different ESTEP projects used small single-board computers, microprocessors, or "smart" devices to develop novel means of assessing cyber vulnerabilities on existing power systems, or to monitor energy use to detect potential cyber-attacks. In other cases, researchers demonstrated the ability to generate and store energy using mechanical and electrical components not typically associated with larger energy applications.

The mechanisms by which learning could be acquired through ESTEP projects, were categorized as:

- integrating mature commercial technologies on DoN installations and adapting solutions to meet DON-specific challenges or requirements such as technical requirements or procedural compliance (**DON-Specific Adaptations**)
- evaluating an emerging technology's maturity, performance, or suitability so that it can be compared to alternative technologies (Evaluate Competing Technologies)
- determining a technology has met relevant requirements and regulations that can help streamline the process of future adoption efforts (Justification For Wider Investment)
- developing new energy applications using existing technologies (New Capability Development)

Table 6 shows the authors' assessment of the most significant ways in which learning provides value to each project in this study.

		Fuelwete	1	
	Navy-Specific		Justification	New
Ducto et Title	Adaptation	Competing	For Wider	Capability
Project Title	Challenges	Technologies	Investment	Development
Wind Powered Cooling with Thermal Storage		х		
Uninterruptible, Renewable Augmented Building Power Circuits		Х	х	х
Building Scale Compressed Air Energy System (CAES)				х
Self Contained Hydrogen to Electrical System		Х		Х
Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals	Х	Х	Х	
Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero				
Energy Goals	Х	х	х	
Real-Time Distribution Analysis for MCBP	Х		х	
Evaluation of Smart -Controllers for Distributed Energy Resources	Х	Х	Х	
Advance Power Electronics for PV Inverters		х		
DC Micro-grid For Solid State Lighting	Х	Х	х	
Networked Building Level Micro-grid	Х	х	Х	
Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration	Х		Х	
Energy Efficient Cloud Computing Evaluationand Demonstration		Х		
RFID Reading Outlets for Device-level Granularity in Building Energy Control	Х	Х	Х	Х
C-SEC On The Move			Х	х
Data Center Smart Metering Evaluation (DC Smart-E)	Х	Х	х	
Building Energy Management Automation	Х	Х		
Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)	Х		Х	Х
SCADA Deploy	Х		Х	Х
Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)	Х		Х	
Smart Plug Side Channel Analysis (SPAMSANDWICH)	Х		Х	Х
ENSURE (Ensuring Reliability and Efficiency)	Х		Х	Х
Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)		Х		Х
Passive and Active Cyber-Defense for Cyber-Physical Systems –Strategies, Implementation, and				
Evaluation		х		
Deep Subgrid-parity Solar		Х		
Energy and Water Recovery by Microbial Fuel Cells		Х		Х
Ad-hoc Portable Power Systems (APPS)		Х		х
Energy Village: A Littoral Energy Test Facility		Х		х
Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study	Х	Х		
Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage		х	Х	
Mobile EMS				Х
Photovoltaic Power Conditioning System for an Energy Management System (EMS)		Х		
RTU Challenge		Х	Х	
Improved Wind Load Design for Rooftop PV Systems	Х		х	
Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-Manage) Seed	Х		х	
Validate SIREN Computer Modeling		Х		
LIDAR Wind Measurement Experiments	Х	Х	х	х
Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind Turbine	Х	Х	Х	Х
Liquid Air Energy Storage (LAES)		Х	Х	
Waste to Energy Hydrogen Generation	Х	Х	Х	
Adhered PV Reliability		Х		
Optimized Cooling for Concentrated Photovoltaic Systems		Х		
Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of				
Wave Energy Conversion		х		x
Valuation and Financing for Energy Storage	Х		Х	
Transportable Micro-grid with Storage	Х	Х	Х	
Modular Micro grid (M2G) System	Х	Х		
Wind Effects on Sun Tracking PV Cell Solar Panels	Х		Х	
Grid Stability in High Penetration Renewables	Х		Х	
NanolubricantHVAC Refrigerant		х	х	
	Х		Х	
Tunable White LED				
Tunable White LED Waste Heat Recovery From Gas Turbine Exhaust	x	Х		X
		X X		X
Waste Heat Recovery From Gas Turbine Exhaust Efficient Implementation of Solid State Transformers (SST)	х			X
Waste Heat Recovery From Gas Turbine Exhaust	х	Х	X	

Table 6.Learning value mechanisms by ESTEP project

Figure 4 shows the distribution of ESTEP projects' learning contribution by mechanism, i.e., DON-Specific Adaptation Challenges, Evaluate Competing Technologies, Justification for Wider Investment and New Capability Development.



Figure 4. ESTEP projects' learning value contributions

As can be seen from Figure 4, a large majority of the 55 ESTEP projects added learning value by evaluating an emerging technology's maturity, performance, or suitability so that it can be compared to alternative technologies. THIS PAGE INTENTIONALLY LEFT BLANK

VI. WORKFORCE DEVELOPMENT

In addition to promoting energy assurance on DON installations and reducing operating costs, projects funded under the ESTEP program have served to develop the DON workforce. PIs and key performers on these projects have gained technologyspecific expertise and developed generalizable technical and professional skills. These projects have also promoted coordination between different DON organizations that must work together to implement large installation improvements. Many of these projects involved significant infrastructure upgrades or coordinating with outside organizations to complete construction projects or source specialty components. In the course of these projects, ESTEP PIs have built a stronger network of contacts within and outside the DOD and have gotten better at navigating the procedural hurdles required to bring different groups together to complete large projects. The projects under ESTEP represent not only an investment in installation energy improvements, but also an investment in the skills and capabilities of the DON workforce.

Many ESTEP projects also improved the DOD workforce by working with the California State University San Marcos Veterans to Energy Careers program.³ This internship program recruited veterans pursuing STEM degrees and assigned them to work with PIs on ESTEP projects. The program also supported the students in other ways to aid in their transition to the workforce. As of July 2017, a total of 61 veteran student interns had participated in the program (reference Table 7; note that many of the 61 interns participated in multiple ESTEP projects). A third of student interns are still completing their degrees, and approximately 80% of those who have graduated went on to work within the DOD as either a civilian employee or contractor⁴. By partnering ESTEP projects with a successful internship program, the DON has been able to cultivate and retain the skills of our returning veterans.

By completing these ESTEP technology demonstration projects, DON S&T personnel have gained experience in navigating the process of transitioning a COTS

³ Veteranstoenergycareers.org

⁴ Intern employment numbers taken from ESTEP Workforce Development Fiscal Year 2018 proposal by Dr. Patricia Reily at California State University San Marcos

technology into a system that is actively in use at DON installations. In addition to the benefits of the technologies demonstrated, the ESTEP program has created value by providing a means for scientists and researchers to better understand the process through which future technologies will be integrated at DON installations. Even technologies that are shown not to be viable have contributed to the intellectual capital of the research communities and will help enable future technology integration efforts.

Table 7.	Number of interns by ESTEP project
----------	------------------------------------

Project No.	Projects	Intern Cour
1	Wind Powered Cooling with Thermal Storage	1
2	Uninterruptible, Renewable Augmented Building Power Circuits	N/A
3	Building Scale Compressed Air Energy System (CAES)	N/A
4	Self Contained Hydrogen to Electrical System	N/A
5	Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals	5
6	Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals	5
7	Real-Time Distribution Analysis for MCBP	N/A
8	Evaluation of Smart -Controllers for Distributed Energy Resources	4
9	Advance Power Electronics for PV Inverters	1
10	DC Micro-grid For Solid State Lighting	4
11	Networked Building Level Micro-grid	1
12	Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration	3
13	Energy Efficient Cloud Computing Evaluationand Demonstration	3
14	RFID Reading Outlets for Device-level Granularity in Building Energy Control	1
15	C-SEC On The Move	4
16	Data Center Smart Metering Evaluation (DC Smart-E)	3
10	Building Energy Management Automation	2
18	Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)	2
18	SCADA Deploy	1
20	Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)	1
20	Smart Plug Side Channel Analysis (SPAMSANDWICH)	N/A 4
21	ENSURE (Ensuring Reliability and Efficiency)	2
23	Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)	N/A
24	Passive and Active Cyber-Defense for Cyber-Physical Systems –Strategies, Implementation, and Evaluation	1
25	Deep Subgrid-parity Solar	6
26	Energy and Water Recovery by Microbial Fuel Cells	6
27	Energy Village: A Littoral Energy Test Facility	4
28	Ad-hoc Portable Power Systems (APPS)	N/A
29	Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study	2
30	Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage	1
31	Mobile EMS	N/A
32	Photovoltaic Power Conditioning System for an Energy Management System (EMS)	N/A
33	RTU Challenge	N/A
34	Improved Wind Load Design for Rooftop PV Systems	N/A
35	Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-Manage) Seed	N/A
36	Validate SIREN Computer Modeling	1
37	LIDAR Wind Measurement Experiments	2
38	Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind Turbine	N/A
39	Liquid Air Energy Storage (LAES)	3
40	Waste to Energy Hydrogen Generation	1
41	Adhered PV Reliability (Completed)	1
42	Optimized Cooling for Concentrated Photovoltaic Systems	N/A
43	Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion	N/A
44	Valuation and Financing for Energy Storage	N/A
45	Transportable Micro-grid with Storage	N/A
46	Modular Micro grid (M2G) System	1
47	Wind Effects on Sun Tracking PV Cell Solar Panels	3
48	Grid Stability in High Penetration Renewables	N/A
49	NanolubricantHVAC Refrigerant	N/A
50	Tunable White LED	N/A
51	Waste Heat Recovery From Gas Turbine Exhaust	N/A
52	Efficient Implementation of Solid State Transformers (SST)	N/A
53	HVAC Control by Means of Predicted Percentage of Dissatisfied Method	2
53	Develop Energy Use Trends with Innovative Visualization/Analysis	2
55	Green Data Center Software Product Evaluation	2 N/A

Key: N/A – not available

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VII. ADOPTION READINESS ADVANCES

As discussed in Chapter VI, few ESTEP projects will have a positive net financial benefit if evaluated in isolation. However, the demonstrations pave the way for future adoption that can produce significant net benefits in the future. For these reasons, the progress towards resolving challenges in adopting the technology in a DON context is an important indicator of ESTEP projects' effectiveness.

Even if a new technology is proven effective in a demonstration environment, there are still significant barriers to cross before the technology can be adopted more broadly. For this reason, the Adoption Readiness Level (ARL) scale, developed as part of ESTEP (Regnier et al., 2017) is used to assess this progress.

The ARL system is an assessment used for measuring a new technology's progress from a successful conceptual demonstration to a system or process that can be readily implemented outside of the original testing or demonstration environment. ARL is different from the more well-known Technology Readiness Level (TRL) system in that TRL focuses solely on the given technology or product as an independent entity, but ARL is more focused on the non-technological challenges that must be met to integrate a mature technology. For example, a TRL assessment might reflect the developmental progress or maturity of a new type of air conditioning system, but ARL would assess the readiness of things such as the availability of a supplier for components, training programs for service technicians, and contractual mechanisms for installations.

The three major focus areas of ARL are systems-level technological integration, alignment with organizational processes, and stakeholder alignment. Systems-level technological integration relates not just to the maturity of the studied technology but its readiness to be integrated in the intended technology system, including components, software or adaptations necessary to connect it to any related systems. Alignment with organizational processes includes attaining any necessary certifications, securing funding, and procuring equipment or service contracts. Stakeholder alignment means acceptance and/or support from all stakeholder groups necessary for successful adoption. Each focus

area of ARL is given a score from one to seven⁵ based on a technology's progression toward adoption. A given technology's overall ARL level is equal to the lowest of its scores across the three areas. Table 8 defines each ARL level, while Table 9 gives the approximate ARL levels of each of the ESTEP projects evaluated in this report at the time of the FY17 IPR as reported by the PIs of each project.

⁵ ESTEP project PIs used a seven step ARL ranking in their IPR report, where the official ARL rankings from Regnier et al is a six step scale. The ARL ranking system used by the ESTEP project PIs includes a separate ranking of "Locally Adopted" before a technology is considered "Fully Adoptable".

Table 8.ARL Definitions

ARL Level ⁱ		Component Technology TRL	Technology Integration	Stakeholders ⁱⁱ	Processes ⁱⁱⁱ
1	Solution Identified	5	Potential to satisfy an existing or anticipated need more effectively than alternatives.	N/A	N/A
2	Demonstration Project Formulated	5	Research plan developed, necessary facilities identified.	Stakeholders identified. Need verified. Objectives, metrics, and demonstration plan validated by stakeholders. Funding budgeted for demonstration phase.	Approvals required for demonstration identified.
3	Prototype Validation	6	Demonstrated at representative research site. Performance documented.	Prototype performance validated by stakeholders.	Approvals required for operational use identified and documented. Testing or modification requirements documented.
4	Representative Demonstration	7	Potential for broader application documented. O&S requirements and any training requirements for O&S documented.	Pilot performance demonstrated and validated by stakeholders. O&S funding levels and personnel requirements for sustainable support in operation estimated.	Process for obtaining necessary approvals for operational use has been documented.
5	Locally Adopted	7	In operational use at at least one installation, which could be the demonstration site.	O&S funding and personnel in place and stakeholders expect to continue funding.	All approvals received for local operational use.
6	Fully Adoptable	8	In sustained operational use at at least one installation for relevant period of time.	Validated and accepted by stakeholders, including budget for procurement and ongoing O&S.	All required technical approvals have been received. Any required updates to Unified Facilities Criteria or Guide Specifications have been made or in process of being updated.

ARL Level	Component Technology TRL	Technology Integration	Stakeholders	Processes
7 Adopted	8	In operational use at multiple installations.	Training and communication programs in place.	Technology installed and in operational use.

ⁱ Barriers in any one domain will be enough to prevent adoption of a technology. Therefore, the ARL definitions are non-compensatory: to achieve a given ARL level, a technology must satisfy the criteria in <u>all three</u> domains.

ⁱⁱ Stakeholders are individuals or entities that have an ongoing interest in the technology if adopted. Commonly overlooked stakeholders include maintenance technicians, trainers, safety managers (structural, fire protection) and information technology managers.

ⁱⁱⁱ The processes domain refers to the administrative process of obtaining the authorizations necessary to implement a project, including budgeting the project under the correct color of money, ensuring that funds will be available for operation and support (O&S), and any legal or regulatory requirements that need to be met in areas including safety, environmental, and information assurance (IA).

Ref #	Project Title	Tech	Process	Stakeholder	Over
1	Wind Powered Cooling with Thermal Storage	N/A	N/A	N/A	N//
2	Uninterruptible, Renewable Augmented Building Power Circuits	4	4	3	3
3	Building Scale Compressed Air Energy System (CAES)	4	3	4	3
4	Self Contained Hydrogen to Electrical System	N/A	N/A	N/A	N/.
5	Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals	4	5	4	4
	Seamless Integration of GIS and Electrical Architecture Models for				
6	Smart Grids and Net-Zero Energy Goals	4	5	4	4
7	Real-Time Distribution Analysis for MCBP	4	5	4	4
8	Evaluation of Smart -Controllers for Distributed Energy Resources	6	4	4	4
9	Advance Power Electronics for PV Inverters	N/A	N/A	N/A	N/
10	DC Micro-grid For Solid State Lighting	3	4	4	3
11	Networked Building Level Micro-grid	4	5	4	4
	Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development,				
12	and Demonstration	N/A	N/A	N/A	N//
13	Energy Efficient Cloud Computing Evaluationand Demonstration	6	6	6	6
10	RFID Reading Outlets for Device-level Granularity in Building Energy				
14	Control	7	7	7	7
15	C-SEC On The Move	4	3	3	3
		4 N/A	N/A	N/A	N//
16	Data Center Smart Metering Evaluation (DC Smart-E)				
17	Building Energy Management Automation	4	4	4	4
10	Resilient Critical Infrastructures through Secure and Efficient Micro				
18	Grids (ReClst)	5	4	3	3
19	SCADA Deploy	5	4	5	5
	Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and				
20	UHWO)	3	3	3	3
21	Smart Plug Side Channel Analysis (SPAMSANDWICH)	3	3	3	3
22	ENSURE (Ensuring Reliability and Efficiency)	4	5	5	5
	Hypercritical Operational Technology Mitigation of Embedded				
23	SploitSyndrome (HOTMESS)	3	2	2	2
	Passive and Active Cyber-Defense for Cyber-Physical Systems				
24	-Strategies, Implementation, and Evaluation	N/A	N/A	N/A	N/.
25	Deep Subgrid-parity Solar	N/A	N/A	N/A	N//
26	Energy and Water Recovery by Microbial Fuel Cells	3	3	3	3
27	Ad-hoc Portable Power Systems (APPS)	TRL9	TRL9	TRL9	TRI
28	Energy Village: A Littoral Energy Test Facility	TRL7	TRL7	TRL7	TRI
	Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility				
29	Study	3	2	1	1
	Optimization of a Decentralized Micro-grid with PEM Fuel Cell,				
30	Electrolyzer and H2 Storage	N/A	N/A	N/A	N/2
31	Mobile EMS	N/A	N/A	N/A	N/
-	Photovoltaic Power Conditioning System for an Energy Management	,		,	,
32	System (EMS)	3	2	2	2
33	RTU Challenge	6	6	6	6
34	Improved Wind Load Design for Rooftop PV Systems	N/A	N/A	N/A	N/
34	Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-	14/7	11//	14/7	14/7
35	Manage) Seed	N/A	N/A	N/A	N/2
36	Validate SIREN Computer Modeling	4	1 1	3	1
37	LIDAR Wind Measurement Experiments	4	1	3	1
37	Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind	4	1	5	1
20		2	2	_	
38	Turbine	3	3	3	3
39	Liquid Air Energy Storage (LAES)	4	3	2	2
40	Waste to Energy Hydrogen Generation	N/A	N/A	N/A	N/.
41	Adhered PV Reliability	5	5	5	5
42	Optimized Cooling for Concentrated Photovoltaic Systems	N/A	N/A	N/A	N//
	Shore Based Test of X-Band Radar Hardware on Mast for Real Time				
43	Hydrodynamic Control of Wave Energy Conversion	3	1	1	1
44	Valuation and Financing for Energy Storage	3	3	1	1
45	Transportable Micro-grid with Storage	6	6	6	6
46	Modular Micro grid (M2G) System	5	4	2	2
47	Wind Effects on Sun Tracking PV Cell Solar Panels	3	3	3	3
	Grid Stability in High Penetration Renewables	N/A	N/A	N/A	N/.
48	NanolubricantHVAC Refrigerant	6	5	6	5
48 49		6	7	6	6
	Tunable White LED	0			2
49		2	2	2	2
49 50	Waste Heat Recovery From Gas Turbine Exhaust		2	2	
49 50 51	Waste Heat Recovery From Gas Turbine Exhaust Efficient Implementation of Solid State Transformers (SST)	2			
49 50 51 52	Waste Heat Recovery From Gas Turbine Exhaust Efficient Implementation of Solid State Transformers (SST) HVAC Control by Means of Predicted Percentage of Dissatisfied	2 3	3	4	3
49 50 51	Waste Heat Recovery From Gas Turbine Exhaust Efficient Implementation of Solid State Transformers (SST)	2			3

Table 9.ARL Levels for each project

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VIII. ARL ROADBLOCKS AND RECOMMENDATIONS

Consistent with the goals of the program, most of the demonstrated ESTEP technologies progress from ARL 1-2 to ARL 3-5 and few achieve the level of fully adopted (ARL 6). During research for this report, it became apparent that there were a few particular challenges that PIs frequently faced in their technology demonstration efforts. These frequently occurring roadblocks are described in the following paragraphs, along with our recommendations to help future PIs to navigate these challenges in future projects.

Common roadblocks related to systems-level technological integration typically involved pushing the limits of commercial technology solutions or using a technology in ways outside of its intended purpose. For example, in the Virtual Smart Grid projects at Camp Pendleton, the researchers used a commercial software tool to model portions of the base's electrical grid. The size and complexity of their model revealed a number of previously undiscovered bugs in the modeling software, and the research team worked extensively with the software vendor's support team to patch the software as new bugs were discovered. In the supercapacitor-based microgrid project at the Naval Postgraduate School, the research team found that there were not any readily available solar charge controllers or power inverters designed to work with supercapacitors as the primary means of energy storage. The research team was able to make the supercapacitor bank work with charge controllers and inverters designed for use with conventional batteries, but the battery protection mechanisms built into these devices placed an artificial limit on the amount of energy storage available from the supercapacitors. In several projects using smart outlets or point-of-use energy monitors, researchers encountered difficulties related to data transfer protocols and lack of access to technical documents or hardware specifications on vendors' products. As in the other projects mentioned above, this required researchers to spend extra time and resources to make a mature commercial technology function in an unexpected context.

To push through challenges related to systems-level technological integration, we recommend future researchers work to improve communication with technology providers to anticipate potential issues and find workarounds as problems arise.

Roadblocks related to systems-level technological integration were often the result of using a mature commercial technology in a way that was slightly outside of the technology's intended scope, so discussing projects with potential technology suppliers could help determine which commercial products would be the best fit for particular applications. When unexpected challenges appear, technology suppliers may be able to help identify solutions because they have access to proprietary documentation and source code.

Common roadblocks related to organizational process alignment were typically a result of delays in the bureaucracy such as when working with contracting or when getting special permitting or approvals. These types of issues would typically arise when researchers were unfamiliar with the types of approvals required to conduct certain work or when working with contracting offices to license technology or hire workers. In several instances, researchers had originally planned to install new technologies or components themselves but later learned that institutional processes required that installations be performed by facilities managers or outside contractors, resulting in significant delays. In many cases, researchers had difficulty determining which office or organization was responsible for approving certain types of work. In many projects, researchers were also plagued by process challenges beyond their control such as funding arriving late or delays in transferring funds to contractors or vendors, delays in the procurement, contracting, or permitting processes, or temporary rules preventing them from or delaying hiring personnel to work on a project. The most common symptoms of process challenges were delays that forced projects to reduce the scope of their work or extend the work into the next fiscal year.

In many instances, researchers encountered difficulties working within established processes because of a lack of familiarity with those processes and uncertainty regarding which processes or policies applied to different types of work. Research teams who were more familiar with existing policies (and knew contacts who could help navigate these processes), were generally more successful in completing their projects on time, and within the full scope of the original project description. In the supercapacitor microgrid project for example, the researchers knew that the installation and approval process would be managed by their installation's Public Works department,

so the team made great efforts to keep public works involved or informed at every step of the system design and planning process. We believe future research teams can be more successful in avoiding unnecessary procedural delays by socializing their projects within their organization to gather input from individuals who might be more familiar with applicable process and approval requirements. These would include stakeholders such as Public Works, safety officers, contracting offices, or utility managers on bases.

Common roadblocks related to stakeholder alignment were typically associated with not carefully coordinating with groups who would be responsible for installing and maintaining equipment or ensuring compliance with applicable policies or regulations. These stakeholder engagement issues were especially persistent in projects related to cybersecurity or energy monitoring where research teams needed stakeholder buy-in to test emerging technologies on live power systems or networks. In many of these cases, the personnel who maintained or managed these systems were reluctant to allow researchers to connect new monitoring systems or probing technologies because they did not fully understand the potential risks and benefits of the technologies being researched. In other cases, research projects were held back due to unexpected challenges in coordinating with stakeholder groups who managed facilities, equipment, technologies, or utilities used in various research efforts. Like the challenges associated with processes, many of these stakeholder roadblocks resulted in delays as different groups struggled to coordinate schedules or establish that intended work was compliant with all applicable rules and requirements.

Like the process alignment challenges mentioned above, many stakeholder alignment issues could potentially be reduced, resolved, or prevented early on by socializing new or upcoming projects with potential stakeholder communities so that stakeholders can offer their input as early as possible. This would also provide researchers with realistic expectations for how quickly things move through the processes controlled by different organizations, allowing researchers to plan for these delays when defining a scope or timeline for their projects. This can help to set scheduling expectations for groups with limited manpower to assist projects and allow researchers to benefit from the institutional knowledge of stakeholders who are more familiar with the processes with their specific sub-organizations.

These organizational process and stakeholder roadblocks demonstrate why workforce development is so important to advancing the use of emerging energy technology in the DON. This reinforces the value of ESTEP program's emphasis on DON personnel serving in key roles. THIS PAGE INTENTIONALLY LEFT BLANK

IX. FINAL NOTES

The ESTEP program provides a significant benefit to the DON in future energy assurance. ESTEP is cultivating a knowledge base and workforce with the skills and experience to implement future energy technologies that improve the DON's capability to ensure the availability of critical energy resources. Although many of the ESTEP projects will not provide a significant operational or monetary benefit in the near term, the skills and experience gained in implementing new technologies will pay dividends as researchers determine which technologies merit further investment and overcome the challenges of implementing these technologies in a DON environment. THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A. DISTRIBUTION OF ESTEP PROJECTS BY BENEFIT SUB-CATEGORY

Figure A-1. Breakdown of ESTEP projects' contribution to introduce/integrate new energy generation





Figure A-2. Breakdown of ESTEP projects' contribution to introduce/integrate new energy storage



Figure A-3. Breakdown of ESTEP projects' contribution to reduce energy demand on bases



Figure A-4. Breakdown of ESTEP projects' contribution to reduced O&S requirements



Figure A-5. Breakdown of ESTEP projects' contribution to physical or cyber security, resiliency, redundancy



Figure A-6. Breakdown of ESTEP projects' contribution to improved modeling or decision support



Figure A-7. Breakdown of ESTEP projects' contribution to improved energy access in remote facilities

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APPENDIX B. PROJECT INFORMATION FORMS

B.1 Project Information Form for Project 1: Wind Powered Cooling with Thermal Storage

Wind Powered Cooling with Thermal Storage

Other Names	s, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Anthony Gannon	831-656-2880	ajgannon@nps.edu	PI	FY13 FY14
POC2					Base / Installation
POC3					NPS

Technology Description

Provide a brief description of the technology being implemented in this research project
Integrate systems composed of wind turbine, chiller units, and ice-based thermal storage units to reduce the cost of cooling data centers and facilities where
significant energy expenditures would go towards cooling

Select up to three different technology types to categorize this project

Technology Type 1	Energy Storage
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)

reduced cost of energy storage at facilities with large cooling demands

Fossil Fuel Consumption

List and desc	List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use			

Renewable Energy

List and desc	List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management			
Realized	Added renewable energy generation capability (wind, solar, etc)			
Realized	Improved efficiency or effectiveness of existing renewable generation			
Realized	Integrated or expanded renewable energy storage			
Realized	Realized Improved efficiency or effectiveness of existing renewable energy storage			

Power Consumption

List and deso	ribe any benefits this technology has or may have on installation power consumption
Demonstrate	Reduced installation power consumption through improved end-user efficiency
Demonstrate	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and desc	List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions					

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy

Infrastructure.						
Potential	Reduced contractor support required to install, maintain, or operate technology					
Demonstrate	Technology requires fewer or less costly replacement components that alternative systems					
Demonstrate	Technology is easier to operate than alternative systems					

Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

non disruptions, or non-disruption of critical systems				

Cyber Security

List and deso	List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure				

Costs

List and desc	List and describe any benefits this technology has or may have on installation energy costs that aren't described above					
Potential	Potential Reduced reliance on systems with expensive replacement parts					
Potential	Reduced wear and tear on mechanical systems					

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

what ways did these	e obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?	
/hat would you descr	ibe as the greatest benefit(s) of having completed this demonstration project?	
	y storage by storing energy in the form in which it will be used later	
/hat specific adaptati	ions (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
nce operationally ma	sture, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?	
	iture, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? / storage for cooling applications, limited/no capability to use stored energy in other ways	
educed cost of energy	y storage for cooling applications, limited/no capability to use stored energy in other ways	
educed cost of energy		
educed cost of energy	y storage for cooling applications, limited/no capability to use stored energy in other ways	
educed cost of energy	y storage for cooling applications, limited/no capability to use stored energy in other ways	
educed cost of energy	y storage for cooling applications, limited/no capability to use stored energy in other ways	
educed cost of energy	y storage for cooling applications, limited/no capability to use stored energy in other ways	
educed cost of energy Vhat advances or obs	y storage for cooling applications, limited/no capability to use stored energy in other ways	
educed cost of energy Vhat advances or obs	y storage for cooling applications, limited/no capability to use stored energy in other ways	
educed cost of energy Vhat advances or obs	y storage for cooling applications, limited/no capability to use stored energy in other ways	
educed cost of energy What advances or obs	y storage for cooling applications, limited/no capability to use stored energy in other ways	
educed cost of energy What advances or obs	y storage for cooling applications, limited/no capability to use stored energy in other ways	

Technology Adoption Considerations

Technology Integration	
Maturity of the technology family	
Maturity/suitability of specific	
systems used in this project	
Integration with Navy-specific	
systems	
Environmental or Installation-	
specific challenges	technology only applicable at facilities with significant cooling needs
Accessibility of required	
components	
Process Challenges	
Certification or Approval	
requirements	
Initial Funding or Resource	
Allocation issues	
Continued Funding or Resource	
Allocation issues	
Contracting / Procurement	
Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	coordination with public works required to install renewable energy sources and chillers
Limitations from stakeholder needs	
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	
Necessary Funding Streams:	
Continued Support	
Continued feedback and	
improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B.2 Project Information Form for Project 2: Uninterruptible, Renewable Augmented Building Power Circuits

Uninterruptible, Renewable Augmented Building Power Circuits

Other Names, Abriviations, etc:		Supercapacitor Based Microgrid for Renewable Augmented Circuits			
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Anthony Gannon	831-656-2880	ajgannon@nps.edu	PI	FY15 FY17
POC2	Andria Holmes			Co-PI	Base / Installation
POC3	Alexander Julian			Co-PI	NPS

Technology Description

Provide a brief description of the technology being implemented in this research project

Microgrid that uses supercapacitors instead of conventional battery storage to store energy from renewable sources, integrating renewable energy into backup systems

Select up to three different technology types to categorize this project				
Technology Type 1	Microgrids, Islanding, Isolation			
Technology Type 2	Energy Storage			
Technology Type 3	Implementation, Integration, Adaptation			

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from

demonstration) Microgrids using supercapacitors are able to avoid many of the difficulties associated with battery storage such as restrictions on the use of lithium batteries or battery capacity degradation

Fossil Fuel Consumption

List and desci	ribe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
Realized	Integrated alternative-powered backup power systems
Potential	Reduced frequency of backup generator use
Demonstrate	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management		
Realized	Integrated or expanded renewable energy storage	
Realized	Improved efficiency or effectiveness of existing renewable energy storage	
Potential	Improved capability to estimate ROI of renewable systems	
Demonstrate	Improved decision support capabilities for investing in renewable systems	

Power Consumption

List and desc	ribe any benefits this technology has or may have on installation power consumption
Demonstrate	Reduced installation power consumption through building control automation
Demonstrate	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions		

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy

Demonstrate Reduced contractor support required to install, maintain, or operate technology	
Realized Technology requires less maintenance labor than alternative systems	
Realized Technology requires fewer or less costly replacement components that alternative systems	
Realized Technology is easier to operate than alternative systems	
Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

nom alstapti	ons, or non-disruption of childen systems
Realized	Reduced reliance on outside energy suppliers
Realized	Increased energy storage capability for independent operation

Cyber Security

	List and descr	ribe any benefits this technology has or may have on the cyber security of installation energy infrastructure
1		

Costs

List and desc	ribe any benefits this technology has or may have on installation energy costs that aren't described above
Realized	Reduced reliance on systems with expensive replacement parts

Second Order Impacts

What additiona	al benefits, information, feedback, or control does this technology offer to the installation energy end user?
Potential II	mproved energy access in remote facilities
What addition	al benefits, information, feedback, or control does this technology offer to the installation energy manager?
What additiona	al benefits, information, feedback, or control does this technology offer to future R&D efforts?
Potential II	mproved access to energy use data

Other

•••••	

Learning process of discov	ering how to use super capacitors for building-scale energy storage while using components designed to work with battery systems
0.	
n what ways did these ob	tacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
equipment designed to wo	rk with batteries would not allow full discharge of capacitors, limiting effective energy storage
What would you describe	is the greatest benefit(s) of having completed this demonstration project?
Demonstrated feasibility o	f using supercapacitors in microgrids, enabling microgrid technologies to be implemented in environments that would preclude battery
based energy storage	
What specific adaptations	
	(if any) would be required to make the commercially available technology more suitable for Navy-specific use? power electronics designed to make full use of capacitors' stored energy
System would benefit from	power electronics designed to make full use of capacitors' stored energy
System would benefit from Once operationally mature	power electronics designed to make full use of capacitors' stored energy
System would benefit from Once operationally mature More expensive than batte	power electronics designed to make full use of capacitors' stored energy , what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be
System would benefit from Once operationally mature More expensive than batte	power electronics designed to make full use of capacitors' stored energy
System would benefit from Once operationally mature More expensive than batte	power electronics designed to make full use of capacitors' stored energy , what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be
System would benefit from Once operationally mature More expensive than batte	power electronics designed to make full use of capacitors' stored energy , what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be
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System would benefit from Once operationally mature More expensive than batte transported with zero char	power electronics designed to make full use of capacitors' stored energy , what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be
System would benefit from Once operationally mature Vore expensive than batter transported with zero chai What advances or observa	power electronics designed to make full use of capacitors' stored energy , what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be ge, which would enable construction of microgrids in austere environments
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System would benefit from Once operationally mature Vore expensive than batter transported with zero chai What advances or observa	power electronics designed to make full use of capacitors' stored energy , what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be ge, which would enable construction of microgrids in austere environments tions were made in this demonstration project that could help justify continued investment in this technology?
System would benefit from Once operationally mature Vore expensive than batter transported with zero chai What advances or observa	power electronics designed to make full use of capacitors' stored energy , what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be ge, which would enable construction of microgrids in austere environments tions were made in this demonstration project that could help justify continued investment in this technology?
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System would benefit from Drice operationally mature Vore expensive than batte ransported with zero cha what advances or observa Demonstrated feasibility of	power electronics designed to make full use of capacitors' stored energy , what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be ge, which would enable construction of microgrids in austere environments tions were made in this demonstration project that could help justify continued investment in this technology?
System would benefit from Once operationally mature More expensive than batte transported with zero cha What advances or observa Demonstrated feasibility of What new skills, competer	power electronics designed to make full use of capacitors' stored energy , what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be ge, which would enable construction of microgrids in austere environments tions were made in this demonstration project that could help justify continued investment in this technology? f large scale supercapacitor energy storage
System would benefit from Once operationally mature More expensive than batt transported with zero chai What advances or observa Demonstrated feasibility of What new skills, competer	power electronics designed to make full use of capacitors' stored energy , what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be ge, which would enable construction of microgrids in austere environments tions were made in this demonstration project that could help justify continued investment in this technology? f large scale supercapacitor energy storage cies, or experience were gained within the Navy workforce during this project?
System would benefit from Once operationally mature More expensive than batter rransported with zero chain What advances or observa Demonstrated feasibility of Mhat new skills, competer	what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? ry storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be ge, which would enable construction of microgrids in austere environments tions were made in this demonstration project that could help justify continued investment in this technology? f large scale supercapacitor energy storage cies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration	
Maturity of the technology family	Maturity of supercapacitor market would lower costs, enabling further implementation
Maturity/suitability of specific	
systems used in this project	Power electronics designed to work with batteries, so protective features limit energy storage potential
Integration with Navy-specific	
systems	
Environmental or Installation-	Supercapacitor energy density (KWH per unit volume) is less than that of batteries, which would limit their use in certain
specific challenges	applications
Accessibility of required	
components	Market for backup power systems using supercapacitors has not yet fully matured

Process Challenges	
Certification or Approval	
requirements	PW approval to integrate new power systems
Initial Funding or Resource	
Allocation issues	high upfront cost
Continued Funding or Resource	
Allocation issues	
Contracting / Procurement	Currently no commercial providers of supercapacitor-based microgrid systems

Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	
Limitations from stakeholder needs	Limited storage capacity may not meet demand
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	large upfront costs compared to comperable battery systems
Necessary Funding Streams:	
Continued Support	
Continued feedback and	
improvement	Control optimization needed to improve system utilization

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers	
Author(s)	Title
1	
Journal Articles, Publications	
Author(s)	Title
8	
NPS Student Theses	
Author(s)	Title (if known)
Gabriel Hernandez	

B.3 Project Information Form for Project 3: Building Scale Compressed Air Energy System (CAES)

Building Scale Compressed Air Energy System (CAES)

Other Name	s, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Anthony Gannon	831-656-2880	ajgannon@nps.edu	PI	FY16 FY17
POC2	Andrea Holmes				Base / Installation
POC3					

Technology Description

Provide a brief description of the technology being implemented in this research project

Construct a building-scale system using excess renewable generation to compress and store air for later energy generation

Select up to three different technology types to categorize this project

Technology Type 1	Energy Storage
Technology Type 2	Microgrids, Islanding, Isolation
Technology Type 3	Implementation, Integration, Adaptation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from

demonstration)
Provides robust and cost-effective energy storage without the use of chemical batteries or other components subject to degradation or special handling concerns

Fossil Fuel Consumption

List and desc	List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use	
Potential	itegrated alternative-powered backup power systems	
Potential	educed frequency of backup generator use	
Potential	Reduced requirement for backup generators to assure power	

Renewable Energy

List and desc	List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management	
Demonstrate	Demonstrate integrated or expanded renewable energy storage	
Demonstrate	Improved efficiency or effectiveness of existing renewable energy storage	

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption	
Potential	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and desc	List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions	

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure

Demonstrat	Demonstrate Technology requires fewer or less costly replacement components that alternative systems	
Demonstrat	trate Technology is easier to operate than alternative systems	

Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

tom disruption of enteel systems		
Potential	Automated backup systems for critical systems	
Potential	Reduced reliance on outside energy suppliers	
Demonstrate	Increased energy storage capability for independent operation	

Cyber Security

List and desc	List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure		

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above		
Potential	Reduced reliance on systems with expensive replacement parts	

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?
Potential Improved energy access in remote facilities
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?
Potential Improved control capabilities for future experiments

Other

Compressed air can be used in systems such as wind tunnels or pneumatic tools

more detailed design that	ed air generators commercially available, required integrating technology from different industries. Small scale generator design require
	n anticipated
n what ways did these o	bstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
	ning generator and acquiring components
ingerig process or design	wig Benerator and actioning combonents
what would you describe	e as the greatest benefit(s) of having completed this demonstration project?
What specific adaptation	is (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
S	
Once operationally matu	re, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
Once operationally matu	re, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
Once operationally matu	re, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
Once operationally matu	re, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
Once operationally matu	re, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
Once operationally matu	ire, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
	re, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What advances or observ	
What advances or observ	vations were made in this demonstration project that could help justify continued investment in this technology?
What advances or observ	vations were made in this demonstration project that could help justify continued investment in this technology?
What advances or observ	vations were made in this demonstration project that could help justify continued investment in this technology?

Technology Adoption Considerations

Technology Integration		
Maturity of the technology family	No small-scale compressed air generators commercially available	
Maturity/suitability of specific		
systems used in this project	generator design optimization still a work in progress	
Integration with Navy-specific		
systems		
Environmental or Installation-		
specific challenges		
Accessibility of required		
components	System requires integrating components from different industries in a novel configuration	

Process Challenges	
Certification or Approval	
requirements	Approval required for installation of components and integration with building wiring
Initial Funding or Resource	
Allocation issues	
Continued Funding or Resource	
Allocation issues	
Contracting / Procurement	System will require contracting/procurement process to source components

Stakeholder Challenges

Stakenoluer challenges	
Impact on and Approval of certain	
stakeholders	Approval required to install CAES system
Limitations from stakeholder needs	
Operation and support labor	
requirements	Operation and maintenance considerations
Necessary Funding Streams:	
Integration	Integration with other renewable systems may require specialized training
Necessary Funding Streams:	
Continued Support	
Continued feedback and	
improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers			
Tech papers Author(s)	Title		
Lournal Anticles Dublic			

Journal Articles, Publications Author(s) Title

NPS Student Theses

Author(s)	Title (if known)
LT Thomas Prinsen	Renewable Powered Compressor System Design
LT Cory McLaughlin	Small Scale Air Driven Demonstation Generator
LT Joshua Williams	Control System Design for Renewable Powered Compression System
LT Todd Vranas	Small Scale Air Driven Generator Control System
LT Nathaniel Pelletier	Ejector Based Small-Scale Air Generator
Michael Souza	Generator Demonstration Unit Design and Build

B.4 Project Information Form for Project 4: Self Contained Hydrogen to Electrical System

HYDROGEN IN AMBIENT AIR AS A RENEWABLE ENERGY SOURCE

Other Name	s, Abriviations, etc:	Self Contained Hydrog	en to Electrical System		
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Garth Hobson	831-656-2165	gvhobson@nps.edu	PI	FY17 FY18
POC2	Andrea Holmes			Co-PI	Base / Installation
POC3					NPS

Technology Description

Browido a brief description	of the technology being implemented in this	recoarch project	
Provide a brief description	of the technology being implemented in this		
Small scale bydrogen colleg	tion from water in ambient air to nower fuel of	ells and provide potable water	
Small scale hydrogen collection from water in ambient air to power fuel cells and provide potable water			
Select up to three differen	t technology types to categorize this project		
Technology Type 1	Renewable Generation		
Technology Type 2	Energy Storage		
Technology Type 3			

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from

demonstration)
enable energy storage from renewable systems in the form of hydrogen fuel cells or stored hydrogen gas for use in other applications

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use	
Potential	Improved efficiency or alternative fueled vehicles on installation

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management		
Demonstrate	Integrated or expanded renewable energy storage	
Potential	Improved efficiency or effectiveness of existing renewable energy storage	

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption		
Potential	Incorporated energy storage to reduce peak power demand	

Power Modeling & Management

List and descr	List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions	

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency
List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery
from disruptions, or non-disruption of critical systems

110111 ulsi upti	off distriptions, of non-distription of critical systems		
Potential	Reduced reliance on outside energy suppliers		
Potential	Increased energy storage capability for independent operation		

Cyber Security

List and d	escribe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and desc	ribe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?
Potential Improved energy access in remote facilities
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

H2 pressure in fuel cell, scalability challenges, consistency of H2 flow, storage, and compression In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? System required continous reconfiguration to address emergent issues What would you describe as the greatest benefit(s) of having completed this demonstration project? Mature system would enable remote facil What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
/stem required continous reconfiguration to address emergent issues //hat would you describe as the greatest benefit(s) of having completed this demonstration project? Iature system would enable remote facil	
ystem required continous reconfiguration to address emergent issues vhat would you describe as the greatest benefit(s) of having completed this demonstration project? Mature system would enable remote facil	
ystem required continous reconfiguration to address emergent issues vhat would you describe as the greatest benefit(s) of having completed this demonstration project? Mature system would enable remote facil	
ystem required continous reconfiguration to address emergent issues Vhat would you describe as the greatest benefit(s) of having completed this demonstration project? Nature system would enable remote facil	
wystem required continous reconfiguration to address emergent issues What would you describe as the greatest benefit(s) of having completed this demonstration project? Wature system would enable remote facil	
System required continous reconfiguration to address emergent issues	
Vhat would you describe as the greatest benefit(s) of having completed this demonstration project? Alature system would enable remote facil	
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Vature system would enable remote facil	
Vlature system would enable remote facil	
Mature system would enable remote facil	
Vlature system would enable remote facil	_
/lature system would enable remote facil	
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
leed capability to assess suitability of system in different environments	
tee capability to assess suitability of system in unreferic environments	
Ince operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?	
mproved energy storage capability and potential to generate potable water in austere environments	

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
Progress to TRL 7
What new skills, competencies, or experience were gained within the Navy workforce during this project?
Familiarity with H2 systems and integrating solar energy in small-scale applications

Technology Adoption Considerations

Technology Integration	
Maturity of the technology family	Technology remains to be proven functional on a large enough scale to be particularly useful
Maturity/suitability of specific	
systems used in this project	system custom made from mature components, but not yet optimized as a system
Integration with Navy-specific	
systems	need to comply with compressed gas storage regs
Environmental or Installation-	
specific challenges	System would be less effective in arid environments
Accessibility of required	
components	system is custom-built from COTS components

Process Challenges	
Certification or Approval	
requirements	approval for compressed H2 storage and solar integration
Initial Funding or Resource	
Allocation issues	acquisition costs and installation costs for energy source
Continued Funding or Resource	
Allocation issues	periodic maintenance
Contracting / Procurement	

Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	possible noise considerations
Limitations from stakeholder needs	
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	component installation
Necessary Funding Streams:	
Continued Support	
Continued feedback and	
improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers		
Tech papers Author(s)	Title	

Journal Articles, Publications

Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)
LCDR Ed Fosson	
LT San Yu	

B.5 Project Information Form for Project 5: Virtual Smart Grids for Achieving Models for Smart Grids and Net-Zero Energy Goals

Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals

Other Name	s, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Eric Evans	619-553-2808	eric.evans@navy.mil	PI	FY15 FY17
POC2	Ron Gauthier	619-553-1597			Base / Installation
POC3					МСВР

Technology Description

Provide a brief description of the technology being implemented in this research project

Develop a virtual smart grid to manage and achieve net-zero energy goals at the regional scale Demonstrate the system in collaboration with Marine Corps Installation West (MCI West) capability as a smart customer in achieving energy independence and net-zero compliance

	Select up to three different technology types to categorize this project					
F	Technology Type 1	Modeling.	Optimization.	Decision	Suppo	

rechnology rype I
Technology Type 2
Technology Type 3

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)

Improved capability to model and plan power grid expansions and improve	distribution efficiency
---	-------------------------

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use		
Improved decision support capability for sizing backup generators		

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management		
Potential	Improved efficiency or effectiveness of existing renewable generation	
Potential	Improved efficiency or effectiveness of existing renewable energy storage	
Potential	Improved capability to estimate ROI of renewable systems	
Potential	Improved decision support capabilities for investing in renewable systems	

Power Consumption

List and desc	List and describe any benefits this technology has or may have on installation power consumption		
Realized	Reduced installation power consumption through improved distribution efficiency		

Power Modeling & Management

List and desc	List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions		
Potential	Power modeling used to optimize grid configuration or expansion		
Demonstrate	Improved metering and monitoring of installation energy use		
Demonstrate	Improved diagnostic capabilities for energy infrastructure components		
Realized	Modeling and simulation to inform energy infrastructure investments		

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency
List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery
from disruptions, or non-disruption of critical systems

nomusiupu	from disruptions, or non-disruption of critical systems		
Potential	Improved fault isolation to prevent cascading blackouts		
Potential	Improved islanding capability to isolate and protect critical systems		

Cyber Security

List and desci	List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure		
Potential	Improved monitoring and detection of potential cyber threats		
Potential	Improved capability to isolate potential vectors for cyber attacks		

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above		
Demonstrate	Increased ability to diagnose need for preventative maintenance	
Realized	Improved decision support tools to inform future investments or funding requirements	

Second Order Impacts

What additi	onal benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additi	onal benefits, information, feedback, or control does this technology offer to the installation energy manager?
Realized	Improved documentation of infrastructure
Potential	Real-time monitoring of energy systems
What additi	onal benefits, information, feedback, or control does this technology offer to future R&D efforts?
Demonstrat	e Improved access to energy use data
Potential	Improved control capabilities for future experiments

Other

TAD former and the fully a	nt obstacles encountered in this technology demonstration project?
TAP Software not yet fully fr	ature for applications of this scale, original power grid documentation did not match actual systems
In what ways did these obsta	les hinder the implementation, operation, or effectiveness of the demonstrated technology?
research team worked with s	oftware developers to identify bugs within ETAP, research team had to devote extra time to updating or correcting grid
documentation	, , , , , , , , , , , , , , , , , , , ,
abcamentation	
What would you describe as t	he greatest benefit(s) of having completed this demonstration project?
Improved documentation of	rid infrastructure and identifying areas for improvement in documentation practices
What specific adaptations (if	any) would be required to make the commercially available technology more suitable for Navy-specific use?
<u> </u>	
grid modeling software needs	to become fully mature
grid modeling software needs	
grid modeling software needs	to become fully mature
grid modeling software needs	to become fully mature hat benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
grid modeling software needs	to become fully mature hat benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

 What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

 identified key shortcomings in documentation practices and discovered (and corrected) inefficiencies in power distribution network that provide cost savings greater than the cost of VSG modeling costs

 What new skills, competencies, or experience were gained within the Navy workforce during this project?

 Hired ESTEP intern Alan Williams to continue work at MCBP

Technology Adoption Considerations

Technology Integration			
Maturity of the technology family	Grid modeling software is not fully mature		
Maturity/suitability of specific			
systems used in this project	ETAP software is not fully mature		
Integration with Navy-specific			
systems	Specific navy-specific systems may require coordination with software developers to model accurately		
Environmental or Installation-			
specific challenges	Each naval installation will require a custom model		
Accessibility of required			
components	limited number of software vendors		

Process Challenges		
Certification or Approval		
requirements	software licensing and support agreements	
Initial Funding or Resource		
Allocation issues	funding for software and labor to construct installation model	
Continued Funding or Resource		

initial runuing of Resource	
Allocation issues	funding for software and labor to construct installation model
Continued Funding or Resource	
Allocation issues	funding required labor to keep model up to date
Contracting / Procurement	software continued support contract
Stakeholder Challenges	

Stakenoluer challenges	
Impact on and Approval of certain	Requires coordination with maintenance and public works to construct software models accurate to actual power
stakeholders	infrastructure
Limitations from stakeholder needs	
Operation and support labor	Labor needed to keep model up to date, requires coordination between modelers and facilities personnel conducting
requirements	maintenance
Necessary Funding Streams:	
Integration	funding for labor
Necessary Funding Streams:	
Continued Support	funding for labor
Continued feedback and	
improvement	feedback process needed to ensure model reflects changes and behavior of grid

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Alan Williams		

References

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B.6 Project Information Form for Project 6: Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals

Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals

Other Names	s, Abriviations, etc:	ETAP Virtual Smart Grid	Real-Time Power Monitoring in	a Geospatial I	Environment
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Eric Evans	619-553-2808	eric.evans@navy.mil	PI	
POC2	Alan Williams				Base / Installation
POC3					MCBP Camp Pendleton

Technology Description

Provide a brief description of the technology being implemented in this research project				
Provide a brief description	of the technology being implemented in this research	Toject		
Integrate geospacial data a	nd real-time monitoring into virtual smart grid system			
integrate geospacial data a				
Select up to three different	t technology types to categorize this project			
Technology Type 1	Management, Monitoring			
Technology Type 2	Modeling, Optimization, Decision Support			
Technology Type 3	Cyber & Physical Security			

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)

Improved documentation of base power architecture and ability to identify or diagnose issues in real-time

Fossil Fuel Consumptio	n
------------------------	---

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use		
Potential	Improved decision support capability for sizing backup generators	
Potential	Reduced requirement for backup generators to assure power	

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management		
Potential	Improved capability to integrate renewables into larger grid	
Potential	Improved capability to estimate ROI of renewable systems	
Demonstrate	Improved decision support capabilities for investing in renewable systems	
Demonstrate	Improved efficiency or effectiveness of existing renewable energy storage	

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption		
Demonstrate Reduced installation power consumption through improved distribution efficiency		
Potential	Reduced installation power consumption through improved end-user efficiency	
Potential	Reduced installation power consumption through building control automation	

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions		
Potential	Power modeling used to optimize grid configuration or expansion	
Demonstrate	Improved metering and monitoring of installation energy use	
Potential	Improved diagnostic capabilities for energy infrastructure components	
Demonstrate	Modeling and simulation to inform energy infrastructure investments	

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure

minuberactar		
Realized	Reduced contractor support required to install, maintain, or operate technology	
Potential	Technology is easier to operate than alternative systems	

Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems Improved fault isolation to prevent cascading blackouts

Potential	Automated backup systems for critical systems
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure		
Potential	Improved monitoring and detection of potential cyber threats	
Potential	Improved capability to isolate potential vectors for cyber attacks	
Potential	Improved capability to restore operation after successful cyber attacks	

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Increased ability to diagnose need for preventative maintenance
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What addit	ional benefits, information, feedback, or control does this technology offer to the installation energy end user?		
What addit	ional benefits, information, feedback, or control does this technology offer to the installation energy manager?		
Realized	Real-time monitoring of energy systems		
Realized	Improved documentation of infrastructure		
What addit	What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?		

Other

Difficulty translating existing grid doe	cumentation into computer model due to inaccuracies or inconsistencies in original documents; power modeling and
nonitoring software still in its infand	cy; existing architecture was not able to transmit live usage data
n what ways did these obstacles hin	ider the implementation, operation, or effectiveness of the demonstrated technology?
Is had to survey existing power arcl	hitecture to verify or correct records before entering into software model; PIs had to work with software developers to
roubleshoot issues from immature :	software; models used recorded logs instead of real-time data
	atest benefit(s) of having completed this demonstration project?
What would you describe as the grea	
What would you describe as the great mproved documentation of power ;	atest benefit(s) of having completed this demonstration project? grid and related utilities will make future repairs or upgrades easier. Monitoring capabilities allow energy managers to identify provements to reduce maintenance or ownership costs.
What would you describe as the great mproved documentation of power ;	grid and related utilities will make future repairs or upgrades easier. Monitoring capabilities allow energy managers to identify
What would you describe as the great mproved documentation of power ;	grid and related utilities will make future repairs or upgrades easier. Monitoring capabilities allow energy managers to identify
What would you describe as the great mproved documentation of power ;	grid and related utilities will make future repairs or upgrades easier. Monitoring capabilities allow energy managers to identify
What would you describe as the great mproved documentation of power potential problems and efficiency im	grid and related utilities will make future repairs or upgrades easier. Monitoring capabilities allow energy managers to identify provements to reduce maintenance or ownership costs.
What would you describe as the great mproved documentation of power potential problems and efficiency in What specific adaptations (if any) wo	grid and related utilities will make future repairs or upgrades easier. Monitoring capabilities allow energy managers to identify a provements to reduce maintenance or ownership costs. Ould be required to make the commercially available technology more suitable for Navy-specific use?
What would you describe as the great mproved documentation of power wotential problems and efficiency in What specific adaptations (if any) wo	grid and related utilities will make future repairs or upgrades easier. Monitoring capabilities allow energy managers to identify provements to reduce maintenance or ownership costs.

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
electronic utility monitoring and documentation would improve energy and facility managers' abilities to address maintenance issues, improve efficiencies, and
identify potential vulnerabilities
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
Current infrastructure documentation methods were shown to be woefully unreliable, and real-time monitoring reveild possible corrections that would drastically
reduce facility operating costs
What new skills, competencies, or experience were gained within the Navy workforce during this project?
ESTEP researchers gained skills and experience relating to documenting power infrastructure, developing software models, and improving grid efficiency

Technology Adoption Considerations

Technology Integration		
Maturity of the technology family	Few software vendors available with products that are not yet fully mature or suitable to the DOD's needs	
Maturity/suitability of specific		
systems used in this project	Few software vendors available with products that are not yet fully mature or suitable to the DOD's needs	
Integration with Navy-specific		
systems	Special agreements needed to sustain software support with vendor and interact with utility provider	
Environmental or Installation-		
specific challenges	Certain facilities may have limitations on sensitivity of energy usage data or ability to transmit data	
Accessibility of required		
components	Software is available, but would require a continued support arrangement	

Process Challenges	
Certification or Approval	
requirements	Various cyber requirements for transmitting energy usage data
Initial Funding or Resource	
Allocation issues	Large initial manpower investment required to build database/model
Continued Funding or Resource	
Allocation issues	Continual effort needed to update and ensure accuracy of database/model
Contracting / Procurement	Contracts will be required to ensure a sustained support arrangement with software provider

Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	Requires buy-in and cooperation of facilities and PW personnel to gather documentation and build power system models
Limitations from stakeholder needs	certain energy usage data may be considered sensitve, utility providers may place certain limitations
Operation and support labor	
requirements	labor required to maintain database/model
Necessary Funding Streams:	
Integration	large initial cost to develop database/model
Necessary Funding Streams:	
Continued Support	upkeep required
Continued feedback and	
improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Alex Arguelles		
Andrew Grewe		
Ammar Ameen		
Bashar Ameen		
Ankit Panchal		

References

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B.7 Project Information Form for Project 7: Real-Time Distribution Analysis for MCBP

Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals



Technology Description

	of the technology being implemented in this research pro	
ntegrate geospacial data ar	d real-time monitoring into virtual smart grid system	
	· · · · ·	
Select up to three different	technology types to categorize this project	
Select up to three different	technology types to categorize this project Management, Monitoring	
· · · · · · · · · · · · · · · · · · ·		

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)

ar architecture and ability to identify or diagnose issues in

1033ii 1 uci	Consumption
List and de	scribe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
Potential	Improved decision support capability for sizing backup generators
Potential	Reduced requirement for backup generators to assure power
Renewable	
	Energy scribe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management
List and de	scribe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management
List and de Potential Potential	scribe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management Improved capability to integrate renewables into larger grid

List and desc	List and describe any benefits this technology has or may have on installation power consumption		
Demonstrate	Reduced installation power consumption through improved distribution efficiency		
Potential	Reduced installation power consumption through improved end-user efficiency		
Potential	Reduced installation power consumption through building control automation		

Power Modeling & Management

Potential Power modeling used to optimize grid configuration or expansion Demonstrate Improved metering and monitoring of installation energy use Potential Improved diagnostic capabilities for energy infrastructure components Demonstrate Modeling and simulation to inform energy infrastructure investments	List and descr	ribe any benefits this technology has or may have on installation power modeling, management, or investment decisions
Potential Improved diagnostic capabilities for energy infrastructure components	Potential	Power modeling used to optimize grid configuration or expansion
	Demonstrate	Improved metering and monitoring of installation energy use
Demonstrate Modeling and simulation to inform energy infrastructure investments	Potential	Improved diagnostic capabilities for energy infrastructure components
	Demonstrate	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Realized	Reduced contractor support required to install, maintain, or operate technology
Potential	Technology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Automated backup systems for critical systems
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and desci	List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure		
Potential	Improved monitoring and detection of potential cyber threats		
Potential	Improved capability to isolate potential vectors for cyber attacks		
Potential	Improved capability to restore operation after successful cyber attacks		

Costs

List and des	cribe any benefits this technology has or may have on installation energy costs that aren't described above
Potential	Increased ability to diagnose need for preventative maintenance
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?		
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?		
Realized	Real-time monitoring of energy systems	
Realized	Improved documentation of infrastructure	
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?		

Other

Other	

What were the most significant obstacles encountered in this technology demonstration project?
Difficulty translating existing grid documentation into computer model due to inaccuracies or inconsistencies in original documents; power modeling and
monitoring software still in its infancy; existing architecture was not able to transmit live usage data
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
PIs had to survey existing power architecture to verify or correct records before entering into software model; PIs had to work with software developers to
To black out to be a set of the s
tioualeshoot issues norminimitature software, models used recorded logs instead of real-time data
What would you describe as the greatest benefit(s) of having completed this demonstration project?
what would you besche as the greatest deneracy or maying compreted this deniratation projects: Improved documentation of power grid and related utilities will make future repairs or upgrades easier. Monitoring capabilities allow energy managers to identify
potential problems and efficiency improvements to reduce maintenance or ownership costs.
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Software needs to fully mature in order to be implemented on additional installations. A specific contract mechanism would be required to ensure a sustainable
and suitable arrangement between naval facilities and software providers to ensure support
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
electronic utility monitoring and documentation would improve energy and facility managers' abilities to address maintenance issues, improve efficiencies, and
identify potential vulnerabilities
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
Current infrastructure documentation methods were shown to be woefully unreliable, and real-time monitoring reveild possible corrections that would drastically
reduce facility operating costs
What new skills, competencies, or experience were gained within the Navy workforce during this project?
ESTEP researchers gained skills and experience relating to documenting power infrastructure, developing software models, and improving grid efficiency
and the second

Technology Adoption Considerations

Technology Integration		
Maturity of the technology family	Few software vendors available with products that are not yet fully mature or suitable to the DOD's needs	
Maturity/suitability of specific		
systems used in this project	Few software vendors available with products that are not yet fully mature or suitable to the DOD's needs	
Integration with Navy-specific		
systems	Special agreements needed to sustain software support with vendor and interact with utility provider	
Environmental or Installation-		
specific challenges	Certain facilities may have limitations on sensitivity of energy usage data or ability to transmit data	
Accessibility of required		
components	Software is available, but would require a continued support arrangement	

Process Challenges		
Certification or Approval		
requirements	Various cyber requirements for transmitting energy usage data	
Initial Funding or Resource		
Allocation issues	Large initial manpower investment required to build database/model	
Continued Funding or Resource		
Allocation issues	Continual effort needed to update and ensure accuracy of database/model	
Contracting / Procurement	Contracts will be required to ensure a sustained support arrangement with software provider	

Stakeholder Challenges		
Impact on and Approval of certain		
stakeholders	Requires buy-in and cooperation of facilities and PW personnel to gather documentation and build power system models	
Limitations from stakeholder needs	certain energy usage data may be considered sensitve, utility providers may place certain limitations	
Operation and support labor		
requirements	labor required to maintain database/model	
Necessary Funding Streams:		
Integration	large initial cost to develop database/model	
Necessary Funding Streams:		
Continued Support	upkeep required	
Continued feedback and		
improvement		

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Alex Arguelles		
Andrew Grewe		
Ammar Ameen		
Bashar Ameen		
Ankit Panchal		

References

Tech papers		
Author(s)	Title	
Journal Articles, Publications		
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B.8 Project Information Form for Project 8: Evaluation of Smart-Controllers for Distributed Energy Resources

Evaluation of Smart-Controllers for Distributed Energy Resources



Technology Description

Provide a brief description of the technology being implemented in this research project

Create a virtual microgrid for evaluating advanced management and control architectures

Select up to three different technology types to categorize this project		
Technology Type 1	Modeling & Optimization	
Technology Type 2	Microgrids, Islanding, Isolation	
Technology Type 3	Decision Support	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)

Assessment of different micro-grid smart controller capabilities for future micro-grid applications in order to determine which control architectures are bestsuited for different applications. This project will produce a standardized and unbiased assessment of the capabilities offered by the different platforms.

Fossil Fuel Consumption

	List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use		
Potential Improved decision support capability for sizing backup generators		Improved decision support capability for sizing backup generators	

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management		
Potential	Initial Improved efficiency or effectiveness of existing renewable generation	
Potential	Improved efficiency or effectiveness of existing renewable energy storage	
Potential	Improved capability to integrate renewables into larger grid	
Potential	Improved decision support capabilities for investing in renewable systems	

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption	

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions		
Potential	ptential Power modeling used to optimize grid configuration or expansion	
Potential	Modeling and simulation to inform energy infrastructure investments	

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure				

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above				
Potential	Intial Improved decision support tools to inform future investments or funding requirements			

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?			
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?			
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?			

Other

one			

What were the most significant obstacles encountered in this technology demonstration project?
Delays in purchasing and software licensing processes
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
delays
What would you describe as the greatest benefit(s) of having completed this demonstration project?
standardized unbiased assessment of different microgrid control capabilities
standardized diblased assessment of dimerent microgrid control capabilities
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Cyber security adaptations?
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
What new skills, competencies, or experience were gained within the Navy workforce during this project?
matter and some competences, or experience were gamed within the nary workforce during this projecti

Technology Adoption Considerations

Technology Integration			
	Technologies are somewhat mature, but not yet widespread enough for a standard comparison or ranking system to show		
Maturity of the technology family	which products are best for a given application		
Maturity/suitability of specific			
systems used in this project			
Integration with Navy-specific			
systems			
Environmental or Installation-			
specific challenges			
Accessibility of required			
components			

Process Challenges			
Certification or Approval			
requirements	Need to establish official standards/feature requirements for selecting a specific micro-grid control system		
Initial Funding or Resource			
Allocation issues			
Continued Funding or Resource			
Allocation issues	Software will require continued operational support and possible tech support contracts		
Contracting / Procurement	Purchasing and software licensing processes		

Stakeholder Challenges

Impact on and Approval of certain				
stakeholders	software and hardware must meet installation energy manager needs			
Limitations from stakeholder needs				
Operation and support labor				
requirements	microgrid hardware/software maintenance and updates			
Necessary Funding Streams:				
Integration				
Necessary Funding Streams:				
Continued Support				
Continued feedback and				
improvement				

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Andrew Grewe		
Amar Ameen		
Bashar Ameen		
Trever Calton		

References

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
-	·
NPS Student Theses	
Author(s)	Title (if known)

B.9 Project Information Form for Project 9: Advance Power Electronics for PV Inverters

Advance Power Electronics for PV Inverters

Other Names, Abriviations, etc:					
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Ken Ho	805-982-1636	ken.ho@navy.mil	PI	FY13 FY15
POC2	Todd Weatherford	831-656-3044	tweatherford@nps.mil	Co-PI	Base / Installation
POC3					NBVC

Technology Description

Provide a brief description of the technology being implemented in this research project

The project will evaluate IPC's PV inverters, which incorporates newer electronic components and a novel topology. The Universal Power Converter[™] Platform will be studied and criteria for a "Universal Converter" for renewable energy generation will be developed.

Select up to three different technology types to categorize this project			
Technology Type 1	Energy Production		
Technology Type 2			
Technology Type 3			

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from

istration)		
Lower cost and improved reliability of new PV installations		

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

otentiai	Integrated alternative-powered backup power systems
otential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management		
Potential Added renewable energy generation capability (wind, solar, etc)		
Demonstrate Improved efficiency or effectiveness of existing renewable generation		
Potential Improved capability to integrate renewables into larger grid		
Potential	Improved capability to estimate ROI of renewable systems	

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Demonstrate	Reduced contractor support required to install, maintain, or operate technology

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

monn ape			
Potential	Reduced reliance on outside energy suppliers		

Cyber Security

cyber Security		
List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure		

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above		
Potential	Reduced reliance on systems with expensive replacement parts	
Potential	Improved decision support tools to inform future investments or funding requirements	

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?		
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?		
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?		
Potential Improved control capabilities for future experiments		

Other



What advances or observations were made in this demonstration project that could help justify continued investment in this technology?		
What new skills, competencies, or experience were gained within the Navy workforce during this project?		

Technology Adoption Considerations

Maturity of the technology family	novel inverter topology requires further testing and vetting
Maturity/suitability of specific	
systems used in this project	novel inverter topology requires further testing and vetting
Integration with Navy-specific	
systems	
Environmental or Installation-	
specific challenges	integration may be limited by existing electrical infrastructure at some facilities
Accessibility of required	
components	

Process Challenges	
Certification or Approval	
requirements	
Initial Funding or Resource	
Allocation issues	
Continued Funding or Resource	
Allocation issues	
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain	
stakeholders	Need maintenance, facilities, and Public Works buy-in
Limitations from stakeholder needs	
Operation and support labor	
requirements	long term support labor tbd
Necessary Funding Streams:	
Integration	
Necessary Funding Streams:	
Continued Support	
Continued feedback and	
improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Darren Parsons		

References

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B.10 Project Information Form for Project 10: DC Micro-grid For Solid State Lighting

DC Micro-grid For Solid State Lighting

Other Names,	Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Ken Ho	(805) 982-1636	ken.ho@navy.mil	PI	FY15 FY17
POC2	Ming Liu				Base / Installation
POC3	Bruce Garrett		bruce.garrett@navy.mil		Port Hueneme

Technology Description

Provide a brief description of the technology being implemented in this research project
Develop a low cost building level microgrid integrating new multi-port PV inverters from prior ESTEP project (Advance Power Electronics for PV Inverters) and
storage from prior NSETTI project (Containerized Micro-grid Battery Storage). Install a DC Micro-grid with 380VDC bus, 15kW PV, 25kWh Li-ion battery, that is gridtied and islandable. Use microgrid to power LED lighting throughout building using low cost COTS products under MILCON threshold.

Select up to three different technology types to categorize this project

Technology Type 1	Microgrids, Islanding, Isolation		
Technology Type 2	Energy Storage		
Technology Type 3	Implementation, Integration, Adaptation		

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration) Will enable cost-effective integration of microgird (including renewable generation and energy storage) into existing buildings and power infrastructure. Low cost components and navigating Li-lon battery approval process will make it easier for installations to acquire these systems.

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use			
Potential	Integrated alternative-powered backup power systems		
Potential	Reduced frequency of backup generator use		
Potential	Reduced requirement for backup generators to assure power		

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management			
Realized	Added renewable energy generation capability (wind, solar, etc)		
Realized	Integrated or expanded renewable energy storage		
Potential	Improved capability to integrate renewables into larger grid		
Demonstrated	Improved decision support capabilities for investing in renewable systems		
Potential	Improved capability to estimate ROI of renewable systems		

Power Consumption

List and describ	List and describe any benefits this technology has or may have on installation power consumption		
Realized	Realized Incorporated energy storage to reduce peak power demand		

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions			

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Realized	Technology requires fewer or less costly replacement components that alternative systems

Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

disruptions, c	in non-distruption of critical systems
Realized	Reduced reliance on outside energy suppliers
Realized	Increased energy storage capability for independent operation
Cyber Securi	ty
List and desc	ribe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above			
Realized	Reduced reliance on systems with expensive replacement parts		
Demonstrated	Improved decision support tools to inform future investments or funding requirements		

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?
List and describe any benefits this technology has or may have that aren't described above

What were the most significant obstacles encountered in this technology demonstration project?
Discovered bug in Power Converter that reduced total PV capacilty; Lack of expertise on PV and energy storage, NBVC PW and EXWC safety rules would not allow
self-install; delays in construction due to local base support; utility interconnect agreement on hold due to telemetry issues; BSSM failed, DC bus has suspected
occasional spikes; Li-ion battery safety certifications; Base PW wanted warranties and bonding; MILCON \$1M threshold for custs
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Reduced power quality, limited total PV potential, caused significant delays in getting system operational
What would you describe as the greatest benefit(s) of having completed this demonstration project?
Gained experience implementing PV and energy storage systems; system reduces base energy demand and provides energy-secure lighting
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Address bugs/failures in IPC and BSSM, streamline process for approving use of Li-Ion battery energy storage
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
Cost-competitive with high ROI/rapid cost recovery; microgrid can be built in stages (one building at a time) to ease the integration process

What advances or observations were made in this demonstration project that could help justify continued investment in this technology? Successful integration of low-cost microgrid at building-scale makes it easier to fund infrastructure projects one building at a time

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Gained experience working with PV systems, energy storage, and microgrids. Lessons Learned: LED lighting controls more complicated than originally thought, system resiliency subject to hardward faults and software bugs in components, utility grid interconnect rules vary by region, system integration costs are the largest costs

Technology Integration

Maturity of the technology family	New technology still has undiscovered bugs and faults
Maturity/suitability of specific systems	IPC bug discovered during commissioning. Had to reduce total PV by 5kW. BSSM failed, DC bus has suspected occasional
used in this project	spikes
Integration with Navy-specific systems	Each building would require its own custom installation of microgrid system
Environmental or Installation-specific	Navy bases in different regions will have to comply with different standards in order to connect facility microgrids to larger
challenges	power grid

Accessibility of required components Li-ion battery power storage requires special approval and certifications

Process Challenges

	Interconnect agreements may prevent microgrid integration into larger power grid; some facilities may require insurance or
Certification or Approval requirements	bonding that vendors are unwilling to provide
Initial Funding or Resource Allocation	
issues	More experience is needed integrating these systems in order to improve cost estimates and avoid unexpected cost overruns
Continued Funding or Resource	
Allocation issues	Batteries will need periodic replacement and regular maintenance
Contracting / Procurement	Facilities commands may require assurances and warranties that suppliers may be unwilling to issue.

Stakeholder Challenges

Stakeholder endlenges	
Impact on and Approval of certain	Base Support must approve the use of Li-Ion battery storage on a case-by-case basis. Utility companies may restrict
stakeholders	microgrid interconnections
Limitations from stakeholder needs	Warranty or Assurance requirements may limit number of suitable vendors
Operation and support labor	
requirements	Batteries require period maintenance to ensure system health
Necessary Funding Streams:	
Integration	Installation and Construction require significant time investment from Public Works
Necessary Funding Streams: Continued	
Support	Labor funding needs to be reserved for system maintenance

Continued feedback and improvement Additional microgrid configurations may be needed to meet the needs of certain buildings

Intern Involvement

Please list any interns who were involved in this project, as well as the year(s) they worked and where they are now (if known). If necessary, use an "x" to represent any interns whose names are unknown.

Intern Name	Year (if known)	Where are they now? (if known)
Kyle Abrahamsen		
Dustin Talley		
Bashar Ameen		

References

Please list any technical papers, publications, or theses that resulted from this project.	
Title	
Title	
NAVFAC EXWC Demonstrates New Renewable Energy Power Management Systm - Currents. Winter 2016-17, 22-27	
Title (if known)	

B.11 Project Information Form for Project 11: Networked Building Level Micro-Grid Demonstration

tworked Building Level Micro-Grid Demonstration					
Other Names,	Abriviations, etc:	DC microgrid for Soli	d State Lighting		
Contacts	Name	Phone	Email	Role	Period of Performan
POC1	Bruce Garrett	805-982-5615	bruce.garrett@navy.mil	PI	FY17 FY
POC2	Kyle Abrahamsen	805-982-3893		Co-PI	Base / Installation
POC3	Ken Ho				NBVC Port Hueneme
hnolog	y Descriptio	n			
	• •		ented in this research project		
Provide a brid	ef description of the to				
Provide a brid	ef description of the to	echnology being impleme	vorked microgrid		
Provide a brid	ef description of the tr tiple building-level mi three different techno	echnology being impleme	vorked microgrid		
Provide a brid Combine mul	ef description of the to tiple building-level mi three different techno ype 1	echnology being impleme icrogrids into a larger netw plogy types to categorize t	vorked microgrid his project , Isolation		

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)			
Will increase the Navy's ability to implement microgrids by simplifying the process of sourcing components and systems to meet unique design needs while keeping costs			
below Milcon thresholds,			

Fossil Fuel Consumption

List and descri	be any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
Demonstrated	Integrated alternative-powered backup power systems
Potential	Reduced requirement for backup generators to assure power

Paga 1
ibe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management
Added renewable energy generation capability (wind, solar, etc)
Integrated or expanded renewable energy storage
Improved capability to integrate renewables into larger grid
Improved capability to estimate ROI of renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption		
	Incorporated energy storage to reduce peak power demand	
Demonstrated		

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure

Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers
Demonstrated	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure Improved monitoring and detection of potential cyber threats Improved capability to restore operation after successful cyber attacks

Costs

COSIS	
List and descri	ibe any benefits this technology has or may have on installation energy costs that aren't described above
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
Improved energy access in remote facilities
nal benefits, information, feedback, or control does this technology offer to the installation energy manager?
nal benefits, information, feedback, or control does this technology offer to future R&D efforts?
,

Other

Technology Demonstration Results

	es encountered in this technology demonstration project?
	t reduced total PV capacity; Lack of expertise on PV and energy storage, NBVC PW and EXWC safety rules would not allow self-install support; utility interconnect agreement on hold due to telemetry issues; BSSM failed, DC bus has suspected occasional spikes.
n what ways did these obstacles hinder	the implementation, operation, or effectiveness of the demonstrated technology?
	ifficulties in networking microgrids due to cybersecutiry and utility interconnect issues
	FAUE /
What would you describe as the greates	t benefit(s) of having completed this demonstration project?
	g-level microgrid systems into a larger base-wide architecture
Vhat specific adaptations (if any) would	d be required to make the commercially available technology more suitable for Navy-specific use?
pproval for cyber requirements, utility	/ interconnect parameters,
Ince operationally mature, what benef	its and/or drawbacks would this technology have over other (mature) alternative technologies?
	microgrids to be build in smaller sections that don't have as stringent funding requirements
at a state of the second s	
nproved capability to integrate micro	ade in this demonstration project that could help justify continued investment in this technology?
iproved capability to integrate intero	grup de unici ene seures
	rience were gained within the Navy workforce during this project?
	rience were gained within the Navy workforce during this project? cyber requirements, familiarity with PW and other processes required to integrate base power systems.
V and energy storage, familiarity with	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
Vandenergystorage, familiarity with	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
V and energy storage, familiarity with	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
V and energy storage, familiarity with nnology Adoption Co echnology Integration Maturity of the technology family	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
V and energy storage, familiarity with nnology Adoption Cc echnology Integration Maturity of the technology family Maturity/suitability of specific systems	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
V and energy storage, familiarity with nnology Adoption Cc echnology Integration Maturity of the technology family Maturity/suitability of specific systems sed in this project	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
V and energy storage, familiarity with nnology Adoption Co echnology Integration Maturity of the technology family Maturity/suitability of specific systems sed in this project ntegration with Navy-specific systems	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
V and energy storage, familiarity with nnology Adoption Cc echnology Integration Maturity/suitability of specific systems sed in this project httegration with Navy-specific systems nvironmental or Installation-specific	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
V and energy storage, familiarity with Inclogy Adoption Co echnology Integration Maturity/suitability of specific systems sed in this project integration with Navy-specific systems nvironmental or Installation-specific hallenges	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
V and energy storage, familiarity with nnology Adoption Cc echnology Integration Maturity of the technology family Maturity/suitability of specific systems sed in this project ntegration with Navy-specific systems nvironmental or Installation-specific hallenges ccessibility of required components	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
V and energy storage, familiarity with nnology Adoption Cc echnology Integration Maturity of the technology family Maturity/suitability of specific systems sed in this project ntegration with Navy-specific systems nvironmental or Installation-specific hallenges ccessibility of required components	cyber requirements, familiarity with PW and other processes required to integrate base power systems.
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90

Maintenance funding

Support

Continued feedback and improvement

Intern Involvement

Please list any interns w	/ho were involved in this proj	ject, as well as the year(s) they worked and where they are now (if known).
If necessary, use an "x" t	o represent any interns whos	se names are unknown.
Intern Name	Year (if known)	Where are they now? (ifknown)
ferences		
	papers, publications, or the	ses that resulted from this project.
	papers, publications, or the	ses that resulted from this project.
	papers, publications, or the	ses that resulted from this project.
Please list any technical	papers, publications, or the	ses that resulted from this project.
Please list any technical Tech papers		ses that resulted from this project.

Author(s)	Title
Ken Ho	NAVFAC EXWC Demonstrates New Renewable Energy Power Management Systems (Currents, Winter 2016-17)
NPS Student Theses	
Author(s)	Title (if known)

B.12 Project Information Form for Project 12: Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration

er-SCAI	DA Energy Ca	pability (C-SI	EC): Evaluation, Deve	lopment, and	Demonstration
		-			
Other Names,	Abriviations, etc:				
Contacts	Name	Phone	Email	Bole	Period of Performance
POC1	Lose Romero-Mariona	619-553-8119	jose.romeromariona@navy.mil	PI	FY15 FY16
POC2	John San Miguel	015 555 0115	john.m.sanmiguel@navy.mil		Base / Installation
POC3					SSC PAC San Diego CA
hnology	y Description				
			ented in this research project		
Provide a brie	f description of the tecl	hnology being impleme			
Provide a brie	f description of the tecl	hnology being impleme	ons and demonstrations of Cyber SCADA	technologies as they ope	erate in their Navy environment. In addition, i
Provide a brie	f description of the tecl	hnology being impleme		technologies as they ope	erate in their Navy environment. In addition, i
Provide a brie C-SEC On The N vill also provi	f description of the tech Nove (OTM), will enable de the ability to address	hnology being impleme much quicker evaluatic problems found with sp	ons and demonstrations of Cyber SCADA pecific solutions/mitigation strategies.	technologies as they op	erate in their Navy environment. In addition, i
Provide a brie C-SEC On The N vill also provi	f description of the tech Nove (OTM), will enable de the ability to address hree different technolo	hnology being impleme much quicker evaluatic problems found with sp	ons and demonstrations of Cyber SCADA pecific solutions/mitigation strategies.	technologies as they op	erate in their Navy environment. In addition, i
Provide a brie C-SEC On The N vill also provi	f description of the tecl Nove (OTM), will enable de the ability to address hree different technolo rpe 1	hnology being impleme much quicker evaluatic problems found with s gy types to categorize t	ns and demonstrations of Cyber SCADA pecific solutions/mitigation strategies.	technologies as they op	erate in their Navy environment. In addition, i
Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration) C-SEC mobile app will allow evaluation team to leverage C-SEC's evaluation capabilities to assess cyber vulnerability, monitor SCADA systems, and diagnose potential issues in a way that does not interfere with SCADA operation

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable En	ergy Dodo 1
List and descril	ergy be any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption	
	-

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure

echnology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

otential	Improved fault isolation to prevent cascading blackouts

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure nproved monitoring and detection of potential cyber threats

mproved capability to isolate potential vectors for cyber attacks nproved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

Vhat were the most significant obstacles encountered in this technology demonstration project?
he nature of the work (critical infrastructure and electrical grid: 1) get a concensus of people that we can reach out and ask question 2) hard to demonstrate work because
one is willing to let us connect to live systems
n what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
idn't allow technology proof of concept to scale up, still working on testing on a scaled-up system
tan canon commonly provide concept to state up, tan normally on cosing on a cance up system
Vhat would you describe as the greatest benefit(s) of having completed this demonstration project?
.) developed cadre of scientists/engineers who have appreciation/skills in energy systems & cyber security and ability to collaborate 2) the ability to develop capabilities in
sec to do things like baselining crit infrastructure network be developing "gentle" techniques 3) grow interactions between gov, academics, industry in working through t
hallenges
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
The specific department of any product of equivalent of the second
is solver a sum of the second substantial for the second
Ince operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
SEC allows you to look at health of network and also holds a library of potential cyber solutions that evaluates suitability of different solutions to address issues
· · · · · · · · · · · · · · · · · · ·
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
othing like this exists in gov capacity that provides objective answers to cyber questions, provides reusability to streamline multiuse, technology being gov-owned includ
raining component with gov mentality and meeting requirements
What new skills, competencies, or experience were gained within the Navy workforce during this project?
mere was some competences of the system and the system shall be competence with academia and some collar and the system shall be collar and the system shal
har by de officer systems (and depreciation of such systems), ability to consubrate with academia and continential

Fechnology Integration	
Maturity of the technology family	Implementation requires scaled-up testing
Maturity/suitability of specific systems	
used in this project	
ntegration with Navy-specific systems	requires access to critical infrastructure
Environmental or Installation-specific	
challenges	each installation is different, requires access to critical infrastructure
Accessibility of required components	Requires "samples" of industry cyber security techology

Process Challenges

Process challenges	
Certification or Approval requirements	
Initial Funding or Resource Allocation	
issues	Access to critical infrastructure is difficult to get
Continued Funding or Resource	
Allocation issues	hard to make a case for continued funding/development due to questions of responsibility
Contracting / Procurement	contracting shops are overtasked

Stakeholder Challenges

Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	requires approval of energy managers to get access to infrastructure
Limitations from stakeholder needs	mission critial energy infrastructure limits access
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	need to identify org responsible for funding integration & support
Necessary Funding Streams: Continued	
Support	need to identify org responsible for funding integration & support
Continued feedback and improvement	feedback systems in place for gov and industry partners

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
David Bright		
Tenika Grant		

References

Tech papers		
Author(s)	Title	
Journal Articles, Publica	ations	
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B13. Project Information Form for Project 13: Energy Efficient Cloud Computing Evaluation and Demonstration

Energ	y Efficie	ent Cloud Co	omputing Ev	aluation	and Dem	onstration		
	Other Name	s, Abriviations, etc:						
	Contacts	Name	Phone		Email	Polo		Period of Performance
		Chris Chen	619-553-6852	chris.s.chen(Role PI		FY17 FY17
		Bobby Nutting						Base / Installation
	POC3	Paul Plummer						SPAWAR Systems Center PAC
Techr	nology [Description						
	Provide a br	ief description of the	e technology being imp	plemented in th	is research projec	t		
			P)-based server and rac the data center will be					with non-production Navy ts server technology.
	Calaatuu ta	thus a different to sh		vise this project				
	Technology		nology types to catego Energy Management		ι			
	Technology	Туре 2	Implementation, Int	egration, Adapt	ation			
	Technology							
Antic	pated I	Benefits of t	this Technol	ogy				
	Bottom Line	Up Front: Describe t	he biggest anticipated	benefit of succes	ssfully implement	ing this technology (operationally (may b	be different from demonstration)
	Reduce ener	gy costs and total ow	nership costs associate	d with running	virtualization/clo			savings to be put into more
	computing	capabilities or avoidir	ng expensive power infi	rastructure upgr	ades			
		onsumption						
	List and des	cribe any benefits this	technology has or may	/ have on installa	ation fossil fuel co	nsumption or backu	ip power generator u	use
					\mathbf{n}			
	Renewable							
	List and des	cribe any benefits this	technology has or may	have on installa	ation renewable e	nergy generation, sto	orage, integration, o	or management
					<u> </u>			
	Power Cons	umption						
			technology has or may					
	Potential	Reduced instantation	power consumption th	irougnimproved	a ena-user enicien	<u>cy</u>		
	Power Mod	eling & Management	t					
	List and des	cribe any benefits this	technology has or may	have on installa	ation power mode	eling, management, o	or investment decisi	ions
	Operation a	nd Support Requiren	nents					
				/ have on the lab	oor, materials, trai	ning, or contracting	needed to support	and operate installation energy
	Fnergy Assu	rance, Independence	e. & Resiliency					
				have on installa	ation energy assur	ance and resiliency,	such as islanding or	isolation capability, recovery from

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	
Costs	
List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential Improved decision support tools to inform future investments or funding requirements	
Second Order Impacts	
What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	
Other	
nology Demonstration Results	
What were the most significant obstacles encountered in this technology demonstration project?	
Energy consumption from servers is hard to benchmark effectively, process and procurement challenges	
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?	
delays	
What would you describe as the greatest benefit(s) of having completed this demonstration project?	
Demonstrate potential cost and energy savings of OCP server architecture	
Demonstrate potential cost and energy savings of OCP server al chitecture	
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
The specific doup detons in any would be required to make the commercially available technology more suitable for hady specific user	
Open expertionally mature, what has office and (or drawbacks yourd this technology have are other (mature) alternative technologies?	
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?	
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? reduce total cost of ownership of advanced computing facilities	
reduce total cost of ownership of advanced computing facilities	
reduce total cost of ownership of advanced computing facilities	
reduce total cost of ownership of advanced computing facilities	
reduce total cost of ownership of advanced computing facilities	
reduce total cost of ownership of advanced computing facilities	
reduce total cost of ownership of advanced computing facilities What advances or observations were made in this demonstration project that could help justify continued investment in this technology?	
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reduce total cost of ownership of advanced computing facilities What advances or observations were made in this demonstration project that could help justify continued investment in this technology?	
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reduce total cost of ownership of advanced computing facilities What advances or observations were made in this demonstration project that could help justify continued investment in this technology?	

Technology Integration	
Maturity of the technology family	Still needs to be officially verified in a DOD capacity
Maturity/suitability of specific	
systems used in this project	Still needs to be officially verified in a DOD capacity
Integration with Navy-specific	
systems	Possible restrictions associated with using open source hardware in DoD
Environmental or Installation-	
specific challenges	possible limits on allowable applications due to open source hardware
Accessibility of required	
components	limited number of vendors to compete for bids

Process Challenges	
Certification or Approval	
requirements	Possible restrictions associated with using open source hardware in DoD
Initial Funding or Resource	
Allocation issues	large upfront cost for installing new server systems
Continued Funding or Resource	
Allocation issues	need continued validation and security reivew processes
Contracting / Procurement	Challenges in acquisition process

Stakeholder Challenges Impact on and Approval of certain stakeholders new server architecture must meet user needs such as not sacrificing speed for reduced operating costs Limitations from stakeholder needs possible limitations on allowable computing projects Operation and support labor requirements maintenance and monitoring Necessary Funding Streams: Integration buy-in needed from DOD IT professionals Necessary Funding Streams: Continued Support Continued feedback and improvement

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Tim Jordon		
Steve Kuczka		Currently at SSC Pacific
Ayron Solomakos		

References

Tech papers		
Author(s)	Title	
Journal Articles, Publ		
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B14. Project Information Form for Project 14: RFID Reading Outlets for Device-level Granularity in Building Energy Control

ID Read	ing Outlets f	or Device-leve	l Granularity in Bui	lding Energy C	ontrol
Other Names,	Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Wayne Liu	619-553-1900	wayne.p.liu@navy.mil	PI	FY14 FY17
POC2	Timi Adeyemi				Base / Installation
POC3	Mike Murphy				MCAS Miramar
Provide a brie	ef description of the to	echnology being impleme	nted in this research project		
	tlets to measure, moni	tor, and control building e	lectrical loads to advance towards N	Vet Zero goals, integrated w	vith MCAS Miramar Public Utility Awareness
Display		1			
Technology T		Energy Management 8			
Technology T		Cyber	twomtoring		
Technology T	, i	Implementation, Inte	gration Adaptation		

Anticipated Benefits of this Technology

Pottom Lino	In Front, Describe the bissert articipated basefit of successfully implementing this technology providenally (may be different from demonstration)
	Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration) of of plugs and lighting, ROI < 5 years in high energy cost environments, better access to energy use data
	······································
Fossil Fuel Co	•
	ibe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
Potential	Reduced natural gas needed for heating or installation operations
Potential	Improved decision support capability for sizing backup generators
Renewable E	
	ribe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management
Potential	Improved capability to estimate ROI of renewable systems
Potential	Improved decision support capabilities for investing in renewable systems
Power Consu	motion
	ibe any benefits this technology has or may have on installation power consumption
Potential	Reduced installation power consumption through building control automation
	ling & Management
-	ribe any benefits this technology has or may have on installation power modeling, management, or investment decisions Improved metering and monitoring of installation energy use
Potential	Improved metering and monitoring of instantation energy use
rotentia	mprotes anglioste exponenterior, etc.P1 under actoric combolierto
	-
	d Support Requirements
	ribe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy
infrastructur	e.
	ance, Independence, & Resiliency
List and desc	ribe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from
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List and desc	ribe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from
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List and desc disruptions, Cyber Securi List and desc List and desc List and desc Description Potential Second Orde What additic Potential Demonstrate Potential	ribe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from or non-disruption of critical systems
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T

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?
Introducing new plug load monitors introduces changes to data collection software and potential network vulnerabilities
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Page 2
What would you describe as the greatest benefit(s) of having completed this demonstration project?
Improved access to energy use data, detection of energy disturbances, cost savings by shutting off "phantom loads"
· · · · · · · · · · · · · · · · · · ·
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
What new skills, competencies, or experience weregained within the Navy workforce during this project?
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Technology Integration	
Maturity of the technology family	
Maturity/suitability of specific systems	
used in this project	Cybersecurity requirements?
Integration with Navy-specific systems	Integration process will vary with energy management software used at different installations
Environmental or Installation-specific	
challenges	
Accessibility of required components	
Process Challenges	
Certification or Approval requirements	cybersecurity requirements? Permitting process to install smart outlets? Compatible with protocols and regulations?
Initial Funding or Resource Allocation	
issues	
Continued Funding or Resource	
Allocation issues	
Contracting / Procurement	Contracting to install outlets
Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	
Limitations from stakeholder needs	RFID outlet shutoff may not be suitable for all loads / users
Operation and support labor	
requirements	special training required to service smart outlets?
Necessary Funding Streams:	
Integration	
Necessary Funding Streams: Continued	
Support	
Continued feedback and improvement	
	J
ntern Involvement	
Intern Name Year	ifknown) Where are they now? (ifknown)
Sam Skinner	in Nowity where are they now (in Niowity)
References	

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B15. Project Information Form for Project 15: C-SEC on the Move

SEC On 1	The Move				
Other Names,	, Abbreviations, etc:				
Contacts POC1	Name Jose Romero-Mariona	Phone 619-553-8119 jg	Email	Role	Period of Performand FY15 FY1
POC1 POC2	John San Miguel	019-555-6119	ose.romeromariona@navy.mil	Co-PI	Base / Installation
POC3	John San Wigder				SSC PAC
nnolog	y Descriptior	1			
Provide a bri	ef description of the teo	chnology being implemented i	n this research project		
Develop mob	ile tools for analyzing SC	CADA systems in order to assess	performance and cyber vulner	abilities, and to explore pos	sible mitigation measures
Select up to t	three different technol	ogy types to categorize this pro	ject		
Technology T	ype 1	Cyber			
Technology T	ype 2	Modeling & Optimization			
Technology T	ype 3				
icipate	d Benefits of	this Technology			
.					
				echnology operationally (m	ay be different from demonstration)
Improved cap	bability to assess health	and vulnerability in SCADA syste	ems		
Fossil Fuel Co		hnology has or may have on ins	tallation fossil fuel consumption	on or backup power generat	oruse
Potential	Reduced frequency of			8	
Renewable E	nergy				
List and descr	ribe any benefits this tec	hnology has or may have on ins	tallation renewable energy ger	heration, storage, integratio	n, or management
Potential	Improved capability to	o integrate renewables into larg	er grid		
Power Consu	mation				
		haalagu hacar may haya an inc	telletion neuror consumption		
List and descr	The any benefits this tec	hnology has or may have on ins	tallation power consumption		
Power Mode	ling & Management				
List and descr	ribe any benefits this teo	hnology has or may have on ins	tallation power modeling, ma	nagement, or investment de	cisions
	1				
	d Support Requiremen				
List and descr	ribe any benefits this tec	hnology has or may have on the	labor, materials, training, or o	contracting needed to supp	ort and operate installation energy
infrastructur	e				
Potential	Technology is easier to	o operate than alternative system	ns		
Potential	Technology reduces no	eed for specialized training			
. .					
	ance, Independence, &				
			tallation energy assurance and	resiliency, such as islanding	or isolation capability, recovery from
	or non-disruption of crit				
Potential	Improved fault isolation	on to prevent cascading blackou	its		
Potential	Improved capability to	o restore grid functionality after	outages		

otential Improved capability to isolate potential vectors for cyber attacks otential Improved failsafes or system logic to limit potential damage from cyber attacks otential Improved capability to restore operation after successful cyber attacks osts Increased ability to diagnose need for preventative maintenance otential Increased ability to diagnose need for preventative maintenance otential Improved decision support tools to inform future investments or funding requirements econd Order Impacts Information, feedback, or control does this technology offer to the installation energy end user? //hat additional benefits, information, feedback, or control does this technology offer to the installation energy manager? Improved documentation of infrastructure //hat additional benefits, information, feedback, or control does this technology offer to future R&D efforts? Improved documentation, feedback, or control does this technology offer to future R&D efforts? //hat additional benefits, information, feedback, or control does this technology offer to future R&D efforts? Improved access to energy use data	Cyber Security	
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	Just scratched i	the surface, openhed trust pathways to more progress
ergy & cyper systems (and appreciation of such systems), ability to collaborate with academia and commercial		

Technology Integration	
Maturity of the technology family	still a proof of concept
Maturity/suitability of specific systems	
used in this project	
Integration with Navy-specific systems	access to infrastructure components
Environmental or Installation-specific	
challenges	need access to equipment and site documentation, knowledge of day-today operations
Accessibility of required components	takes a while to order stuff

Process Challenges

Certification or Approval requirements	TBD, not "blessed" yet
Initial Funding or Resource Allocation	
issues	
Continued Funding or Resource	
Allocation issues	need funds to continue development and taking to different sites
Contracting / Procurement	see above

Stakeholder Challenges

Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	approval of Energy managers and operators
Limitations from stakeholder needs	TBD
Operation and support labor	
requirements	Will eventually transition to a team performing these cyber evaluations
Necessary Funding Streams:	
Integration	Not clear who will take ownership
Necessary Funding Streams: Continued	
Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
David Bright		
Tenika Grant		
Henry Brooks		
Geancarlo Coca		

References

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
	Security in the Industrial Internet of Things: The C-SEC Approach
NPS Student Theses	
Author(s)	Title (if known)

B16. Project Information Form for Project 16: Data Center Smart Metering Evaluation (DC Smart-E)

Other Names	Abriviations, etc:				
	·				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Daniel Grday	619-553-2793	daniel.grady@navy.mil	PI	FY16 FY1
POC2	Chris Chen				Base / Installation
POC3					SSC PAC San Diego
hnolog	y Descriptio	n			
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Provide a brid	ef description of the t	echnology being impleme			
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Provide a brid Consolidate of Select up to t	ef description of the t lata centers in order to hree different techno ype 1	echnology being impleme	ement more effective metering		

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration) Reduced energy consumption through larger, more efficient data centers, estimated 5%-20% annual reduction in power and energy costs

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable En List and descril	ergy be any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption		
Realized	Reduced installation power consumption through improved end-user efficiency	

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions		
Demonstrated Improved metering and monitoring of installation energy use		

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

otential Reduced contractor support required to install, maintain, or operate technology

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

tial Improved monitoring and detection of potential cyber threats

Costs

ist and describe any benefits this technology has or may have on installation energy costs that aren't described above			
Demonstrated	emonstrated improved decision support tools to inform future investments or funding requirements		

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?
Demonstrated Real-time monitoring of energy systems
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

alized Improved access to energy use data

Other

other	

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
What would you describe as the greatest benefit(s) of having completed this demonstration project?
Reduced O&S cost of data center operation, improved ROI analysis for data center metering
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
what advances of observations were made in this demonstration project that could neip justify continued investment in this technology?
What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations
Technology Integration

	Technology Integration	
	Maturity of the technology family	
Í	Maturity/suitability of specific systems	
	used in this project	
Í		
	Integration with Navy-specific systems	possible challenges in migrating data centers for consolidation
	Environmental or Installation-specific	
	challenges	possible challenges in migrating data centers for consolidation
	Accessibility of required components	

Process Challenges

r

riocess enuneriges	
Certification or Approval requirements	Potential lengthy approval process to migrate data centers
Initial Funding or Resource Allocation	
issues	
Continued Funding or Resource	
Allocation issues	
Contracting / Procurement	

Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	
Limitations from stakeholder needs	Stakeholder needs present potential limitations on data center consolidation
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	
Necessary Funding Streams: Continued	
Support	
Continued feedback and improvement	Feedback needed to ensure energy conservation measures do not negatively impact data center performance

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Alex Salerno		
Ayron Solomakos		
Dondi Jones		

References

Tech papers		
Author(s)	Title	
Journal Articles, Publication	ns	
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B17. Project Information Form for Project 17: Building Energy Management Automation

Buildir	ng Ene	ergy Manage	ment Automa	ation		
1	Other Nam	es, Abriviations, etc:	Office Buildings Energy	Management Automation		
_	Contacts	Name	Phone	Email	Role	Period of Performance
	POC1 POC2	Chris Chen	619-553-6852	chris.s.chen@navy.mil	PI	FY16 FY17 Base / Installation
-	POC3					
Techn	ology	Description				
	Provide a l	prief description of the	technology being imple	emented in this research project		
				uilding controls in a way that faci vices to share data for smarter ene		and is cyber secure. Integrate smart light bulbs
-						
	Select up t Technolog		ology types to categori Energy Management &			
	Technolog		Cyber			
-	Technolog		Implementation, Integ			
Anticip	pated	Benefits of t	his Technolo	gy		
1	Bottom Lir	e Up Front: Describe th	e biggest anticipated be	enefit of successfully implementin	ig this technology ope	rationally (may be different from demonstration)
	Improved	efficiency in building co	ntrol and improved acc	ess to building energy use data		
-		.				
		Consumption scribe any benefits this	technology has or may h	ave on installation fossil fuel con	sumption or backup p	ower generator use
	Potential		eeded for heating or inst			
-						
-	Demoki			200		
	Renewable List and de		technology has or may h	ave on installation renewable en	ergy generation, stora	ge, integration, or management
-						
	Power Cor	sumption				
		-	technology has or may h	ave on installation power consur	nption	
_	Potential	Reduced installation p	ower consumption thro	ough building control automation	n	
			<u></u>			
	Power Mo	deling & Management				
	List and de	scribe any benefits this	technology has or may h	ave on installation power modeli	ing, management, or i	nvestment decisions
	Potential	Improved metering an	d monitoring of installa	tion energy use		
	Operation	and Support Requirem	ents			
				ave on the labor, materials, train	ing, or contracting ne	eded to support and operate installation energy
	Fnerøv Δcc	urance, Independence	& Resiliency			
				ave on installation energy assura	nce and resiliency, suc	h as islanding or isolation capability, recovery from
[

1	Cyber Security
	List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure
	Costs
	List and describe any benefits this technology has or may have on installation energy costs that aren't described above
	Second Order Impacts What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?
	what additional benefits, information, recuback, or control does this technology one to the instanation energy end user :
	What additional benefits, information, feedback, or control does this technology offer to the installation energy manager? Potential Real-time monitoring of energy systems
	What additional benefits, information, feedback, or control does this technology offer to future R&D efforts? Potential Improved access to energy use data
	Potential Improved control capabilities for future experiments
	O llow
	Other
Techn	ology Demonstration Results
Teenn	
	What were the most significant obstacles encountered in this technology demonstration project?
	In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
	What would you describe as the greatest benefit(s) of having completed this demonstration project? Improved understanding of how IoT devices can be used in an installation energy context, reduce energy consumption in buildings
	iniproved differsioning of now for devices can be used in an instantion energy context, reduce energy consumption in buildings
	What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
	Cyber security features, compliant with existing policies
	Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
	Technology is scalable with new IoT devices
	What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
	What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Integration	
Maturity of the technology family	IoT cybersecurity is not yet fully developed
Maturity/suitability of specific	
systems used in this project	
Integration with Navy-specific	
systems	cybersecurity concerns
Environmental or Installation-	
specific challenges	calibration required for various lighting and climate controls
Accessibility of required	
components	

Process Challenges	
Certification or Approval	
requirements	cyber approval required for transmitting devices
Initial Funding or Resource	
Allocation issues	
Continued Funding or Resource	
Allocation issues	
Contracting / Procurement	

Stakeholder Challenges

Stakenoluer chanenges	
Impact on and Approval of certain	
stakeholders	Require stakeholder buy-in on automated controls
Limitations from stakeholder	
needs	certain stakeholders may not be willing to cede manual control
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	
Necessary Funding Streams:	
Continued Support	
Continued feedback and	
improvement	calibration for climate and lighting systems

Intern Involvement

	Year (if known)	Where are they now? (if known)
Tim Jordon		
Jason Sneddon		

References

Tech papers		
Author(s)	Title	
Iournal Articles, Pub	ications	
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B18. Project Information Form for Project 18: Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)

Re	silient C	ritical Infrastr	uctures thro	ugh Secure and Efficie	ent Micro (Grids (ReClst)
	Other Names	, Abriviations, etc:				
	Contacts	Name	Phone	Email	Role	Period of Performance
	POC1	Jose Romero-Mariona	619-553-8199	jose.romeromariona@navy.mil		FY16 FY18
	POC2	Maxine Major				Base / Installation
	POC3	Eva Regnier				SSC PAC
Те	chnolog	y Description				
	Provide a bri	ef description of the tech	nology being implemer	nted in this research project		
	Scan ICS and	SCADA components withi	n microgrids to assess se	curity and efficiency		
	Select up to	three different technolog	gy types to categorize th	is project		
	Technology T	ype 1	Cyber			
	Technology T	ype 2	Microgrids, Islanding,	Isolation		
	Technology T	ype 3	Modeling & Optimizat	ion		

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration) Improved assessment of cyber vulnerabilities and estimated ROI for ICS and SCADA systems in micro-grids

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation ren neration, storage, integration, or management newabl Potential Improved decision support capabilities for investing in renewable sys

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure Improved monitoring and detection of potential cyber threats Improved capability to isolate potential vectors for cyber attacks Improved failsafes or system logic to limit potential damage from cyber attacks Improved capability to restore operation after successful cyber attacks

List and desc Potential	Improved decision support tools to inform future investments or funding requirements
rotentia	
	J
Second Orde	r Impacts
	mappeds nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
what address	The benefits, internation, recebbely or control does this technology and to the instantiation energy and user.
What additio	nal benefits, information, feedback, or control does this technology offer to the installation energy manager?
what address	nar defents, mormation, recuback, or control does this technology oner to the instanation energy manager:
المرامعة مططنة م	nal benefits, information, feedback, or control does this technology offer to future R&D efforts?
	nar benefits, miorination, reeduack, or control does this technology offer to future kad enorts:
Other	
Other	
hnolog	v Demonstration Results
hnolog	y Demonstration Results
	·
What were th	e most significant obstacles encountered in this technology demonstration project?
What were th	·
What were th	e most significant obstacles encountered in this technology demonstration project?
What were th	e most significant obstacles encountered in this technology demonstration project?
What were th	e most significant obstacles encountered in this technology demonstration project?
What were th	e most significant obstacles encountered in this technology demonstration project? op model ROI for costs/risks of cyber security, never done before
What were th	e most significant obstacles encountered in this technology demonstration project?
What were th	e most significant obstacles encountered in this technology demonstration project? op model ROI for costs/risks of cyber security, never done before
What were th	er most significant obstacles encountered in this technology demonstration project? op model ROI for costs/risks of cyber security, never done before did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Page 2
What were th rried to devel in what ways What would	ere most significant obstacles encountered in this technology demonstration project? op model ROI for costs/risks of cyber security, never done before did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Page 2 you describe as the greatest benefit(s) of having completed this demonstration project?
What were th tried to devel In what ways What would	e most significant obstacles encountered in this technology demonstration project? op model ROI for costs/risks of cyber security, never done before did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Page 2
What were th tried to devel In what ways What would	ere most significant obstacles encountered in this technology demonstration project? op model ROI for costs/risks of cyber security, never done before did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Page 2 you describe as the greatest benefit(s) of having completed this demonstration project?
What were th tried to devel In what ways What would	ere most significant obstacles encountered in this technology demonstration project? op model ROI for costs/risks of cyber security, never done before did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Page 2 you describe as the greatest benefit(s) of having completed this demonstration project?
What were th tried to devel In what ways What would	ere most significant obstacles encountered in this technology demonstration project? op model ROI for costs/risks of cyber security, never done before did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Page 2 you describe as the greatest benefit(s) of having completed this demonstration project?
What were th tried to devel in what ways What would can assess the	e most significant obstacles encountered in this technology demonstration project? op model ROI for costs/risks of cyber security, never done before did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Page 2 you describe as the greatest benefit(s) of having completed this demonstration project? ROI and other benefits of cyber security and energy investments
What were th tried to devel in what ways What would can assess the	ere most significant obstacles encountered in this technology demonstration project? op model ROI for costs/risks of cyber security, never done before did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Page 2 you describe as the greatest benefit(s) of having completed this demonstration project?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? provides modeling capability on ROI investments, some folks mifght not like the results

What advances or observations were made in this demonstration project that could help justify continued investment in this technology? being done by Gov helps preserve knowledge & compliance, helps build skillsets, helps inform future investments

What new skills, competencies, or experience weregained within the Navy workforce during this project? energy & cyber systems (and appreciation of such systems), ability to collaborate with academia and commercial

I	Technology Integration					
Maturity of the technology family			Technology must be able to probe ICS and SCADA systems without interfering with operations			
_	Maturity/suitability of speci					
	used in this project		still a proof-of-concept			
	Integration with Navy-specific systems Environmental or Installation-specific		(see CSEC)			
	challenges		Technology must be adapted to work with different ICS and SCADA components employed at different naval installations			
	chanenges		recented by must be adapted to work with an eleft res and sender components employed at an eleft matanations			
	Accessibility of required cor	mponents				
	· · ·					
	Process Challenges					
	C-110-11-					
	Certification or Approval re Initial Funding or Resource		Requires approval to probe ICS and SCADA systems while in use. Accrediation issues to implement suggested solutions			
	issues	Anocation	justification of need to model or use system			
	Continued Funding or Reso	urce				
	Allocation issues		need funding to continue support/improvements			
	Contracting / Procurement		hardware components must be produced/acquired in sufficient quantities to conduct testing at multiple installations			
	Stakaholdor Challenaa					
I	Stakeholder Challenges Impact on and Approval of c	certain				
	stakeholders	certain	pushback on results			
			Testing/probing cannot interfere with SCADA/ICS operations, identified cyber securitity measures must be implemented without			
	Limitations from stakeholde	er needs	interfering with SCADA/ICS operations			
	Operation and support labo	or				
	requirements					
	Necessary Funding Streams:	:				
	Integration	Contin	ownership			
	Necessary Funding Streams: Support	: Continued	ownership			
	Jupport		ownersing			
	Continued feedback and im	provement				
nt	ern Involvemen	nt				
-		-				
	Intern Name	Year (i	if known) Where are they now? (if known)			
	Giancarlo Coca					
	Henry Brooks					
<u>ke</u> t	erences					
	Tech papers					
1	Author(s)		Title			
	Journal Articles, Publicatio	ons				
	Author(s)		Title			
	NPS Student Theses					
1	Author(s)		Title (if known)			

B19. Project Information Form for Project 19: SCADA Deploy

SCADA Deploy

Other Names, Abriviations, etc:		Deployable SCADA Ar	chitecture for Non-Intrusive Ene	ergy System	Evaluation (SCADA Deploy)
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Henry Au	808-474-4179	henry.au@navy.mil	PI	FY16 FY17
POC2	Richard Kam				Base / Installation
POC3	Brian Tagami				MCBH - Hawaii

Technology Description

Provide a brief description of the technology being implemented in this research project

Map existing SCADA systems at various Commands and Joint Bases in Hawaii to develop SCADA network models for legacy and next gen SCADA integration. Determine network availability for newer technology and cyber security.

Select up to three different technology types to categorize this project

Technology Type 1	Cyber
Technology Type 2	Energy Management & Monitoring
Technology Type 3	Modeling & Optimization

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from Improved documentation and assessment of SCADA systems at Marine Corps Base Hawaii to determine cyber vulnerabilities and best strategies for improvements/upgrades

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential Reduced installation power consumption through improved distribution efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

 Potential
 Power modeling used to optimize grid configuration or expansion

- Potential Improved diagnostic capabilities for energy infrastructure components
- Demonstra Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation

Energy Assurance, Independence, & Resiliency

List and de	List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability,					
Potential	Improved fault isolation to prevent cascading blackouts					
Potential	Improved capability to restore grid functionality after outages					

Demonsti	Improved monitoring and detection of potential cyber threats
	Improved capability to isolate potential vectors for cyber attacks
	Improved failsafes or system logic to limit potential damage from cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks
Costs	
	escribe any benefits this technology has or may have on installation energy costs that aren't described above
Potential	Increased ability to diagnose need for preventative maintenance
Domonst	Improved decision support tools to inform future investments or funding requirements
pernonsti	improved decision support tools to inform rutare investments of runaing requirements
Jemonsti	improved decision support tools to inform future investments of futuring requirements
econd C	rder Impacts
Second C What add	rder Impacts itional benefits, information, feedback, or control does this technology offer to the installation energy end user?
Second O What add What add	rder Impacts itional benefits, information, feedback, or control does this technology offer to the installation energy end user? itional benefits, information, feedback, or control does this technology offer to the installation energy manager?
Second C What add What add Potential	rder Impacts itional benefits, information, feedback, or control does this technology offer to the installation energy end user? itional benefits, information, feedback, or control does this technology offer to the installation energy manager? Real-time monitoring of energy systems
Second C What add What add Potential Demonsti	rder Impacts itional benefits, information, feedback, or control does this technology offer to the installation energy end user? itional benefits, information, feedback, or control does this technology offer to the installation energy manager? Real-time monitoring of energy systems Improved documentation of infrastructure
Second C What add What add Potential Demonstr What add	rder Impacts itional benefits, information, feedback, or control does this technology offer to the installation energy end user? itional benefits, information, feedback, or control does this technology offer to the installation energy manager? Real-time monitoring of energy systems Improved documentation of infrastructure itional benefits, information, feedback, or control does this technology offer to future R&D efforts?
Second C What add What add Potential Demonstr What add	rder Impacts itional benefits, information, feedback, or control does this technology offer to the installation energy end user? itional benefits, information, feedback, or control does this technology offer to the installation energy manager? Real-time monitoring of energy systems Improved documentation of infrastructure
Second C What add What add Potential Demonstr What add	rder Impacts itional benefits, information, feedback, or control does this technology offer to the installation energy end user? itional benefits, information, feedback, or control does this technology offer to the installation energy manager? Real-time monitoring of energy systems Improved documentation of infrastructure itional benefits, information, feedback, or control does this technology offer to future R&D efforts?
Second C What add What add Potential Demonstr What add	rder Impacts itional benefits, information, feedback, or control does this technology offer to the installation energy end user? itional benefits, information, feedback, or control does this technology offer to the installation energy manager? Real-time monitoring of energy systems Improved documentation of infrastructure itional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Technology Demonstration Results

	Vhat were the most significant obstacles encountered in this technology demonstration project?
-	
	cale of PH shipyard, difficulties in coordinating with contractors responsible for SCADA systems
1	n what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
	Vhat would you describe as the greatest benefit(s) of having completed this demonstration project?
1	mproved assessment of SCADA cyber vulnerabilities and improved documentation of existing SCADA systems
١	Vhat specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
(Ince operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
(Ince operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
(nce operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
1	Ince operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
1	Ince operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
(Ince operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
	Vhat advances or observations were made in this demonstration project that could help justify continued investment in this technology?
	Vhat advances or observations were made in this demonstration project that could help justify continued investment in this technology?
1	Vhat advances or observations were made in this demonstration project that could help justify continued investment in this technology?
1	Vhat advances or observations were made in this demonstration project that could help justify continued investment in this technology?
1	Vhat advances or observations were made in this demonstration project that could help justify continued investment in this technology? dentified vulnerability to cyber threats can justify improvements in SCADA infrastructure
١	Vhat advances or observations were made in this demonstration project that could help justify continued investment in this technology?
1	Vhat advances or observations were made in this demonstration project that could help justify continued investment in this technology? dentified vulnerability to cyber threats can justify improvements in SCADA infrastructure
1	Vhat advances or observations were made in this demonstration project that could help justify continued investment in this technology? dentified vulnerability to cyber threats can justify improvements in SCADA infrastructure
١	Vhat advances or observations were made in this demonstration project that could help justify continued investment in this technology? dentified vulnerability to cyber threats can justify improvements in SCADA infrastructure
1	Vhat advances or observations were made in this demonstration project that could help justify continued investment in this technology? dentified vulnerability to cyber threats can justify improvements in SCADA infrastructure

Technology Adoption Considerations

Technology Integration	
Maturity of the technology	
family	
Maturity/suitability of specific	Existing systems lack updated documentation and the institutional knowledge required to effectively maintain and
systems used in this project	operate these SCADA systems has been lost
Integration with Navy-specific	Improving SCADA situation will require certifying a new SCADA architecture and navigating the contracting process to
systems	implement new systems
Environmental or Installation-	
specific challenges	Each installation will have a unique layout and individual challenges
Accessibility of required	
components	
Process Challenges	
Certification or Approval	
requirements	Reliance on SCADA systems and inability to tolerate disruptions will create challenges during aproval process
Initial Funding or Resource	
Allocation issues	Scale and depth of SCADA system use will make improvements an expensive and lengthy process
Continued Funding or Resource	
Allocation issues	Scale and depth of SCADA system use will make improvements an expensive and lengthy process
Contracting / Procurement	
Challed and Challen and	
Stakeholder Challenges	
certain stakeholders	Improving SCADA architecture will likely result in disruptions to energy availability
Limitations from stakeholder	Improving SCADA architecture win interviesur in disruptions to energy availability
needs	
Operation and support labor	
requirements	O&S personell will need to be trained on new SCADA systems
Necessary Funding Streams:	
Integration	
Necessary Funding Streams:	
Continued Support	
Continued feedback and	

Intern Involvement

Intern Name	Year (if known)	_Where are they now? (if known)
Timothy Gunderson	FY16	

References

Tech papers	Title
Author(s)	
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B20. Project Information Form for Project 20: Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)

ni Cybe	er SCADA Lab	oratory Wo	orkforce Developme	nt (SSC	PAC and UHWO)
Other Name	s, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performanc
POC1	Jose Romero-Mariona	619-553-8199	jose.romeromariona@navy.mil	PI	FY17 FY18
POC2	Geancarlo Palavicini				Base / Installation
POC3	Matt Chapman				SSC PAC & UHWO
Provide a br	ief description of the te	cnnology being impl	emented in this research project		
	·			rdinate with U	niveristy of Hawaii on energy projects to enga
Build a form	·	Joint Cyber-SCADA la		rdinate with U	niveristy of Hawaii on energy projects to enga
Build a forma students & a	al collaboration link and cademia and build intell	Joint Cyber-SCADA la ectual capital.	b environment in order to better coo	rdinate with U	niveristy of Hawaii on energy projects to enga
Build a forma students & a Select up to	al collaboration link and cademia and build intell three different technol	Joint Cyber-SCADA la ectual capital.	b environment in order to better coo	rdinate with U	niveristy of Hawaii on energy projects to engag
Build a forma students & a Select up to Technology	al collaboration link and cademia and build intell three different technol Type 1	Joint Cyber-SCADA la ectual capital. ogy types to categor Cyber	b environment in order to better coo	rdinate with U	niveristy of Hawaii on energy projects to enga
Build a forma students & a Select up to	al collaboration link and cademia and build intell three different technol Type 1 Type 2	Joint Cyber-SCADA la ectual capital.	b environment in order to better coo	rdinate with U	niveristy of Hawaii on energy projects to engag

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)

increased capability to link DoD personnel with academia and student interns for coordinated research efforts in the field of cyber security, SCADA, and critical energy infrastructure protection

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and desc	List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure				
Potential	mproved monitoring and detection of potential cyber threats				
Potential	Improved capability to isolate potential vectors for cyber attacks				
Potential	Improved failsafes or system logic to limit potential damage from cyber attacks				
Potential	Improved capability to restore operation after successful cyber attacks				

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?
scheduling

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

cilliology Adop					
Tochnology Integration					
Technology Integration					
Maturity of the technology	family				
Maturity/suitability of speci	ific				
systems used in this project					
Integration with Navy-speci	ific				
systems					
Environmental or Installatio		Difficultion	consisted with tailoring subsystemates at a site specific bardware		
specific challenges Accessibility of required		Difficulties a	ssociated with tailoring cyber solutions to site-specific hardware		
components					
Process Challenges					
Certification or Approval					
requirements		Approval to v	work with a non-DOD agency		
Initial Funding or Resource		Difficulture of	Internine DOI selevisities for initial investment		
Allocation issues Continued Funding or Resou		Difficult to determine ROI calculation for initial investment			
Allocation issues		Will require o	continual funding renewal		
Contracting / Procurement					
Stakeholder Challenges					
Impact on and Approval of					
stakeholders		DOD needs v	rs UHWO needs		
Limitations from stakeholde	er needs				
Operation and support labo					
requirements					
Necessary Funding Streams	:				
Integration					
Necessary Funding Streams	:				
Continued Support Continued feedback and					
improvement					
ern Involveme	nt				
Intern Name	Year (i	f known)	Where are they now? (if known)		
ferences					
Tech papers					
		Title			
Journal Articles, Publications Author(s) T					
		Title			
NPS Student Theses					
Author(s)		Title (if know	(n)		

B21. Project Information Form for Project 21: Smart Plug Side Channel Analysis (SPAMSANDWICH)

mart Plug	g Side Channe	l Analysis (SPA	MSANDWICH)		
Other Names,	, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Lawrence Kerr	619-553-7907	Ikerr@spawar.navy.mil	PI	FY17 FY18
POC2	Maxine Major				Base / Installation
POC3	Johnny Phan				SSC Pacific Cyber SCADA lab
echnolog	y Description				
Provide a brie	ef description of the tech	nology being implemente	ed in this research project		
Evaluate COTS cyber attacks		to determine their suitab	ility for use in larger energy	monitoring efforts and using da	ta collected by the smart plugs to detect possible
Select up to t	three different technolog	gy types to categorize this	project		
Technology T		Energy Management & N	lonitoring		
Technology T		Cyber			
Technology T					
nticipate	d Benefits of t	this Technolog	Σ Υ		
Bottom Line	Un Front: Describe the big	ggest anticinated benefit o	fsuccessfully implementing	g this technology operationally	(may be different from demonstration)
					frastructure, as well as provide researchers with
additional da	ta into facility energy use.	. Monitoring power consu	mption at outlets allows no	on intrusive analysis of SCADA sys	items
Forcil Fuel Co	numntion				
Fossil Fuel Co		nology has or may have on	installation fossil fuel cons	umption or backup power gener	rator use
List and desci	be any benefits this teem	norogy nasor may nave on		amption of backup power gener	
				\sim 1	
Renewable E					
				rgy generation, storage, integrat	tion, or management
Potential	Improved decision supp	port capabilities for investi	ng in renewable systems		
Power Consu	mption				
List and descr	ibe any benefits this tech	nology has or may have on	installation power consum	nption	
Potential			improved end-user efficier		
Potential	Reduced installation por	wer consumption through	building control automati	ion	
Power Mode	ling & Management				
		nology has or may have on	installation power modeli	ng, management, or investment	decisions
Potential	Power modeling used to	o optimize grid configurati	on or expansion		
Demonstrate	c Improved metering and	monitoring of installation	energy use		
Potential	Modeling and simulation	n to inform energy infrastr	ucture investments		
	d Support Requirements		the labor materials traini	ng or contracting pooded to cur	oport and operate installation energy
infrastructure		norogy has of may have on	the labor, materials, traini	ing, of contracting needed to sup	port and operate instantion energy
mastructure	c.				
	ance, Independence, & R				
			installation energy assuran	ce and resiliency, such as islandi	ing or isolation capability, recovery from
disruptions, o	or non-disruption of critic	cal systems			

Potential	scribe any benefits this technology has or may have on the cyber security of installation energy infrastructure Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved failsafes or system logic to limit potential damage from cyber attacks
Costs	
List and des	scribe any benefits this technology has or may have on installation energy costs that aren't described above
Potential	Improved decision support tools to inform future investments or funding requirements
Second Ord	ler Impacts
	der Impacts ional benefits, information, feedback, or control does this technology offer to the installation energy end user? Increased awareness of energy use
What addit Potential	ional benefits, information, feedback, or control does this technology offer to the installation energy end user?
What addit Potential	ional benefits, information, feedback, or control does this technology offer to the installation energy end user? Increased awareness of energy use
What addit Potential What addit Potential	ional benefits, information, feedback, or control does this technology offer to the installation energy end user? Increased awareness of energy use ional benefits, information, feedback, or control does this technology offer to the installation energy manager? Real-time monitoring of energy systems
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What addit Potential What addit Potential What addit Demonstrat Potential	ional benefits, information, feedback, or control does this technology offer to the installation energy end user? Increased awareness of energy use Ional benefits, information, feedback, or control does this technology offer to the installation energy manager? Real-time monitoring of energy systems Ional benefits, information, feedback, or control does this technology offer to future R&D efforts?
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Technology Demonstration Results

What were the most significant obstacles encountered in this technology	nology demonstration project?
	ted number of COTS high sampling rate devices, DoD security policies
In what ways did these obstacles hinder the implementation, operat	ation or effectiveness of the demonstrated technology?
Limited ability to purchase and install systems for testing	age Z
What would you describe as the greatest benefit(s) of having comple	leted this demonstration project?
What specific adaptations (if any) would be required to make the co	ommercially available technology more suitable for Navy-specific use?
Once operationally mature, what benefits and/or drawbacks would	d this technology have over other (mature) alternative technologies?
What advances or observations were made in this demonstration pr	project that could help justify continued investment in this technology?
What new skills, competencies, or experience were gained within th	the Navy workforce during this project?

I

Technology Adoption Considerations

Technology Integration	
	Limited number of vendors, and published specs don't provide enough information to properly guage a product's performance in
Maturity of the technology family	application
Maturity/suitability of specific systems	
used in this project	
Integration with Navy-specific systems	Multiple DoD security constraints
Environmental or Installation-specific	
challenges	
Accessibility of required components	Difficult to determine which products are suitable for this application
Process Challenges	
Certification or Approval requirements	required security certifications?
Initial Funding or Resource Allocation	
issues	
Continued Funding or Resource	
Allocation issues	Ideal application will require regular updates to improve detection of emerging cyber attack vectors
Contracting (Decourses ont	
Contracting / Procurement	
Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	
•	
Limitations from stakeholder needs	
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	
Necessary Funding Streams: Continued	
Support	
Continued feedback and improvement	Labor required to continually improve data analysis as installation energy use changes over time

Intern Involvement

	Intern Name	Year (if known)	Where are they now? (if known)		
Ref	ferences				

Title
Title
Title (if known)
B22. Project Information Form for Project 22: ENSURE (Ensuring Reliability and Efficiency)

NSURE (Ensuring Reliab	oility and Effic	iency)		
Other Names, Abriviations, etc:				
Contacto	Dhana	Email	Dele	Period of Performance
Contacts Name POC1 Josiah Bryan	Phone 619-553-7193	josiah.bryan@navy.mil	Role	FY17 FY18
POC2 Jose Romero-Mariona				Base / Installation
POC3 John San-Miguel				SSC Pacific - San Diego
echnology Description				
Provide a brief description of the tech	nology being implement	ed in this research project		
evaluate and monitor Energy Critical In	frastructures and SCADA	echnologies by creating an integrat	ed framework of binary a	analysis tools, security technologies, and efficienc
metrics on small single board compute	r devices to discover emb	edded firmware functionality that c	ould cause devices to wa	aste resources.
Select up to three different technolog		project		
Technology Type 1 Technology Type 2	Cyber Energy Management & M	Appitoring		
Technology Type 3	Modeling & Optimizatio			
nticipated Benefits of t	this Technolog	SY		
Bottom Line Up Front: Describe the big		of successfully implementing this ter	chnology operationally (may be different from demonstration)
Improved efficiency and cyber security	of SCADA devices			
Fossil Fuel Consumption				
List and describe any benefits this techn	nology has or may have or	installation fossil fuel consumption	n or backup power gener	ator use
Potential Reduced frequency of ba	ackup generator use			
Renewable Energy				
List and describe any benefits this techn	nology has or may have or	installation renewable energy gene	eration, storage, integrat	ion, or management
Power Consumption				
List and describe any benefits this techn				
Potential Reduced installation pov	wer consumption throug	n improved distribution efficiency		
Power Modeling & Management				
List and describe any benefits this techn	nology has or may have or	installation power modeling, man	agement, or investment of	decisions
	pabilities for energy infras			
Operation and Support Requirements		-		next and encode installation or survey
List and describe any benefits this techn infrastructure.	norogy has or may have or	i the labor, materials, training, or co	minacting needed to sup	port and operate instandtion energy
Energy Assurance, Independence, & R				
-		installation energy assurance and r	esiliency, such as islandi	ng or isolation capability, recovery from
disruptions, or non-disruption of critic				
	to prevent cascading bla			
Potential Improved capability to r	estore grid functionality	after outages		

Default and any pretenses that solutioning it near in the rate of the type of the solution of the provide of the solution of t		be any benefits this technology has or may have on the cyber security of installation energy infrastructure
https://www.income/ability.toreetone oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to restore oppretion after successful cyber attacks between my over dapability to detect vyber abilities embedded within power control formware between attacks and formation feedback and for the successful cyber attacks between attacks betw		
Benefit in proceed capability to restore operation after successful cyber attack: Cost is and described any benefits this technology has or may have on installation energy costs that aren't described above Benefits in technology has or may have on installation energy costs that aren't described above Second Order Impacts What additional benefits, information, feebback, or control does this technology offer to the installation energy end user? What additional benefits, information, feebback, or control does this technology offer to the installation energy end user? What additional benefits, information, feebback, or control does this technology offer to the installation energy end user? What additional benefits, information, feebback, or control does this technology offer to the installation energy end user? What additional benefits, information, feebback, or control does this technology offer to future R&D efforts? Borner Increase of outrol capabilities for future experiments What ways did these obstacles hinder the implementation, or effectiveness of the demonstration forology? Project dodgs due to lack of workers What would you describe as the greatest benefit(i) of having completed this demonstration project? Improved patient on the specific wytews in use at newal facilities What would you would be required to make the connerectally available technology more suitable for Navy specific use? What advances or observations were made in this demonstration project? Evolutional provide capability of describe shader the installation greaters. What would you describe as the greatest benefit(i) of having completed this demonstration project? The project dodgs due to lack of workers What would you describe as the greatest benefit(i) of having completed		
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echnology Adoption Co	onsiderations
Technology Integration	
Maturity of the technology family	Human-Machine Interface flexibility, Communication Extensibility & Autonomy, Scalability and Analysis performance
Maturity/suitability of specific systems	
used in this project	
Integration with Navy-specific systems	Specific hardware systems may require updates or additions to ENSURE framework
Environmental or Installation-specific	
challenges	Technology must adapt to the specific systems used across different installations
Accessibility of required components	
Process Challenges	
	s Approvals required for testing detection systems on live SCADA components
Initial Funding or Resource Allocation	
issues Continued Funding or Resource	
Allocation issues	
Anocationissues	
Contracting / Procurement	supply chain considerations for ENSURE device
Challes had down Challes was a	
Stakeholder Challenges Impact on and Approval of certain	T
stakeholders	Energy manager and Cyber approval needed to interface with live SCADA components
stakenoluers	Lifergy manager and cyber approval needed to interface with the SCROK components
Limitations from stakeholder needs	
Operation and support labor	4
requirements	Need to determine who will conduct testing across installations
Necessary Funding Streams:	
Integration	
Necessary Funding Streams: Continued	
Support	
Continued feedback and improvement	usability vetting by operators
ntern Involvement	
Intern Name Year	(if known) Where are they now? (if known)
David Bright	
eferences	
Tech papers	
Author(s)	Title

Author(s)	Title	
Journal Articles, Publica	tions	
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B23. Project Information Form for Project 23. Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)

	percritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)
Proc. income on the second polarization Proc. income on the second polarization of the second polarizati	Other Names, Abriviations, etc:
	Contacts Name Phone Email Role Period of Performance
Process Description Market Privity 300 Process	POC1 Geancarlo Palavicini 619-553-7904 geancarlo palavicini@navy.mil PI FY17 FY19
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By cause a sady at & vulnerability research and embedded forfunare accurry assessment using network and protocol dynamic analysis Exercise for the set of the set o	Provide a brief description of the technology being implemented in this research project
Set up to three different technology types to categorize this project Technology Types Technology Types Technology Types Technology Types Technology Types	
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Technology Type 3 bit consumption Technology Type 3 bit consumption Consumpti Consumption	
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Potential Improved capability to isolate potential vectors for cyber attacks Potential Improved failsafes or system logic to limit potential damage from cyber attacks	List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure
Potential Improved failsafes or system logic to limit potential damage from cyber attacks	

CUSIS	
List and descri	ibe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additio	nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additio	nal benefits, information, feedback, or control does this technology offer to the installation energy manager?
Potential	Improved documentation of infrastructure
What additio	nal benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

/hat were the most significant obstacles encountered in this technology demonstration project?	- 1
any SCADA devices have proprietary system architecures, which makes in-depth analysis more difficult. Labor constraints and purchasing delays	
what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?	_
/hat would you describe as the greatest benefit(s) of having completed this demonstration project?	-
mark would you describe as the greatest benefity of maning completed and benefitiat action project i proved capability to assess the security posture of deployed JACE / SCADA devices within DON. Improved understanding and awareness of vulnerabilities, as well as	
Injector adjustice of a set of the second product of deproyee sets (second concernment of the improved and concernment of the	
FAUE	
/hat specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	-
nproved access to inner workings of JACE and SCADA devices would improve ability to analyze devices for potential vulnerabilities	
nce operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?	_
nproved capability to assess the security of JACE and SCADA energy management devices, discover inherant vulnerabilities, and protect against known and discovered	
ulnerabilities	
	_
/hat advances or observations were made in this demonstration project that could help justify continued investment in this technology? iscovered vulnerabilities, presented technical paper	_
iscovered vulneradirities, presented technical paper	
that new skills commatancies or experience were gained within the Naw workforce during this project?	
/hat new skills, competencies, or experience were gained within the Navy workforce during this project?	
/hat new skills, competencies, or experience were gained within the Navy workforce during this project?	
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/hat new skills, competencies, or experience were gained within the Navy workforce during this project?	

Technology Adoption Considerations

Technology Integration	
Maturity of the technology family	Penetration testing capabilities not yet mature
Maturity/suitability of specific systems	
used in this project	
Integration with Navy-specific systems	large variety of systems that need to be tested
Environmental or Installation-specific	limited capability to test systems while in use: specific naval installations may present greater challenges to finding time to conduct
challenges	testing
Accessibility of required components	

Process Challenges	
Certification or Approval requirements	Approval needed to access SCADA systems while in operations
Initial Funding or Resource Allocation	
issues	
Continued Funding or Resource	
Allocation issues	Continual funding needed for testing as vulnerability discovery capability improves
Contracting / Procurement	possible contractor support needed to safely access power systems
Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	Need approval and support of PW to access power systems
Limitations from stakeholder needs	Stakeholder operational needs limit ability to test on live systems
Operation and support labor	
requirements	Volume of systems requires considerable man-hours for testing
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued	
Support	
	Periodic updates to testing procedure as new vulnerability vectors discovered
ern Involvement	
Intern Name Year ((if known) Where are they now? (if known)
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NPS Student Theses Author(s)

Title (if known)

B24. Project Information Form for Project 24. Passive and Active Cyber-Defense for Cyber-Physical Systems – Strategies, Implementation and Evaluation



Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)
Improved effectiveness of active cyber defense technologies
Fossil Fuel Consumption
List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
Potential Reduced frequency of backup generator use
Renewable Energy
List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management
Party Commenting
Power Consumption
List and describe any benefits this technology has or may have on installation power consumption
Power Modeling & Management
List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions
Exe and decrete any potential curve of the compared on the compared on the compared on the curve of the curve
Improve any investor exponentes or exergi initiat determinitiente
Operation and Support Requirements
List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy
infrastructure.
Energy Assurance, Independence, & Resiliency
List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from
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Potential Improved fault isolation to prevent cascading blackouts
Potential Improved islanding capability to isolate and protect critical systems
Cyber Security
Types accuring List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure
List and describe any detents on its technology has or may have on the cyber security of installation energy initiastructure Personatate III improved monitoring and detection of potential cyber threats
Realized Improved capability to isolate potential vectors for cyber attacks
Potential Improved failsafes or system logic to limit potential damage from cyber attacks
Potential Improved capability to restore operation after successful cyber attacks
Costs
List and describe any benefits this technology has or may have on installation energy costs that aren't described above
Second Order Impacts
What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?
o)
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?
Other

Technology Demonstration Results

W/hat were the most significant of the	as accountered in this technology demonstration project?
what were the most significant obstacl	es encountered in this technology demonstration project?
In what ways did these obstacles hinder	the implementation, operation, or effectiveness of the demonstrated technology?
	t benefit(s) of having completed this demonstration project?
Improved situational awareness of Navy	Cyber-Physical Power System use, earlier indications of compromise, faster reactions to new threats
What specific adaptations (if any) would Expand to the wide variety of systems in	I be required to make the commercially available technology more suitable for Navy-specific use?
expand to the write variety of systems in	use at havai facilities
Once operationally mature what benef	its and/or drawbacks would this technology have over other (mature) alternative technologies?
energe and any mature, what benef	
What advances or observations were ma	ade in this demonstration project that could help justify continued investment in this technology?
What new skills, competencies, or expe	rience were gained within the Navy workforce during this project?
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hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project	Active cyber defense tools are immature and constantly evolving
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Intern Involvement

Necessary Funding Streams: Continued Support

Intern Name Year (if known) Where are they now? (if known)

Continued feedback and improvement continued evaluation needed to ensure that active cyber defense tools are adapting to meet evolving threats

References

Tech papers	
Author(s)	Title
Journal Articles, Publications Author(s)	THE PAGe 3
NPS Student Theses	
Author(s)	Title (if known)

B25. Project Information Form for Project 25: Deep Subgrid-parity Solar

Deep S	Deep Subgrid-parity Solar					
Other I	Names,	Abriviations, etc:				
Cont	tacts	Name	Phone	Email	Role	Period of Performance
PO	DC1	Randall Olsen	619-553-8713	randall.olsen@navy.mil	PI	FY16 FY17
PO	DC2	Nathan Stevens				Base / Installation
PO	0C3					SSC PAC, Miramar
Techno	مارم	y Description	`			
recime	JUS	y Description				
Provid	e a brie	of description of the te	chnology being impleme	nted in this research project		
Concer	Concentrated solar panel system composed of mirror arrays reflecting light on to PV panels in order to reduce the cost required for PV generation.					
Select	Select up to three different technology types to categorize this project					
Techno	ology Ty	/pe1	Renewable Generatio	n		
Techno	ology Ty	/pe 2	Renewable Integratio	n		
Techno	ology Ty	/pe 3				

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration) Reduced cost PV generation achieved by using inexpensive mirrors to concentrate light onto fewer expensive PV panels **Fossil Fuel Consumption** List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use Integrated alternative-powered backup power systems otentia Reduced requirement for backup generators to assure power Potential Renewable Energy List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management nstrated Added renewable energy generation capability (wind, solar, etc) trate mproved efficiency or effectiveness of existing renewable generation Power Consumption List and describe any benefits this technology has or may have on installation power consumption Power Modeling & Management List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions **Operation and Support Requirements** List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure echnology requires less maintenance labor than alternative systems Technology requires fewer or less costly replacement components that alternative systems Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems Reduced reliance on outside energy suppliers **Cyber Security** List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure Costs List and describe any benefits this technology has or may have on installation energy costs that aren't described above Reduced reliance on systems with expensive replacement parts

Potential	Improved energy access in remote facilities
	Improved energy access in remote lacing estimates
What additio	and benefits, information, feedback, or control does this technology offer to the installation energy manager?
What additio	nal benefits, information, feedback, or control does this technology offer to future R&D efforts?
Other	· · · · · · · · · · · · · · · · · · ·
hnolog	y Demonstration Results
0	,
What were th	e most significant obstacles encountered in this technology demonstration project?
	uoting, and procurement far slower than expected. Late in the process, NAVFAC decided this was Construction. Electrical production lower than theoreti
	cerbated by mirror degradation. Degraded coating on mirrors required new (more expensive) vendor
In what ways	did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Delayed acqu	isitions process, reduced output from theoretical expectations
	FADE
What would	
	you describe as the greatest benefit(s) of having completed this demonstration project?
	you describe as the greatest benefit(s) of having completed this demonstration project?
	you describe as the greatest benefit(s) of having completed this demonstration project?
	you describe as the greatest benefit(s) of having completed this demonstration project?
	you describe as the greatest benefit(s) of having completed this demonstration project?
	adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
UV stabilizers	adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? in mirror coating formula, determine nature of "construction" classification, identify causes for discrepencies between theoretical and actual energy
UV stabilizers	adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
UV stabilizers	adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? in mirror coating formula, determine nature of "construction" classification, identify causes for discrepencies between theoretical and actual energy
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Technology Integration					
Maturity of the technology family	Long-term duration / UV stabilization of mirror coating solution				
Maturity/suitability of specific systems					
used in this project	identify causes of discrepencies between actual and theoretical energy yield				
Integration with Navy-specific systems	integration with larger utility grid				
Environmental or Installation-specific					
challenges	cost/benefit assessment for installations with less sunlight available				
Accessibility of required components	Need to establish partnerships to produce components in larger quantities				
Process Challenges					
Certification or Approval requirements	Construction approval for solar projects				
Initial Funding or Resource Allocation					
issues					
Continued Funding or Resource					

Allocation issues	
Contracting / Procurement	technology licensing approval for private industry partnerships

Stakeholder Challenges

Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	Required agreements for utility grid tie-in
Limitations from stakeholder needs	possible rooftop installation or space use considerations from stakeholders, reliability concerns
Operation and support labor	
requirements	maintencance considerations
Necessary Funding Streams:	
Integration	
Necessary Funding Streams: Continued	
Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
John Hernandez		
Dan Reil		
Chris Hardy		
Gaston Ragazzo		
Jeff Leigh		

References

Tech papers	
Author(s)	Title
-	
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B26. Project Information Form for Project 26. Energy and Water Recovery by Microbial Fuel Cells

rgy and					
Other Names,	, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performanc
POC1	Lewis Hsu	619-553-4934	lewis.hsu1@navy.mil	PI	FY14 FY1
POC2					Base / Installation
POC3					RTS Warner Springs, MCB H
nnolog	y Descriptio	n			
			ented in this research project		
			ewater treatment at Navy facilities tewater practices, useable power g		reusable water from wastewater, resultir recovery
elect up to t	three different techno	ology types to categorize t	his project		
echnology T		Waste Energy Recover			
echnology T		Renewable Generatio	in		
echnology T	ype 3				
icipate	d Benefits o	of this Technology	ogy		
					ay be different from demonstration)
lelps reduce energy securi		s and meet Navy Net-Zero g	oals by reducing impact from wast	tewater, recovering water for re	euse, and generating power, thereby impr
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Technolo	ogy Integration			
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challenge	25		Scalability, re	strictions regarding large-scale use of certain microbes in protected environments? Climate impact on microbes?
Accessibil	lity of required com	nponents	Commercial d	lesign and speed of manufacturing challenges
Process C	Challenges			
			certifications	for reuse of recovered water, health & safety, regulatory compliance
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Support				
Continue	ed feedback and imp	roverent		
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ntern In	nvolvement	t		
Intern Na	ime	Year (i	if known)	Where are they now? (if known)
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Author(s))		Title	

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Journal Articles, Publicat	ions	
Author(s)	Title	
	÷	
NPS Student Theses		
Author(s)	Title (if known)	

B27. Project Information Forms for Project 27: Ad-Hoc Portable Power Systems (APPS)

HUC PO	rtable Powe	er Systems (AP	PS)		
		, <u>,</u>	•		
Other Names,	, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Wayne Liu	619-553-1900	wayne.p.liu@navy.mil	PI	FY17 FY19
POC2	Lewis Hsu				Base / Installation
POC3	Nathan Johnson				SSC PAC San Diego
hnolog	y Descriptio	n			
	•		ented in this research project		
Provide a brid	ef description of the to	echnology being impleme		field test sites around naval t	test facilities using waterside energy general
Provide a brid	ef description of the to	echnology being impleme		field test sites around naval t	test facilities using waterside energy generat
Provide a brid	ef description of the to ems and methods for p ystems. 500W fuel cell	echnology being impleme roviding Ad-Hoc or tempo ls are mounted to golf cart	prary power at water-side or remote is with solar charging systems.	ield test sites around naval t	test facilities using waterside energy generat
Provide a brid Evaluate syste and storage so Select up to t	ef description of the to ems and methods for p ystems. 500W fuel cell three different techno	echnology being impleme roviding Ad-Hoc or tempo Is are mounted to golf cart plogy types to categorize t	prary power at water-side or remote as with solar charging systems. this project	field test sites around naval t	test facilities using waterside energy generat
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Anticipated Benefits of this Technology

	Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)
would enable	e cost-effective power for testing facilities, TRL demonstrations, and other applications that don't require a permanent grid infrastructure
Fossil Fuel Co	nsumption
	ibe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
	Reduced reliance on portable fossil fuel power generators
Demonstrate	Improved efficiency or alternative fueled vehicles on installation
Renewable E	
List and descr	ibe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management
	Added renewable energy generation capability (wind, solar, etc)
	Integrated or expanded renewable energy storage
Potential	Improved decision support capabilities for investing in renewable systems
Power Consu	mption
	be any benefits this technology has or may have on installation power consumption
Power Mode	ling & Management
	ing & wanggement ibe any benefits this technology has or may have on installation power modeling, management, or investment decisions
	d Support Requirements ibe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy
infrastructur	
Potential	Reduced contractor support required to install, maintain, or operate technology
Potential	Technology requires less maintenance labor than alternative systems
Potential	Technology reduces need for specialized training
Energy Assur	ance Independence & Resiliency
	ance, Independence, & Resiliency ibe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from
List and descr disruptions, o	ibe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from or non-disruption of critical systems
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Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?
Pierside conditions can lead to degradation of equipment and fuel cells
n what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Page 2
What would you describe as the greatest benefit(s) of having completed this demonstration project?
Vhat specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
what specific adaptations (in any) would be required to make the commerciany available technology more suitable for wavy-specific user
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
What new skills, competencies, or experience were gained within the Navy workforce during this project?
what they skins, completencies, or experience we agained within the way workforce during this project?
עבי כבוי צאבורווא, אמנאמצווא שינוי רפסטי ני מוואטיו ביצוועיבא

Technology Integration Must become cost competitive with portable conventional generators Maturity/suitability of specific systems used in this project Must become cost competitive with portable conventional generators Integration with Navy-specific systems Scalability issues will need to be addressed for certain applications or test sites Environmental or Installation-specific challenges Long term suitability subject to factors such as corrosion resistance. Effectiveness subject to solar availability Accessibility of required components Limited number of suppliers available Process Challenges Certification or Approval requirements issues Continued Funding or Resource Allocation issues pressurized hydrogen gas storage? Initial Funding or Resource Allocation issues Initial Funding or Resource	
Maturity of the technology family Must become cost competitive with portable conventional generators Maturity/Suitability of specific systems	
Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Scalability issues will need to be addressed for certain applications or test sites Environmental or Installation-specific challenges Long term suitability subject to factors such as corrosion resistance. Effectiveness subject to solar availability Accessibility of required components Limited number of suppliers available Process Challenges Certification or Approval requirements pressurized hydrogen gas storage? Initial Funding or Resource Allocation Issues Continued Funding or Resource Allocation issues	
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Initial Funding or Resource Allocation issues Continued Funding or Resource Allocation issues	
issues Continued Funding or Resource Allocation issues	
Allocation issues	
Contracting / Procurement System procurement as a complete package (including vehicle) or retrofitting existing vehicles	
Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	
Limitations from stakeholder needs Operation and support labor	
requirements system operation training	
Tequirements system operation craning Necessary Funding Streams:	
Necessary transportants	
Recessary Funding Streams: Continued	
Support Fuel cell and related system maintenance training	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers	
Author(s)	Title
-	
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B28. Project Information Forms for Project 28: Energy Village: A Littoral Energy Test Facility

nergy Vill	age: A Littora	l Energy Test F	acility		
Other Names.	, Abriviations, etc:				
Contacts	Name	Phone Phone	Email	Role	Period of Performance
POC1 POC2	Wayne Liu Alan Williams	619-553-1900	wayne.p.liu@navy.mil	PI	Base / Installation
POC3	Max Kerber				SSC San Diego
echnolog	y Description				
Provide a brie	ef description of the tech	nology being implemente	d in this research project		
Microgrid for	pierside UUV testing cons	sisting of a microgrid with s	olar panels, microbial fuel ce	ells, and underwater charging c	onnectors
Select up to t	three different technolog	gy types to categorize this p	roject		
Technology Ty	ype 1	Microgrids, Islanding, Iso	ation		
Technology Ty		Implementation, Integrat	ion, Adaptation		
Technology Ty	ype 3	Other			
nticipate	d Benefits of t	this Technolog	V		
			-		
					
					nay be different from demonstration)
	tegrating underwater cha teries and generators for p		more efficient testing of UU	vs in pierside and litoral enviro	nments where researchers have traditionally had
Fossil Fuel Co	insumption				
List and descr	ribe any benefits this tech	nology has or may have on i	nstallation fossil fuel consun	nption or backup power genera	ator use
Demonstrated	<mark>c</mark> Reduced frequency of ba	ackup generator use			
		or backup generators to assu			
Potential	Integrated alternative-p	owered backup power syst	ems		
Renewable E	nerm		\mathbf{O}		
		nology has or may have on i	nstallation renewable energy	generation, storage, integration	on or management
		y generation capability (wir			
		renewable energy storage			
Demonstrate	c Improved efficiency or e	ffectiveness of existing ren	wable energy storage		
Devues Consu					
Power Consu	•	nology has or may have on i	nstallation power consumpt	ion	•
			improved distribution efficie		
		rage to reduce peak power			
	ling & Management		and all address and the second s		
List and descr	tipe any benefits this tech	nology has or may have on	nstallation power modeling,	management, or investment d	
	d Support Requirements				
		nology has or may have on	he labor, materials, training,	or contracting needed to supp	port and operate installation energy
infrastructure					
Demonstrated Potential		port required to install, ma operate than alternative sys	intain, or operate technolog	У	
Potential	rectificitory is easier to o	perate than alternative sys	.em5		
Energy Assura	ance, Independence, & R	esiliency			
			nstallation energy assurance	and resiliency, such as islandin	g or isolation capability, recovery from
	or non-disruption of critic				
Potential	Automated backup syste				
Demonstrated			t an availant		
Demonstrated Potential		e capability for independen ability to isolate and protec			
roteittidi	improved islanding capa	asiney to isolate and protec	control systems		

Cyber Security

	List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure
	Costs
	List and describe any benefits this technology has or may have on installation energy costs that aren't described above
	Potential Reduced reliance on systems with expensive replacement parts

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?
Demonstrated Improved energy access in remote facilities
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?
Demonstrated Real-time monitoring of energy systems
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?
Demonstrated Improved control capabilities for future experiments
Potential Improved access to energy use data
Other

Demonstrated Supports continuous UUV operation and data transfer

Reduced wear and tear on mechanical systems

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?
purchasing delays
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Page 2
What would you describe as the greatest benefit(s) of having completed this demonstration project?
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
Allows for continuous UUV operations in environments where conventional grid power is limited or impractical, does not require replenishment of liquid fuel for generators,
and facilitates data transfer in addition to energy production/transfer
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
What new skills, competencies, or experience were gained within the Navy workforce during this project?

Environmental or Installation-specific challenges Undersea environments may limit space available for MFC chargers Accessibility of required components few if any commercial suppliers available for MFC and charging systems Process Challenges Certification or Approval requirements Will require environmental permitting, data transmission cyber security certifications Difficult to establish a ROI to justify funding Continued Funding or Resource Allocation issues Contracting / Procurement Limited number of suppliers? Stakeholder Challenges Contracting / Procurement Limited number of suppliers? Stakeholder Steeps Impact on and Approval of certain stakeholder needs Deperation and support labor requirements Necessary Funding Streams: Ambiguity as whether this would be funded under operational energy or installational energy? Continued feedback and improvement	Technology Integration	
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and involvement	ern Involvement	-

Intern Name	Year (if known)	Where are they now? (if known)
Amar Ammeen		
Bashar Ammeen		
Jeff Kadis		
Nataly Pestana		

References

Tech papers		
Author(s)	Title	
Journal Articles, Publications		
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B29. Project Information Form for Project 29: Decentralized Micro-Grid with Fuel Cell Energy Storage: Feasibility Study

ecentrali	zed Micro-g	rid with Fuel Ce	ell Energy Storag	e: Feasibility Stu	dy
Other Names	, Abriviations, etc:	Facility-Scale Decentral	ized Micro-grid with PEM fuel	cell, H2 Production and stora	ge, and PV feasibility
Contacts POC1	Name Arthur Rubio	Phone 619-553-1904	Email rubio@spawar.navy.mil	Role	Period of Performance FY16 FY17
POC2	Jeremy Poche	019-555-1504		r i	Base / Installation
POC3	Mike Putman				TBD
chnolog	y Descriptio	on			
	-				
Provide a bri	ef description of the f	technology being implemen	ted in this research project		
	implementing a hybri ge, H2 production fro		ith energy storage is a feasible	solution for increasing energy	security. Microgrid will include PV generation, H2
Select up to 1	three different techn	ology types to categorize thi	s project		
Technology T	ype 1	Microgrids, Islanding, I	solation		
Technology T		Energy Storage			
Technology T		Renewable Integration			
ticipate	d Benefits o	of this Technolo	gy		
Bottom Line	In Front: Describe th	e higgest anticinated henefit	of successfully implementing t	his technology operationally	(may be different from demonstration)
					lation used to size and select components for
	plementation			Ŭ	
Fossil Fuel Co	nsumption				
		echnology has or may have o	n installation fossil fuel consu	nption or backup power gene	rator use
Potential	Integrated alternati	ve-powered backup power sy	stems		
Potential	Improved efficiency	or alternative fueled vehicles	s on installation		
Potential	Improved decision s	support capability for sizing b	ackup generators		
Potential	Reduced requireme	nt for backup generators to a	ssure power		
Renewable E					
Potential		or effectiveness of existing re	n installation renewable energy	y generation, storage, integra	tion, or management
Potential		to estimate ROI of renewable			
		support capabilities for invest			
Power Consu	-				
			n installation power consump	tion	
Demonstrate	Incorporated energy	y storage to reduce peak pow	er demand		
Power Mode	ling & Management				
List and desci	ribe any benefits this t	echnology has or may have o	n installation power modeling	, management, or investment	decisions
Potential	Power modeling use	ed to optimize grid configurat	tion or expansion		
Demonstrate	Modeling and simul	ation to inform energy infras	tructure investments		
0		4 -			
	d Support Requirement		n the labor materials training	or contracting needed to sur	oport and operate installation energy
infrastructur				, or contracting needed to sup	sport and operate instantation energy
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			n installation energy assurance	e and resiliency, such as island	ing or isolation capability, recovery from
	or non-disruption of c	,			
Potential Potential		outside energy suppliers prage capability for independ	entoneration		
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Reduced mainte	

Technology Integration	
Maturity of the technology family	large scale fuel cells not yet commerically mature, requires coordination with multiple contractors
Maturity/suitability of specific systems	
used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific	
challenges	Possible barriers in allocating space for large fuel cell and hydrogen storage, dependent on scale of project
Accessibility of required components	must coordinate with multiple contractors to build a complete system
Process Challenges	
Certification or Approval requirements	interconnect agreements needed to facilitate grid-tied systems
Initial Funding or Resource Allocation	
issues	large up front cost
Continued Funding or Resource	
Allocation issues	possible contractual delays may force continuation of funds to complete projects
Contracting / Procurement	difficulties in coordinating multiple contractors for sourcing parts and installing components
Stakeholder Challenges	
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stakeholders	location of hydrogen storage could impact certain stakeholders
Limitations from stakeholder needs	limitations on available space suitable for system
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	
Necessary Funding Streams: Continued	
Support	possible maintenance considerations
Cantinual feedback and improvement	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Jeremy Poche		

References

Tech papers	
Author(s)	Title
-	
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B30. Project Information Form for Project 30: Optimization of a Decentralized Microgrid with PEM Fuel Cell, Electrolyzer and H2 Storage



Anticipated Benefits of this Technology

ttomlin	
	Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)
	pability to deploy independent or networked microgrids on naval facilities to improve energy assurance through energy storage and islanding capabilities
ril Eucl (onsumption
	ribe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
tential	Reduced natural gas needed for heating or installation operations
tential	Integrated alternative-powered backup power systems
tential	Reduced frequency of backup generator use
newable	Enormy
	rine any tenefits this technology has or may have on installation renewable energy generation, storage, integration, or management
tential	Improved efficiency or effectiveness of existing renewable generation
tential	Improved efficiency or effectiveness of existing renewable energy storage
tential	Improved capability to integrate renewables into larger grid
alized	Improved decision support capabilities for investing in renewable systems
wer Cons	umption
	ribe any benefits this technology has or may have on installation power consumption
monstrat	en Incorporated energy storage to reduce peak power demand
wer Mod	eling & Management
	ring as management
monstrat	ad Modeling and simulation to inform energy infrastructure investments
erationa	nd Support Requirements
	Tibe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy
rastructu	re
	rance, Independence, & Resiliency
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Technology Demonstration Results

sues related to test system setup: software communications, deionized water conductivity, labview integration. Personnel leaving and acquisition issues	
what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?	
what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?	
what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?	
what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?	
what ways did these obstacles indee the implementation, operation, or enectiveness of the demonstrated technology:	
/hat would you describe as the greatest benefit(s) of having completed this demonstration project?	
mar would you describe as the greatest detention of maning compreted this denominant action project: emonstrated increased capability to integrate cost-effective energy storage and improve power stability on naval facilities	
consistence include topology and the include concentration of the proversion of the include of t	
FAUE /	
vhat specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
what specific doubtions (in any would be required to make the commenciary available commonly more suitable for heavy specific does more doubting to integrate with existing systems	
inproved capability to intregrate with existing systems	
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?	
ystem would require less maintenance than alternative energy storage systems due to lack of moving parts or battery degradation	
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?	
Achieved TRL5 for PEM microgrid system	
Vhat new skills, competencies, or experience were gained within the Navy workforce during this project?	

Technology Integration	
Maturity of the technology family	system ROI limited by efficiency of PEM fuel cell technology maturity
Maturity/suitability of specific systems	
	limitations due to test bed setup
Integration with Navy-specific systems	Efficiency of system limits potential use cases
Environmental or Installation-specific	
challenges	
Accessibility of required components	

Process Challenges

Certification or Approval requirements	approval required to integrate system with larger power grid or as a backup power supply
Initial Funding or Resource Allocation	
issues	cost of components limits scale of demonstration project
Continued Funding or Resource	
Allocation issues	
Contracting/Procurement	Possible lengthy procurement process for components

Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	approval and support from PW needed to integrate large scale systems
Limitations from stakeholder needs	limited efficiency of fuel cell system may limit potential applications
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	large up front cost for installing system
Necessary Funding Streams: Continued	
Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Jeremy Poche		

References

Tech papers		
Author(s)	Title	
Journal Articles, Publications		
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	
		_

B31. Project Information Forms for Project 31: Mobile EMS

Mobile EM	15				
Other Names.	Abriviations, etc:				
Contacts POC1	Name	Phone 831-656-2637	Email	Role	Period of Performance FY15 FY16
POC1 POC2	Dr. Giovanna Oriti Dr. Julian	831-656-2637	goriti@nps.edu	PI	FY15 FY16 Base / Installation
POC3					NPS
echnolog	y Description				
Provide a brid	of description of the tech	nology being implemente	d in this research project		
				can be moved to differen	nt locations for practical demonstrations and
microgrid stu		ducational platform for NP			e connected to the grid or in islanding mode
Select up to t	hree different technolog	y types to categorize this p	project		
Technology Ty					
Technology T Technology T					
-					
Anticipate	d Benefits of t	his Technolog	Y		
Bottom Line	Up Front: Describe the big	gest anticipated benefit of	successfully implementing this tecl	nnology operationally (n	nay be different from demonstration)
Improved mic	crogrid demonstration an	d education capabilities to	justify further expansion of larger r	nicrogrid projects	
5					
Fossil Fuel Co	•	nology has or may have on i	nstallation fossil fuel consumption	or backup power genera	ator use
Potential		owered backup power syste			
Potential	Reduced requirement fo	r backup generators to assu	irepower		
Renewable E	norm		000		
		hology has or may have on i	nstallation renewable energy gener	ation, storage, integratio	on, or management
Potential		generation capability (win			
Potential	Integrated or expanded i	renewable energy storage			
Potential		stimate ROI of renewable s			
Potential	Improved decision supp	ort capabilities for investin	g in renewable systems		
Power Consu	mption				
	-	nology has or may have on i	nstallation power consumption		
Potential	Incorporated energy sto	rage to reduce peak power	demand		
Power Mode	ling & Management				
List and descr	ibe any benefits this techr	nology has or may have on i	nstallation power modeling, mana	gement, or investment d	ecisions
Operation and	d Support Requirements				
		hology has or may have on t	he labor, materials, training, or co	ntracting needed to supp	port and operate installation energy
infrastructure Potential		d for specialized training			
Fotentia	reamonogy reduces need	a tor specialized training			
	ance, Independence, & R		notellation on organization of	allianau augh e-teles P	g or isolation capability, recovery from
	or non-disruption of critic	0, ,	instantation energy assurance and re	smency, such as Islandin	ig or isolation capability, recovery from
Potential	Reduced reliance on out				
Potential		capability for independen	t operation		
Potential	Improved islanding capa	bility to isolate and protec	t critical systems		
Potential	Improved capability to r	estore grid functionality af	ter outages		

Costs	ni ha any hanafita this tagka alam, has a may have an installation an error easts that error had an error had a
Realized	rribe any benefits this technology has or may have on installation energy costs that aren't described above Improved decision support tools to inform future investments or funding requirements
econd Orde	er Impacts
	onal benefits, information, feedback, or control does this technology offer to the installation energy end user?
Potential	Increased awareness of energy use
	ed Improved energy access in remote facilities onal benefits, information, feedback, or control does this technology offer to the installation energy manager?
Vilat addite	Sharberete, mormator, recodect, or control dees this teemology one to the installation energy manager.
	onal benefits, information, feedback, or control does this technology offer to future R&D efforts?
otential	Improved control capabilities for future experiments
Other	
	be most significant obstacles encountered in this technology demonstration project?
What were t	
What were t n what way What would	he most significant obstacles encountered in this technology demonstration project? s did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Page 2 I you describe as the greatest benefit(s) of having completed this demonstration project?
Vhat were t n what way Vhat would	he most significant obstacles encountered in this technology demonstration project? s did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
What were t n what way What would Demonstrat	he most significant obstacles encountered in this technology demonstration project? s did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Page 2 I you describe as the greatest benefit(s) of having completed this demonstration project?
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What were t n what way What would Demonstrat What specifi Dince operat Demonstrat	he most significant obstacles encountered in this technology demonstration project?

echnology Adopt	ion Co	nsidera	tions
Technology Integration			
Maturity of the technology f		Limited availa	bility of prepackaged COTS systems for larger integration
Maturity/suitability of speci	fic systems		
used in this project			
Integration with News enact	C. a. ustama		
Integration with Navy-specif Environmental or Installatio			
challenges	in-specific	Interconnecti	on issues with base power grid
enunenges		linterconnectio	Sin 1550c5 with base power gift
Accessibility of required com	nponents		
Process Challenges			
Certification or Approval rec		Interconnect a	agreements with local utility providers
Initial Funding or Resource A	Allocation		
issues Continued Funding or Resou	Irco		
Allocation issues	nce	funding for tra	veling demonstrations
			vering demonstrations
Contracting / Procurement			
Stakeholder Challenges			
Impact on and Approval of c	ertain		
stakeholders		PW approval r	needed to connect into larger power grid
Limitations from stakeholde			
Operation and support labor	r		
requirements		support labor	needed for traveling demonstrations
Necessary Funding Streams:			
Integration			
Necessary Funding Streams:	Continued		
Support			
Continued feedback and imp	provement	System must b	e updated periodically to adapt to changing needs
tern Involvemen	t		
Intern Name	Year (i	fknown)	Where are they now? (if known)
foroncoc			
ferences			
Tech papers			
Author(s)		Title	
Journal Articles, Publication Author(s)	ns	Title	

NPS Student Theses Author(s)

Title (if known)

B32. Project Information Form for Project 32: Photovoltaic Power Conditioning System for an Energy Management System (EMS)

hotovolta	aic Power Co	onditioning Sys	tem for an Energy	Management	System (EMS)
Other Names,	, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Giovana Oriti	831-656-2637	goriti@nps.edu	PI	FY16 FY18
POC2	Alex Julian				Base / Installation
POC3					NPS
	y Descriptio	n			
Provide a brie	ef description of the t	echnology being implemen	ted in this research project		
Continue dev	elopment of Energy M		rporate supercapacitor energy stor	age to increase battery life	and improve the effectiveness of energy storage.
Continue dev Improvement	elopment of Energy M t of solar energy contro	anagement Systems to inco	rporate supercapacitor energy stor oduction from PV	age to increase battery life	and improve the effectiveness of energy storage.
Continue dev Improvement	elopment of Energy M t of solar energy contr three different techno	anagement Systems to inco oller to maximize energy pro	rporate supercapacitor energy stor oduction from PV	age to increase battery life	and improve the effectiveness of energy storage.
Continue dev Improvement Select up to t	elopment of Energy M t of solar energy contri three different techno ype 1	anagement Systems to inco oller to maximize energy pro ology types to categorize th	rporate supercapacitor energy stor dduction from PV	age to increase battery life	and improve the effectiveness of energy storage.

Anticipated Benefits of this Technology

Bottom Line	Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)
	iciency of energy management system
	onsumption
ist and deso otential	ribe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use Integrated alternative-powered backup power systems
otential	Reduced frequency of backup generator use
otential	Reduced requirement for backup generators to assure power
Renewable	
otential	ribe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management Improved efficiency or effectiveness of existing renewable generation
otential	Improved efficiency or effectiveness of existing renewable energy storage
otential	Improved capability to estimate ROI of renewable systems
ower Cons	•
otential	ribe any benefits this technology has or may have on installation power consumption Incorporated energy storage to reduce peak power demand
Potential	Reduced installation power consumption through improved distribution efficiency
. –	
	eling & Management
otential	ribe any benefits this technology has or may have on installation power modeling, management, or investment decisions Power modeling used to optimize grid configuration or expansion
otentia	
	ribe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy re.
nfrastructu	
nfrastructu inergy Assu	
nfrastructu Energy Assu ist and deso lisruptions,	e. ance, Independence, & Resiliency ribe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from or non-disruption of critical systems
nfrastructu Energy Assu List and desc disruptions, Potential	e. ance, Independence, & Resiliency ribe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from or non-disruption of critical systems Automated backup systems for critical systems
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I
Technology Demonstration Results

••
What were the most significant obstacles encountered in this technology demonstration project?
n what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Page 2
What would you describe as the greatest benefit(s) of having completed this demonstration project?
mproved efficiency in energy management systems that can be scaled up to larger microgrid systems
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
what specific adaptations (if any) words be required to make the commentant warrance team to be an adaptation of the system that are commentant of the custom-build lab solution.
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
mproved efficiency in energy management systems that can be scaled up to larger microgrid systems
inproved enclency in energy management systems that can be scaled up to harger interogrid systems
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
Adding supercapacitors to battery systems improves battery life and may improve cost effectiveness of battery energy storage systems
What new skills, competencies, or experience weregained within the Navy workforce during this project?
אוום וופא אווה, כטווףברוכובי, טו באףבורבוכב שבו במחובע אונוווו גווב אסטץ אטראטיכב לעוווק נווג פו טובען

Technology Integration	
Maturity of the technology family	lack of mature COTS solutions
Maturity/suitability of specific systems	
used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific	
challenges	possible challenges when integrating with power grids at specific bases
Accessibility of required components	lack of mature COTS solutions
Process Challenges	
	approval required for integration into larger grid or power distribution networks
Initial Funding or Resource Allocation	
issues	
Continued Funding or Resource	
Allocation issues	periodic battery replacement
Contracting / Procurement	component procurement, possible contracting challenges when integrating larger systems
Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	Installation of EMS must not interfere with grid operation, need to coordinate with PW
Limitations from stakeholder needs	
Operation and support labor	
requirements	maintenance needed to ensure battery health and replace degraded batteries
Necessary Funding Streams:	
Integration	
Necessary Funding Streams: Continued	
Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

Tech papers	
Author(s)	Title
Oriti et all	Power Electronics Enabled Energy Management Systems
Oriti et all	SLR Converter Design for Multi-Cell Battery Charging
Oriti et all	Reducing Fuel Consumption in a Forward Operating Base using an Energy Management System
Journal Articles, Publications	
Author(s)	Title
Oriti et all	Reducing fuel consumption at a remote military base: introducing an energy management system
Oriti et all	Battery Management System with Cell Equalizer for Multi-Cell Battery Packs
Oriti et all	PV Power Conditioning System with LLC Resonant Converter in DCM
NPS Student Theses	
Author(s)	Title (if known)
LCDR Gabe Hernandez	
LT Jason Valiani	
LT Cody Keesee	

B33. Project Information Form for Project 33: RTU Challenge

RTU Chall	enge				
Other Names	s, Abriviations, etc:				
	.,				
Contacts	Name	Phone Phone	Email	Role	Period of Performance
POC1 POC2	Max Hogan Paul Kistler	805-982-1557 805-982-1387	max.hogan@navy.mil paul.kistler@navy.mil		FY14 FY17 Base/Installation
POC3					NAS Key West
Technolog	gy Description				
Provide a br	ief description of the tech	hnology being implemente	d in this research project		
Test and imp	lement new-to-market hig	gh efficiency roof top air co	nditioning units with potential energy	savings of 40%	
Select up to	three different technolog	gy types to categorize this	project		
Technology ⁻		Implementation, Integra	tion, Adaptation		
Technology		-			
Technology ⁻					
Anticipate	ed Benefits of	this Technolog	y		
•		¥	•		
Bottom Line	• Up Front: Describe the bi	ggest anticipated benefit o	f successfully implementing this techn	ology operationally (m	ay be different from demonstration)
Reduce the e	energy demands of HVAC sy	ystems by adopting new en	ergy efficient rooftop AC units		
Fossil Fuel C	onsumption				
List and desc	ribe any benefits this tech	inology has or may have on	installation fossil fuel consumption or	backup power generat	tor use
Renewable I List and desc		nology has or may have on	installation renewable energy generati	ion, storage, integratio	on, or management
Power Cons	umption				
		inology has or may have on	installation power consumption		
Demonstrate	ec Reduced installation po	ower consumption through	improved end-user efficiency		
Power Mode	eling & Management				
		inology has or may have on	installation power modeling, manager	ment, or investment de	ecisions
Onenation	nd Cumment De suive mente	_			
	nd Support Requirements cribe any benefits this tech		the labor, materials, training, or contr	acting needed to supp	ort and operate installation energy
infrastructu		0,,,	, , , , , , , , , , , , , , , , , , ,	0	
Energy Accord	rance, Independence, & F	Resiliency			
			installation energy assurance and resil	iency, such as islanding	g or isolation capability, recovery from
	or non-disruption of criti				

Costs	ho any herefits this technology has as may have an installation on any sosts that area's described above
list and descri	be any benefits this technology has or may have on installation energy costs that aren't described above
econd Order	•
Vhat addition	al benefits, information, feedback, or control does this technology offer to the installation energy end user?
Vhat addition	al benefits, information, feedback, or control does this technology offer to the installation energy manager?
Vhat addition	al benefits, information, feedback, or control does this technology offer to future R&D efforts?
Other	
hnolog	· Deve exetuation Devulte
noiog	y Demonstration Results
Vhat were the	P DEMONSTRATION RESUITS e most significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order
Vhat were the ignificant del	e most significant obstacles encountered in this technology demonstration project?
What were the significant del	e most significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Vhat were the ignificant del n what ways o roject compl Vhat would y	emost significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Page 2 ou describe as the greatest benefit(s) of having completed this demonstration project?
What were the ignificant del n what ways o Project compl What would y	ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years
Vhat were the ignificant del n what ways o roject compl Vhat would y	emost significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Page 2 ou describe as the greatest benefit(s) of having completed this demonstration project?
Vhat were the ignificant del n what ways o roject compl Vhat would y	emost significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Page 2 ou describe as the greatest benefit(s) of having completed this demonstration project?
What were the ignificant del n what ways of rroject compl What would y Demonstrated	e most significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Decouple as the greatest benefit(s) of having completed this demonstration project? I the viability of new RTUs adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
What were the ignificant del n what ways of rroject compl What would y Demonstrated	emost significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Decouple as the greatest benefit(s) of having completed this demonstration project? I the viability of new RTUs
What were the ignificant del n what ways of rroject compl What would y Demonstrated	e most significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Decouple as the greatest benefit(s) of having completed this demonstration project? I the viability of new RTUs adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
What were the ignificant del n what ways of rroject compl What would y Demonstrated	e most significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Decouple as the greatest benefit(s) of having completed this demonstration project? I the viability of new RTUs adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
What were th ignificant del n what ways Project compl Project compl What would y Demonstratec Mhat specific insure RTUs w	emost significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Decoupled this demonstration project? ou describe as the greatest benefit(s) of having completed this demonstration project? I the viability of new RTUs adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? on't corrode in a coastal environment
What were the ignificant del n what ways of Project compl Project compl What would y Demonstrated What specific insure RTUs w Dnce operatic	e most significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Decouple as the greatest benefit(s) of having completed this demonstration project? I the viability of new RTUs adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
What were the ignificant del n what ways of Project compl Project compl What would y Demonstrated What specific insure RTUs w Dnce operatic	e most significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Decouped as the greatest benefit(s) of having completed this demonstration project? It he viability of new RTUs adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? on't corrode in a coastal environment nally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What were the ignificant del n what ways of Project compl Project compl What would y Demonstrated What specific insure RTUs w Dnce operatic	e most significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Decouped as the greatest benefit(s) of having completed this demonstration project? It he viability of new RTUs adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? on't corrode in a coastal environment nally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What were the ignificant del n what ways of roject compl Vhat would y Demonstratec What specific insure RTUs w Droce operatio	emost significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order and these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years and the delayed by the years and
What were the iignificant del n what ways of roject compi What would y Demonstrated What specific insure RTUs w Drice operation Vore efficient What advance	emost significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order and these obstacles hinder the implement attor, operation, or effectiveness of the demonstrated technology? etion date delayed by three years Dagoe 2 ou describe as the greatest benefit(s) of having completed this demonstration project? Ithe viability of new RTUs adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? on t corrode in a coastal environment nally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? than systems currently in use sor observations were made in this demonstration project that could help justify continued investment in this technology?
What were the iignificant del n what ways of roject compi What would y Demonstrated What specific insure RTUs w Drice operation Vore efficient What advance	emost significant obstacles encountered in this technology demonstration project? ays caused by changing requirements, manufacturing delays, and an incorrect equipment order and these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? etion date delayed by three years and the delayed by the years and the years and the delayed by the years and

Technology Integration					
Maturity of the technology family	Possible delays in manufacturing of new units				
Maturity/suitability of specific systems					
used in this project					
Integration with Navy-specific systems					
Environmental or Installation-specific					
challenges	System efficiency will vary based on local climate				
Accessibility of required components	Limited number of new high efficiency RTUs available				
Process Challenges					
Certification or Approval requirements	Vendor approval authorizations				
Initial Funding or Resource Allocation					

issues	Must secure funding for installation costs				
Continued Funding or Resource					
Allocation issues	New RTU design may require additional maintenance funding				
Contracting / Procurement	Vendor approval and contracting authorizations to install and maintain units				

Stakeholder Challenges

Stakenolder Challenges					
Impact on and Approval of certain					
stakeholders	End user approval of new AC systems				
Limitations from stakeholder needs	Possible reliability considerations with new technology				
Operation and support labor					
requirements	Maintenance requirements unknown				
Necessary Funding Streams:					
Integration	Up front installation costs				
Necessary Funding Streams: Continued					
Support	Maintenance requirements unknown				
Continued feedback and improvement	environmental operating conditions could necessitate further modifications				

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B34. Project Information Sheet for Project 34. Improved Wind Load Design for Rooftop PV Systems

nproved W	ind Load De	sign for Roo	ftop PV S	Systems		
Other Names, Ab	riviations, etc:					
Contacts POC1 Fe	Name ernand Marguis	Phone 8316562	880 fmarguis@	Email	Role	Period of Performance
POC2	quis	0010002				Base / Installation
POC3						NPS
echnology I	Description					
Provide a brief d	escription of the techn	ology being impleme	nted in this rese	arch project		
					gn). Develop light-we	eight, non-adhesive, non-ballasted and non-
	ftop PV mounting solut ts. Validate that the pro					speed of 150 mph without the use of adhesives or ests
	e different technology		his project			
Technology Type		Energy Production				
Technology Type Technology Type						
nticipated	Benefits of t	his Technolo	ogy			
Bottom Line Up F	Front: Describe the bigg	gest anticipated benef	it of successfully	implementing this te	echnology operation	ally (may be different from demonstration)
Improved ROI on	PV systems by prevent	ing extreme weather d	lamage to system	is, and enabling PV sy	ystems at locations w	ith more extreme weather events
Famil Fuel Care						
Fossil Fuel Consu	any benefits this techn	ology has or may have	on installation f	ossil fuel consumptio	on or backup power a	renerator use
	- ,					
Renewable Energy		ology has or may have	on installation r	enewable energy gen	peration storage inte	egration, or management
	ded renewable energy				lerutron, storage, mit	
	nproved efficiency or eff					
Demonstrated Im	nproved capability to es	timate ROI of renewa	ble systems			
Demonstrated Im	nproved decision suppo	ort capabilities for inve	esting in renewat	ole systems		
Power Consumpt	tion any benefits this techn	ology has or may have	on installation p	oower consumption		
Power Modeling	, ,					
	any benefits this techn				nagement, or investm	nent decisions
Potential Mo	odeling and simulation	to inform energy infra	astructure invest	ments		
	upport Requirements		an tha labor m	toriale training or a	antropting pooled to	a support and an availabilities around
infrastructure.	any benefits this techn	ology has or may have	on the labor, ma	aterials, training, or c	contracting needed to	o support and operate installation energy
Demonstrated Re	educed contractor supp	ort required to instal	l, maintain, or op	perate technology		
Demonstrated Te	chnology requires less	maintenance labor th	an alternative sys	stems		
List and describe	e, Independence, & Re any benefits this techn on-disruption of critica	ology has or may have	on installation e	energy assurance and	resiliency, such as isl	anding or isolation capability, recovery from

List and desci	ibe any benefits this technology has or may have on the cyber security of installation energy infrastructure
Costs	
List and descr Realized	ibe any benefits this technology has or may have on installation energy costs that aren't described above Reduced wear and tear on mechanical systems
Demonstrate	Improved decision support tools to inform future investments or funding requirements
Second Order	Impacts
	nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
Potential	Improved energy access in remote facilities
What additio	nal benefits, information, feedback, or control does this technology offer to the installation energy manager?
What additio	l nal benefits, information, feedback, or control does this technology offer to future R&D efforts?
Other	
hnolog	
	v Demonstration Results
	y Demonstration Results
What were th	y Demonstration Results e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models
What were th	e most significant obstacles encountered in this technology demonstration project?
What were th Scheduling fo	e most significant obstacles encountered in this technology demonstration project?
What were th Scheduling fo In what ways	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models
What were th Scheduling fo In what ways What would y	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
What were th Scheduling fo In what ways What would y	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Describe as the greatest benefit(s) of having completed this demonstration project?
What were th Scheduling fo In what ways What would y	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Describe as the greatest benefit(s) of having completed this demonstration project?
What were th Scheduling fo In what ways What would y Improved cap	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events
What were th Scheduling fo In what ways What would y Improved cap	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Describe as the greatest benefit(s) of having completed this demonstration project?
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What were th Scheduling fo In what ways What would y Improved cap	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events
What were th Scheduling fo In what ways What would y Improved cap	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events
What were th Scheduling fo In what ways What would y Improved cap What specific	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events
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What were th Scheduling fo In what ways What would y Improved cap What specific	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
What were th Scheduling fo In what ways What would y Improved cap What specific	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
What were th Scheduling fo In what ways What would y Improved cap What specific Once operatic	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the asset of the demonstrated technology and the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? enally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What were th Scheduling fo In what ways What would y Improved cap What specific Once operatic	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
What were th Scheduling fo In what ways What would y Improved cap What specific Once operatic	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the asset of the demonstrated technology and the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? enally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What were th Scheduling fo In what ways What would y Improved cap What specific Once operatic	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the asset of the demonstrated technology and the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? enally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
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What were th Scheduling fo In what ways What would y Improved cap What specific Once operatio	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Device the asset of the demonstrated technology and the demonstrated technology? rou describe as the greatest benefit(s) of having completed this demonstration project? ability to extend lifetime of PV installations in areas with frequent extreme weather events adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? enally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What were th Scheduling fo In what ways What would y Improved cap What specific Once operatio	e most significant obstacles encountered in this technology demonstration project? r wind tunnel use and coordinating testing dates with completion of scale models did these obstacles hinder the implementation, or effectiveness of the demonstrated technology? Baba Baba Baba Baba Baba Baba Baba Baba

• •		
Technology Integration		
Maturity of the technology family	limited availa	blity of mature commercial solutions that meet navy-specific needs
Maturity/suitability of specific syste	ems	
used in this project		
Integration with Navy-specific syste	ms	
Environmental or Installation-speci		
challenges		constraints dependent on facility roof types
Accessibility of required componen	ts Delays for Cor	nmercial production of NPS-designed mounting systems
Process Challenges		
Certification or Approval requireme	ents PW and contr	racting approval to install PV systems, possible interconnect agreements with local utilities
Initial Funding or Resource Allocati		O-PPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
issues		
Continued Funding or Resource		
Allocation issues		
Contracting / Procurement	Contracting	o install PV systems
Stakeholder Challenges		
Impact on and Approval of certain		
stakeholders		
Limitations from stakeholder needs	Limitiation b	ased on roof type of specific buildings
Operation and support labor		
requirements		
Necessary Funding Streams:		
Integration		
Necessary Funding Streams: Contin	ued	
Support		
Continued feedback and improvem	ent Long term fee	dback needed to ensure that system life cycle performance matches scale model results
tern Involvement		
Intern Name Ye	ear (if known)	Where are they now? (if known)
-		

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B35. Project Information Sheet for Project 35: Marine Corps Base Hawaii Energy Management Evaluation (MCHB E-Manage) Seed

Marine Co	rps Base Hawa	aii Energy Man	agement Evalua	tion (MCBH E-N	/lanage) Seed
Other Names,	Abriviations, etc:				
Contacts POC1	Name Tyler Chun	Phone 808-471-3494	Email tyler.chun@navy.mil	Role	Period of Performance FY13 FY14
POC2	Jack Munechika				Base / Installation
POC3	Eric Inouye				MCBH
Technolog	y Description				
Provide a brie	ef description of the techr	nology being implemente	d in this research project		
					ity. The objective is to evaluate a cost-effective Easeof Utility –Human Interaction
Select up to t Technology T		y types to categorize this p	project		
Technology T					
Technology T					
Anticipate	d Benefits of t	his Technolog	У		
Bottom Line	Up Front: Describe the big	gest anticipated benefit of	successfully implementing this	technology operationally (r	nay be different from demonstration)
		ase, data regarding specific			
Fossil Fuel Co	•	ology has or may have on i	installation fossil fuel consump	tion or backup power genera	atorusa
Eist and deser	be any benefits this teening	ology has of hidy have on i		tion of backup power genera	
Renewable En List and descr		ology has or may have on i	installation renewable energy g	eneration, storage, integrati	on, or management
Power Consu List and descr	-	ology has or may have on i	installation power consumptio	n	
			improved end-user efficiency		
Demonstrated	Reduced installation pov	ver consumption through	building control automation		
-					
	ling & Management	ology has or may have on i	installation power modeling, m	anagement, or investment of	lecisions
Potential		optimize grid configuratio			
Realized		monitoring of installation			
Potential	A A LEAST AND A LEAST	abilities for energy infrastr	and the second		
Demonstrated	inoueinig and simulation	i to inform energy infrastru			
	d Support Requirements				
	,	ology has or may have on t	the labor, materials, training, o	r contracting needed to supp	port and operate installation energy
infrastructure	e.				
List and descr	ance, Independence, & Re ibe any benefits this techn or non-disruption of critica	ology has or may have on i	installation energy assurance ar	nd resiliency, such as islandir	ng or isolation capability, recovery from

Potential	ribe any benefits this technology has or may have on the cyber security of installation energy infrastructure Improved monitoring and detection of potential cyber threats
. J. Contentin	
Costs	
	ribe any benefits this technology has or may have on installation energy costs that aren't described above
Potential	Increased ability to diagnose need for preventative maintenance
Realized	Improved decision support tools to inform future investments or funding requirements
Second Orde	r Impacts
	onal benefits, information, feedback, or control does this technology offer to the installation energy end user?
Realized	Increased awareness of energy use
	onal benefits, information, feedback, or control does this technology offer to the installation energy manager?
Realized	Real-time monitoring of energy systems
What additio) onal benefits, information, feedback, or control does this technology offer to future R&D efforts?
Realized	Improved access to energy use data
Other	
hnolog	n Demonstration Recults
hnolog	y Demonstration Results
	y Demonstration Results ne most significant obstacles encountered in this technology demonstration project?
What were th	ne most significant obstacles encountered in this technology demonstration project?
What were th	
What were th	ne most significant obstacles encountered in this technology demonstration project?
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What were the second se	ne most significant obstacles encountered in this technology demonstration project?
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What were the second se	ne most significant obstacles encountered in this technology demonstration project?
What were the second se	ne most significant obstacles encountered in this technology demonstration project?
What were the second se	ne most significant obstacles encountered in this technology demonstration project?
What were the second se	ne most significant obstacles encountered in this technology demonstration project?
What were the second se	ne most significant obstacles encountered in this technology demonstration project?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Гес	chnology Adopt	ion Co	nsidera	tions
	Technology Integration			
	Maturity of the technology			
	Maturity/suitability of spec	ific systems		
	used in this project			
			Energy monit	oring systems must interface with legacy systems
	Environmental or Installation-specific			
	challenges			
	Accessibility of required cor	mponents		
	Process Challenges			
	Certification or Approval re		possible perm	itting requirements
	Initial Funding or Resource	Allocation		
	issues Continued Funding or Reso	urce		
	Allocation issues			
	Contracting/Procurement			
	contracting/ Procurement]		
	Stakeholder Challenges			
	Impact on and Approval of	certain		
	stakeholders		Coordination	with public works to install energy monitoring system
	Lindentin and the second shall also			
	Limitations from stakehold Operation and support labor			
	requirements)1		
	Necessary Funding Streams:			
	Integration			
	Necessary Funding Streams:	Continued		
	Support			
	Continued foodbook and in			
	Continued feedback and im	provement		
nt	ern Involvemen	t		
		•		
	Intern Name	Year (i	fknown)	Where are they now? (if known)
Ref	ferences			
	Tech papers			
	Author(s)		Title	
	Journal Articles, Publicatio			
	Author(s)		Title	
	Author(s)		nue	
	NPS Student Theses			
	Author(s)		Title (if knowr)

B36. Project Information Form for Project 36: Validate SIREN Computer Modeling

idate S	IREN Compu	ter Modeling			
Other Names	, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Ben Wilcox	805-982-2180	benjamin.p.wilcox@navy.mil	PI	FY14 FY16
POC2	Yuktaka Sugiyama				Base / Installation
POC3	Kurt Myers				NBVC San Nicolas Island
hnolog	y Descriptio	n			
	•		ented in this research project		
Provide a bri	ef description of the te	echnology being impleme		ion from wind 9, color a	nd changes in land caused buunching condition
Provide a bri	ef description of the te	echnology being impleme sign software utilizing we	ather models to predict power generati		nd changes in load caused by weather conditio
Provide a bri	ef description of the te	echnology being impleme sign software utilizing we			nd changes in load caused by weather conditic
Provide a brid Further devel (heating & co	e f description of the te lop SIREN microgrid des poling), incorporate sto	echnology being impleme sign software utilizing we	ather models to predict power generati and integrate with LIDAR wind measur		nd changes in load caused by weather conditio
Provide a brid Further devel (heating & co	ef description of the te lop SIREN microgrid de poling), incorporate sto three different techno	echnology being impleme sign software utilizing wer red energy management,	ather models to predict power generati and integrate with LIDAR wind measur ihis project		nd changes in load caused by weather conditic
Provide a bri Further devel (heating & co Select up to t	ef description of the te lop SIREN microgrid de poling), incorporate sto three different techno Type 1	echnology being impleme sign software utilizing we red energy management, logy types to categorize t	ather models to predict power generati and integrate with LIDAR wind measur this project ation		nd changes in load caused by weather conditio

Anticipated Benefits of this Technology

Bottom Line	Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)
	can help reduce costs of microgrid planning (especially storage) and simplify acquisition by providing better estimates of electrical load changes and renewab
generation c	nanges due to weather events
Fossil Fuel C	nsumption ribe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
Potential	Improved decision support capability for sizing backup generators
Renewable I	
Potential	ribe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management Improved decision support capabilities for investing in renewable systems
Potential	Improved capability to estimate ROL of renewable systems
Potential	Improved efficiency or effectiveness of existing renewable energy storage
Power Cons	•
	ibe any benefits this technology has or may have on installation power consumption
Potential	Reduced installation power consumption through improved distribution efficiency
Power Mode	ling & Management
	ribe any benefits this technology has or may have on installation power modeling, management, or investment decisions
	Power modeling used to optimize grid configuration or expansion
	Modeling and simulation to inform energy infrastructure investments
Potential	Improved metering and monitoring of installation energy use
One ration a	d Support Doguiromonte
	d Support Requirements ribe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy
nfrastructu	
	ance, Independence, & Resiliency ribe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from
	or non-disruption of critical systems
Cyber Secur	•
ist and desc	ribe any benefits this technology has or may have on the cyber security of installation energy infrastructure
osts	
ist and desc	ribe any benefits this technology has or may have on installation energy costs that aren't described above
emonstrate	Improved decision support tools to inform future investments or funding requirements
econd Orde	r Impacts
	r impacts inal benefits, information, feedback, or control does this technology offer to the installation energy end user?
Vhat additio	nal benefits, information, feedback, or control does this technology offer to the installation energy manager?
emonstrate	Improved documentation of infrastructure
	nal benefits, information, feedback, or control does this technology offer to future R&D efforts?
Potential	Improved access to energy use data
Potential	Improved control capabilities for future experiments
Deb an	
Other	

B37. Project Information Sheet for Project 37: LIDAR Wind Measurement Experiments

AR Win	d Measurem	nent Experime	ents		
Other Names,	Abriviations, etc:				
Contonto	Name	Phone	Email	Role	Period of Performance
Contacts POC1	Ben Wilcox	805-982-2180			
		805-982-2180	benjamin.p.wilcox@navy.mil	PI	FY14 FY1
POC2 POC3	Yuktaka Sugiyama				Base / Installation
PUC3	Kurt Myers				INRS JIM Creek
hnolog	y Descriptio	n			
	• •		ented in this research project		
	• •		ented in this research project		
Provide a brie	ef description of the te	chnology being impleme			
Provide a brie	ef description of the te	chnology being impleme	ented in this research project	al at sites with rough ter	rain or open ocean.
Provide a brie	ef description of the te able trailer with LIDAR	chnology being impleme mast system and software	e used to measure wind energy potentia	I at sites with rough ter	rain or open ocean.
Provide a brie Develop port: Select up to t	ef description of the te able trailer with LIDAR three different techno	chnology being impleme mast system and software logy types to categorize t	e used to measure wind energy potentia	I at sites with rough ter	rain or open ocean.
Provide a brie Develop porta Select up to t Technology T	ef description of the te able trailer with LIDAR three different technol ype 1	chnology being impleme mast system and software logy types to categorize t Modeling & Optimiza	e used to measure wind energy potentia	I at sites with rough ter	rain or open ocean.
Provide a brie Develop port: Select up to t	ef description of the te able trailer with LIDAR three different technol ype 1	chnology being impleme mast system and software logy types to categorize t	e used to measure wind energy potentia	I at sites with rough ter	ʻain or open ocean.

Anticipated Benefits of this Technology

icipate	d Benefits of this Technology
	Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)
	ability to size renewable production resources (wind and solar) for microgrids in austere environments; Improved ability to estimate electrical load and
enerationp	tential in response to weather events
st and descu	nsumption ibe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
St and deser	the any benefits and contrology has on may have on instantion rosan der consumption of backup power generator use
enewable E	nergy ibe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management
	Improved capability to estimate ROI of renewable systems
emonstrate	Improved decision support capabilities for investing in renewable systems
ower Consu	•
st and desci	ibe any benefits this technology has or may have on installation power consumption
	ling & Management
	ibe any benefits this technology has or may have on installation power modeling, management, or investment decisions
otential	Modeling and simulation to inform energy infrastructure investments
peration an	d Support Requirements
st and desci	ibe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy
frastructur	
	ince, Independence, & Resiliency
	ibe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from or non-disruption of critical systems
yber Securi	y ibe any benefits this technology has or may have on the cyber security of installation energy infrastructure
st and desci	be any benefits this technology has on may have on the cyber security of instanation energy nin astructure
osts	
st and desci emonstrate	ibe any benefits this technology has or may have on installation energy costs that aren't described above Improved decision support tools to inform future investments or funding requirements
oatrate	
cond Orde	Impacts
hat additio	nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
/hat additio	al benefits, information, feedback, or control does this technology offer to the installation energy manager?
/hat additio	nal benefits, information, feedback, or control does this technology offer to future R&D efforts?
	Improved wind modeling capability
ther	

B38. Project Information Form for Project 38: Shroud with RF Mesh to Suppress Radar Cross-Section of Small World Turbine

roud wit	th RF Mesh	to Suppress Ra	adar Cross-section of	Small Wind	Turbine
Other Names,	, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Ben Wilcox	805-982-2180	benjamin.p.wilcox@navy.mil	Co-PI	FY15 FY17
POC2	David Jenn	831-656-2254	jenn@nps.navy.mil	Co-PI	Base / Installation
POC3					NBVC Port Hueneme
	y Descriptio				
Provide a brie	ef description of the t	echnology being impleme	nted in this research project		
Radar absorbe	ent material shrouds u		Itered radar cross-section of wind turbi	ine rotors in order to p	prevent wind turbine interference near line-of-sight
Radar absorbe radars, permit	ent material shrouds u itting wind power gene	used to suppress Doppler fil	Itered radar cross-section of wind turbi vith these radar systems	ine rotors in order to p	prevent wind turbine interference near line-of-sight
Radar absorbe radars, permit	ent material shrouds u itting wind power gene three different techno	used to suppress Doppler file	ltered radar cross-section of wind turbi vith these radar systems his project	ine rotors in order to p	revent wind turbine interference near line-of-sight
Radar absorbe radars, permit	ent material shrouds u itting wind power gene three different techno ype 1	used to suppress Doppler fil eration near installations v ology types to categorize ti	ltered radar cross-section of wind turbi vith these radar systems his project	ine rotors in order to p	revent wind turbine interference near line-of-sight

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration) Enables wind generation at sites that would otherwise not allow it due to radar interference

eration, storage, integration, or management

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy List and describe any benefits this technology has or may have on installation ren

Potential

Potential

Power Consumption List and describe any benefits this technology has or may have on installation power consumption

Added renewable energy generation capability (wind, solar, etc)

Improved efficiency or effectiveness of existing renewable generati

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs	
List and describe any benefits this	s technology has or may have on installation energy costs that aren't described above
Second Order Impacts	
What additional benefits, inform	nation, feedback, or control does this technology offer to the installation energy end user?
What additional benefits, inform	ation, feedback, or control does this technology offer to the installation energy manager?
What additional benefits, inform	ation, feedback, or control does this technology offer to future R&D efforts?
Other	
Other	
hnology Demonst	ration Results
	bstacles encountered in this technology demonstration project?
	bstacles encountered in this technology demonstration project? : of key personnel, unexpected properties of RF mesh
Delays in shroud fabrication, loss	of key personnel, unexpected properties of RF mesh
Delays in shroud fabrication, loss	of key personnel, unexpected properties of RF mesh
Delays in shroud fabrication, loss	of key personnel, unexpected properties of RF mesh
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US A	hinder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests in FY17 Army 7X10 wind tunnel tests in FY17
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US / What would you describe as the g	hinder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests the FY17 Baba Baba Baba Baba Baba Baba Baba Baba
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US / What would you describe as the g	hinder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests in FY17 Army 7X10 wind tunnel tests in FY17
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US / What would you describe as the g	hinder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests the FY17 Baba Baba Baba Baba Baba Baba Baba Baba
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US / What would you describe as the g	hinder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests the FY17 Baba Baba Baba Baba Baba Baba Baba Baba
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US / What would you describe as the g	hinder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests the FY17 Baba Baba Baba Baba Baba Baba Baba Baba
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US A What would you describe as the g enable wind turbine energy at nar	inder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests in FY17 Page 2 greatest benefit(s) of having completed this demonstration project? val installations using line-of-sight radar systems
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US A What would you describe as the g enable wind turbine energy at nav	inder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests in FY17 Page 2 greatest benefit(s) of having completed this demonstration project? val installations using line-of-sight radar systems) would be required to make the commercially available technology more suitable for Navy-specific use?
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US A What would you describe as the g enable wind turbine energy at nav	inder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests in FY17 Page 2 greatest benefit(s) of having completed this demonstration project? val installations using line-of-sight radar systems
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US A What would you describe as the g enable wind turbine energy at nav	inder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests in FY17 Page 2 greatest benefit(s) of having completed this demonstration project? val installations using line-of-sight radar systems) would be required to make the commercially available technology more suitable for Navy-specific use?
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US A What would you describe as the g enable wind turbine energy at nav	inder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests in FY17 Page 2 greatest benefit(s) of having completed this demonstration project? val installations using line-of-sight radar systems) would be required to make the commercially available technology more suitable for Navy-specific use?
Delays in shroud fabrication, loss In what ways did these obstacles I Missed window for testing at US A What would you describe as the g enable wind turbine energy at nav	inder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests in FY17 Page 2 greatest benefit(s) of having completed this demonstration project? val installations using line-of-sight radar systems) would be required to make the commercially available technology more suitable for Navy-specific use?
Delays in shroud fabrication, loss n what ways did these obstacles I Wissed window for testing at US A What would you describe as the g enable wind turbine energy at nar What specific adaptations (if any) demonstrate that wind turbine sh	inder the implementation, operation, or effectiveness of the demonstrated technology? Army 7X10 wind tunnel tests in FY17 Page 2 greatest benefit(s) of having completed this demonstration project? val installations using line-of-sight radar systems) would be required to make the commercially available technology more suitable for Navy-specific use?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Demonstrated reduced radar interference in 1/30 scale model shroud configurations

What new skills, competencies, or experience were gained within the Navy workforce during this project? Exposure to windfarm compatability issues

Technology Integration	
Maturity of the technology family	Shroud Technology still in early stages of development
Maturity/suitability of specific systems	
used in this project	unable to test systems at larger scales thus far
Integration with Navy-specific systems	radar interference measurements are done on a case-by-case basis
Environmental or Installation-specific	
challenges	radar interference measurements are done on a case-by-case basis
Accessibility of required components	difficulty in fabricating radar shrouds. No commercially available shrouds yet
<u> </u>	

Process Challenges

Certification or Approval requirements	Approval process needed to approve shrouded wind turbines for use at airfields and other locations with line-of-sight radar
Initial Funding or Resource Allocation	
issues	funding timelines must agree with availability of testing facilities
Continued Funding or Resource	
Allocation issues	possible maintenance considerations on shrouded turbines
Contracting / Procurement	contracting mechanism to install shrouds on turbines

Stakeholder Challenges

Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	need buy-in of PW or contractors who would install shrouds on turbines
Limitations from stakeholder needs	safety and design constraints in adding shrouds to existing available wind turbines
Operation and support labor	
requirements	possible maintenance considerations
Necessary Funding Streams:	
Integration	site-specific testing requires funding to line up with availability of personnel
Necessary Funding Streams: Continued	
Support	maintenance
Continued feedback and improvement	need to establish mechanism to receive feedback on long-term performance of shrouded turbines

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

Tech papers		
Author(s)	Title	
Journal Articles, Publications		
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B39. Project Information Form for Project: Liquid Air Energy Storage (LAES)

Other Names, A		e (LAES)			
	Abriviations, etc:				
Contacts POC1	Name Ken Ho	Phone (805) 982-1626	Email ken.ho@navy.mil	Role	Period of Performance
1	Dustin Talley	(803) 982-1030	Ken.noternavy.nm		Base / Installation
	Matthew Barnet				JBPHH
hnology	Description				
Provide a brief	f description of the tech	nology being implemente	d in this research project		
					s pumped to high pressure, evaporated, and nalysis of costs & efficiency for full scale design
Select up to th	nree different technolog	y types to categorize this p	project		
Technology Ty		Energy Storage			
Technology Ty		Waste Energy Recovery			
Technology Ty					
cicipatec	d Benefits of t	his Technolog	У		
Bottom Line !!	In Front: Describethetic	ract anticipated honofit of	successfully implementing the	his technology operationally (-	any he different from demonstration)
					nay be different from demonstration) ronmentally benign large scale energy storage
		ergy penetration and micro			onnertany beingn tage scare energy scorage
Fossil Fuel Con	sumption				
		nology has or may have on i	installation fossil fuel consum	nption or backup power genera	tor use
		owered backup power syste		<u></u>	
	Reduced frequency of ba				
Potential	Reduced requirement fo	r backup generators to assu	irepower		
			\mathbf{O}		
Renewable En					
			installation renewable energy	generation, storage, integration	on, or management
		renewable energy storage estimate ROI of renewable s	uctome -	-	
		ffectiveness of existing rene			
- occirciai			indore energy storage		
Power Consum	nption				
		nology has or may have on i	installation power consumpt	ion	
List and descri	be any benefits this tech	nology has or may have on i rage to reduce peak power		ion	
List and descri	be any benefits this tech			ion	
List and descri	be any benefits this tech			ion	
List and descri	be any benefits this tech			ion	
List and descril Potential	be any benefits this techn Incorporated energy sto			ion	
List and descrii Potential Power Modeli	be any benefits this techn Incorporated energy sto	rage to reduce peak power	demand		ecisions
List and descrii Potential Power Modeli	be any benefits this techn Incorporated energy sto	rage to reduce peak power	demand	ion management, or investment d	ecisions
List and descrii Potential Power Modeli	be any benefits this techn Incorporated energy sto	rage to reduce peak power	demand		ecisions
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List and descril Potentia Power Modeli List and descril Operation and List and descril	be any benefits this techn Incorporated energy sto ing & Management be any benefits this techn I Support Requirements be any benefits this techn	rage to reduce peak power	demand	management, or investment d	
List and descril Potential Power Modeli List and descril Operation and List and descril infrastructure.	be any benefits this techn Incorporated energy sto ing & Management be any benefits this techn I Support Requirements be any benefits this techn	rage to reduce peak power	demand	management, or investment d	
List and descril Potential Power Modeli List and descril Ust and descril Operation and List and descril Infrastructure. Energy Assurar	be any benefits this techn Incorporated energy sto ing & Management be any benefits this techn Support Requirements be any benefits this techn 	rage to reduce peak power nology has or may have on i nology has or may have on i esiliency	demand installation power modeling, the labor, materials, training,	management, or investment d	
List and descril Potential Power Modeli List and descril Operation and List and descril infrastructure. Energy Assurar List and descril	be any benefits this techn Incorporated energy sto ing & Management be any benefits this techn Support Requirements be any benefits this techn 	rage to reduce peak power hology has or may have on i hology has or may have on i esiliency hology has or may have on i	demand installation power modeling, the labor, materials, training,	management, or investment d	ort and operate installation energy
List and descril Potentia Power Modeli List and descril Operation and List and descril infrastructure. Energy Assurar List and descril disruptions, or	be any benefits this techn Incorporated energy sto ing & Management be any benefits this techn be any benefits this techn I Support Requirements be any benefits this techn 	rage to reduce peak power hology has or may have on i hology has or may have on i esiliency hology has or may have on i al systems	demand installation power modeling, the labor, materials, training,	management, or investment d	ort and operate installation energy
List and descril Potential Power Modeli List and descril Uist and descril Description and List and descril Description Energy Assurar List and descriptions, or Potential	be any benefits this techn Incorporated energy sto ing & Management be any benefits this techn I Support Requirements be any benefits this techn	rage to reduce peak power hology has or may have on i hology has or may have on i esiliency hology has or may have on i al systems ims for critical systems	demand installation power modeling, the labor, materials, training,	management, or investment d	ort and operate installation energy
List and descril Potential Power Modeli List and descril List and descril Operation and List and descril infrastructure: Energy Assurar List and descril disruptions, or Potential Potential Potential Potential	be any benefits this techn Incorporated energy sto ing & Management be any benefits this techn be any benefits this techn be any benefits this techn be any benefits this techn nce, Independence, & R be any benefits this techn non-disruption of critic Automated backup syste Reduced reliance on out	rage to reduce peak power hology has or may have on i hology has or may have on i esiliency hology has or may have on i al systems ims for critical systems	demand installation power modeling, the labor, materials, training, installation energy assurance	management, or investment d	ort and operate installation energy

	ribe any benefits this technology has or may have on the cyber security of installation energy infrastructure
Costs	
	ribe any benefits this technology has or may have on installation energy costs that aren't described above
	The any defends this technology has of may have on instantion energy costs that are it to school above
Second Ord	er Impacts
	on a benefits, information, feedback, or control does this technology offer to the installation energy end user?
Potential	Improved energy access in remote facilities
What additi	onal benefits, information, feedback, or control does this technology offer to the installation energy manager?
What additi	onal benefits, information, feedback, or control does this technology offer to future R&D efforts?
What additi Potential	nonal benefits, information, feedback, or control does this technology offer to future R&D efforts?
Potential	
Potential	
Potential	
Potential	
Potential Other	

High system costs >\$50M, only cost competitive at large scale >10MW; Requires lots of land >35,000sqft	
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?	
Only able to complete a mock-up and cost analysis Page 2	
What would you describe as the greatest benefit(s) of having completed this demonstration project?	
Established techinal requirements, stakeholder buy-in, and business case;	
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
Technology needs to become economically viable at a smaller scale to fit within budget constraints.	
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?	
Technology requires significant upfront investment >\$50M and can only be implemented effectively at large scales. Technology uses combination of relative	elv mature
technologies that should be fairly robust with long life cycle once the market matures	ci y macare
technologies that should be lan ty robust with forg the cycle of ce the market matures	
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?	
High potential return on investment when technology matures at a smaller scale	
What new skills, competencies, or experience were gained within the Navy workforce during this project?	
Thermodynamics analysis, business case study, procedural experiences	

	Technology Integration			
	Maturity of the technology	family	Few large-scal	e demonstration projects exist; technology market is not yet mature.
	Maturity/suitability of speci			
	used in this project		Demonstratio	n components were only a mock-up
	Integration with Navy-speci	ific systems	Technology is	only cost-competitive on large-scale systems, which would require large investments that would be hard to fund
	Environmental or Installation	on-specific	Technology is	only cost-competitive on large-scale systems, which would require large amounts of land. Cost-effective operation
	challenges		would require	existing renewable generation capabilities and/or utility provider grid integration agreements
	Accessibility of required cor	mponents	market not ye	t fully mature
	Process Challenges			
				mature, so small number of vendors would impede contracting process. Cost effective operation would require
	Certification or Approval re		integrating wi	th larger grid and would involve utility interconnection agreements
	Initial Funding or Resource	Allocation		
	issues		Requires enor	mous upfront investment.
	Continued Funding or Reson	urce	Machanical	
	Allocation issues		Mechanical co	omponents may require periodic maintenance
	Contracting / Procurement		Not enough a	uitable vendors for equipment,
	contracting/ riocureillelit			and the relation of the requipment,
	Stakeholder Challenges			
	Impact on and Approval of c	certain		
	stakeholders		Large land red	uirement might infringe upon other stakeholders
	Limitations from stakeholde	er needs		
	Operation and support labo	or		
	requirements		periodic main	tenance for mechanical components
	Necessary Funding Streams:	:		
	Integration		No current fur	nding streams exist to support the large front-end cost of \$50M
	Necessary Funding Streams:	: Continued		
	Support			
	Continued feedback and im	provement	Further study	required to optimize effectiveness of stored energy use
Int	ern Involvemen	nt		
	Please list any interns who y	vere involve	d in this project	rt, as well as the year(s) they worked and where they are now (if known).
	If necessary, use an "x" to rep			
	intecessary, use an x to rep	preserventy	interns whose	
	Intern Name	Year (i	if known)	Where are they now? (ifknown)
	Andria Marquez		,	
	Michalla Geer			(STEM, not ESTEP)
	Bashar Ameen			
	Kyle Abrahamson			
Re	ferences			
ne		ore publica	tions or the	s that resulted from this project.
	Prease list any technical pap	pers, publica	itions, or these	s that resulted from this project.
	T			
	Tech papers Author(s)		Title	
	Author(s)		Inte	
	Journal Articles, Publicatio	ons		
	Author(s)		Title	
	NPS Student Theses			
	Author(s)		Title (if known)

B40. Project Information Form for Project 40: Waste to Energy Hydrogen Generation

aste to I	Energy Hydrog	en Generatior	1		
Other Names	, Abriviations, etc:	Waste to Hydrogen			
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Ken Ho	805-982-1636	ken.ho@navy.mil		FY15 FY18
POC2 POC3	Keith Archbold Bryan Law				Base / Installation
FOCS	Di yan Law				
chnolog	y Description				
Provide a bri	ef description of the tech	nology being implemente	d in this research project		
	nced Melter processes haza ng of hazardous materials	ardous waste and recovers	hydrogen gas and recyclable materials	to achieve a net posi	itive energy recovery and reduce costs associate
	three different technolog		project		
Technology T		Renewable Generation			
Technology T		Waste Energy Recovery			
Technology T	ype 3	Decision Support			
ticipate	d Benefits of t	his Technolog	У		
Bottom Line	Up Front: Describe the big	gest anticipated benefit of	successfully implementing this techno	ology operationally	(may be different from demonstration)
					rted, and burned to offset energy demand.
Fossil Fuel Co	onsumption				
List and desci	ribe any benefits this techn	nology has or may have on	installation fossil fuel consumption or	backup power gener	rator use
Potential	Integrated alternative-po	owered backup power syst	ems		
Potential	Improved efficiency or al	Iternative fueled vehicles of	on installation		
Renewable E	nergy	\mathbf{P}	and	1	
			installation renewable energy generati	on, storage, integrat	tion, or management
Potential		generation capability (wi	nd, solar, etc)		
Potential		renewable energy storage			
Potential	Improved efficiency or ef	ffectiveness of existing ren	ewable energy storage		
Power Consu	Imption				
List and desci	ribe any benefits this techn	nology has or may have on	installation power consumption		
Potential	Incorporated energy stor	rage to reduce peak power	demand		
Power Mode	ling & Management				
List and desci	ribe any benefits this techn	hology has or may have on	installation power modeling, manager	nent, or investment	decisions
	d Support Requirements				
		hology has or may have on	the labor, materials, training, or contr	acting needed to sup	oport and operate installation energy
infrastructur	e.				
List and descr	·	nology has or may have on	installation energy assurance and resili	ency, such as islandi	ing or isolation capability, recovery from
disruptions,	or non-disruption of critic	al systems			
Potential	Reduced reliance on out:	side energy suppliers			
Potential	Increased energy storage	e capability for independer	t operation		

LIST and descri	be any benefits this technology has or may have on the cyber security of installation energy infrastructure	_
Costs		
List and descri	be any benefits this technology has or may have on installation energy costs that aren't described above	
Second Order	Impacts	
	Impacts al benefits, information, feedback, or control does this technology offer to the installation energy end user?	
	•	
	•	
What addition	al benefits, information, feedback, or control does this technology offer to the installation energy end user?	
What addition	•	
What addition	al benefits, information, feedback, or control does this technology offer to the installation energy end user?	
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What addition What addition What addition Other	al benefits, information, feedback, or control does this technology offer to the installation energy end user? al benefits, information, feedback, or control does this technology offer to the installation energy manager? al benefits, information, feedback, or control does this technology offer to future R&D efforts?	
What addition What addition What addition	a benefits, information, feedback, or control does this technology offer to the installation energy end user? al benefits, information, feedback, or control does this technology offer to the installation energy manager?	

Technology Demonstration Results

Continued feedback and improvement

What were the most significant obstacl	es encountered in this technology demonstration project?
	as recovery and hazardous materials handling
n what ways did these obstacles hinder	the implementation, operation, or effectiveness of the demonstrated technology?
What would you describe as the greates	t benefit(s) of having completed this demonstration project?
, ,	ng, and construction of PEM melter system
Vhat specific adaptations (if any) would	d be required to make the commercially available technology more suitable for Navy-specific use?
invironmental certifications to comply	with federal regulations
	its and/or drawbacks would this technology have over other (mature) alternative technologies?
	g hazardous wastes for shipment/disposal; recovers net positive energy in the form of useful hydrogen gas that can be used for e-fueled vehicles, etc; recovers recyclable metals
rectricity generation, power arternativ	endeled vehicles, etc. recovers recyclable inclais
Vhat advances or observations were ma	ade in this demonstration project that could help justify continued investment in this technology?
nology Adoption Co	nsiderations
	onsiderations
hnology Adoption Co	nsiderations
	onsiderations
echnology Integration Aaturity of the technology family Aaturity/suitability of specific systems	
rechnology Integration Maturity of the technology family	
echnology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project	
echnology Integration Maturity of the technology family Maturity/suitability of specific systems ised in this project ntegration with Navy-specific systems	
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Intern Involvement

Intern Name Andria Marquez	Year (if known)	Where are they now? (if known)
Anurra Marquez		

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)

B41. Project Information Form for Project 41: Adhered PV Reliability (Completed)

hered P	V Reliability 8	& Performance	Validation		
Other Names	Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Robert Schoff	805-982-3572	robert.schoff@navy.mil	PI	FY14 FY16
	Peter Ly				Base / Installation
	Rob Tyzzer				Guam, Port Hueneme
	NOD TYLECT				outing i of the deficitie
hnology	y Description				
Provide a brie	af description of the tech	nology being implemente	d in this research project		
				rations. Effort also include	d power modeling/measurements for thin fi
panels					
	-	gy types to categorize this	project		
Technology Ty	/pe1	Renewable Generation			
Technology Ty	/pe 2	Implementation, Integrat	tion, Adaptation		
Technology Ty	ine 3				
		this Technolog	У		
					may be different from demonstration)
		wable generation capabiliti	es on roottop surfaces that can n	ot support panel-mounted	PV cells for reasons such as rooftop penetra
ssues, security	y concerns, etc				
ossil Fuel Cor	nsumption				
		nology has or may have on	installation fossil fuel consumpti	on or backup nower generation	atoruse
Potential					
		eded for heating or installat			
Potential	Integrated alternative-p	owered backup power syst	ems		
Potential	Reduced requirement for	or backup generators to ass	ure power		
				peration storage integrati	on or management
List and descri	ibe any benefits this tech	nology has or may have on y generation capability (win	installation renewable energy gen hd, solar, etc)	heration, storage, integrati	on, or management
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List and descri Demonstrated Demonstrated Potential Power Consur List and descri Demonstrated Demonstrated Demonstrated Demonstrated Demonstrated Demonstrated Demonstrated	ibe any benefits this techn Added renewable energy Improved decision supp Improved efficiency or e be any benefits this techn be any benefits this techn be any benefits this techn Modeling and simulatio be any benefits this techn and simulatio be any benefits this techn be any benefits this	y generation capability (wir ort capabilities for investir effectiveness of existing ren- nology has or may have on n to inform energy infrastru- nology has or may have on n to inform energy infrastru- nology has or may have on eport required to install, may exercise the second second second second port required to install, may apply the second second second second second port required to install, may exercise the second seco	nd, solar, etc) ig in renewable systems ewable generation installation power consumption installation power modeling, ma acture investments the labor, materials, training, or aintain, or operate technology	nagement, or investment of	decisions
List and descri Demonstrated Demonstrated Potential Power Consur List and descri Demonstrated Demonstrated Demonstrated Demonstrated Demonstrated Demonstrated Demonstrated Demonstrated Demonstrated Demonstrated	ibe any benefits this techn Added renewable energy Improved decision supp Improved efficiency or e be any benefits this techn be any benefits this techn be any benefits this techn Modeling and simulatio be any benefits this techn and simulatio be any benefits this techn be any benefits this	y generation capability (wir ort capabilities for investir effectiveness of existing ren- nology has or may have on n to inform energy infrastru- nology has or may have on n to inform energy infrastru- nology has or may have on eport required to install, may exercise the second second second second port required to install, may apply the second second second second second port required to install, may exercise the second seco	nd, solar, etc) ig in renewable systems ewable generation installation power consumption installation power modeling, ma acture investments the labor, materials, training, or aintain, or operate technology	nagement, or investment of	decisions

LIST and descri	ibe any benefits this technology has or may have on the cyber security of installation energy infrastructure
Costs	
List and descri	ibe any benefits this technology has or may have on installation energy costs that aren't described above
	Reduced wear and tear on mechanical systems
Second Order	Impacts
Second Order What addition	Impacts nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
What addition	nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
What addition	
What addition	nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
What addition	nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
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What addition What addition	al benefits, information, feedback, or control does this technology offer to the installation energy end user?
What addition What addition What addition	al benefits, information, feedback, or control does this technology offer to the installation energy end user?

Technology Demonstration Results

What were the most significant obstacl	es encountered in this technology demonstration project?
Limited number of thin film panel vend	ors, Increase heat flux creates complicates energy economics (possible increased AC costs)
	the implementation, operation, or effectiveness of the demonstrated technology?
difficult purchasing process, additional	study needed for rooftop heat retention
	t benefit(s) of having completed this demonstration project?
Improved understanding of adhered thi	n film PV performance, heat transfer, and suitability for different roof types
What specific adaptations (if any) would	d be required to make the commercially available technology more suitable for Navy-specific use?
	its and/or drawbacks would this technology have over other (mature) alternative technologies?
Thin film adhered PV allows installation	of PV capabilities on rooftops that could not support pannel-mounted PV arrays
What advances or observations were m	ade in this demonstration project that could help justify continued investment in this technology?
mproved understanding of performance	e characteristics to help determine suitability for future applications
What new skills, competencies, or evoe	rience were gained within the Navy workforce during this project?
	neice were gamed within the navy workforce during this project:
entres of expe	nence were gamed within the Navy worklorce during this project:
	nence were gamed within the navy worklonce during this project:
in the same competences, of expe	nence were gamed within the navy worklotte during this project:
	nence were gamed within the Navy worklotte during this project:
	nence were gamed within the navy worklotte during this project:
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hnology Adoption Co fechnology Integration Vaturity of the technology family Vaturity/suitability of specific systems	insiderations
hnology Adoption Co fechnology Integration Vaturity of the technology family Vaturity/suitability of specific systems	insiderations
hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project	Thin film PV is less efficient, leading to lower ROI
hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems	insiderations
hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific	Thin film PV is less efficient, leading to lower RQI
hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific challenges	Thin film PV is less efficient, leading to lower ROI Thin film PV is less efficient, leading to lower ROI Thin Film pv system used dependent on rooftop material In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generati
hnology Adoption Co fechnology Integration Maturity of the technology family Waturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific challenges	Thin film PV is less efficient, leading to lower RQI
hnology Adoption Co fechnology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific challenges	Thin film PV is less efficient, leading to lower ROI Thin film PV is less efficient, leading to lower ROI Thin Film pv system used dependent on rooftop material In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generati
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hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific challenges Accessibility of required components Process Challenges	Thin film PV is less efficient, leading to lower ROI Thin film PV is less efficient, leading to lower ROI Thin Film pv system used dependent on rooftop material In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generati
hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific challenges Accessibility of required components Process Challenges Certification or Approval requirements Initial Funding or Resource Allocation	Thin film PV is less efficient, leading to lower RQI Thin film PV is less efficient, leading to lower RQI Thin Film pv system used dependent on rooftop material In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generati COTS product but only available from a few suppliers environmental considerations for increased heat flux
hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific challenges Accessibility of required components Process Challenges Certification or Approval requirements Initial Funding or Resource Allocation issues	Thin film PV is less efficient, leading to lower ROI. Thin film PV is less efficient, leading to lower ROI. Thin Film pv system used dependent on rooftop material In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generati COTS product but only available from a few suppliers
hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific challenges Accessibility of required components Process Challenges Certification or Approval requirements Initial Funding or Resource Allocation issues Continued Funding or Resource	Thin film PV is less efficient, leading to lower ROL Thin film PV is less efficient, leading to lower ROL Thin Film pv system used dependent on rooftop material In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generati COTS product but only available from a few suppliers environmental considerations for increased heat flux System acquisition and rooftop surface prep
hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific challenges Accessibility of required components Process Challenges Certification or Approval requirements Initial Funding or Resource Allocation issues Continued Funding or Resource	Thin film PV is less efficient, leading to lower RQI Thin film PV is less efficient, leading to lower RQI Thin Film pv system used dependent on rooftop material In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generati COTS product but only available from a few suppliers environmental considerations for increased heat flux
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hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific challenges Accessibility of required components Process Challenges Certification or Approval requirements nitial Funding or Resource Allocation ssues Continued Funding or Resource Nocation issues	Thin film PV is less efficient, leading to lower ROI Thin film PV is less efficient, leading to lower ROI Thin Film pv system used dependent on rooftop material In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generati COTS product but only available from a few suppliers environmental considerations for increased heat flux System acquisition and rooftop surface prep
hnology Adoption Co Technology Integration Maturity of the technology family Maturity/Suitability of specific systems used in this project ntegration with Navy-specific systems Environmental or Installation-specific challenges Accessibility of required components Process Challenges Certification or Approval requirements nitial Funding or Resource Allocation ssues Continued Funding or Resource Allocation issues Contracting / Procurement Stakeholder Challenges	Thin film PV is less efficient, leading to lower ROI Thin film PV is less efficient, leading to lower ROI Thin Film pv system used dependent on rooftop material In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generati COTS product but only available from a few suppliers environmental considerations for increased heat flux System acquisition and rooftop surface prep Requires a further understanding of long term maintenance requirements / repair / replacement
hnology Adoption Co Technology Integration Maturity of the technology family Maturity/suitability of specific systems used in this project Integration with Navy-specific systems Environmental or Installation-specific challenges Accessibility of required components Process Challenges Certification or Approval requirements Initial Funding or Resource Allocation issues	Thin film PV is less efficient, leading to lower RQI Thin film PV is less efficient, leading to lower RQI Thin Film pv system used dependent on rooftop material In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generati COTS product but only available from a few suppliers environmental considerations for increased heat flux System acquisition and rooftop surface prep Requires a further understanding of long term maintenance requirements / repair / replacement

Impact on and Approval of certain	
stakeholders	increased heat flux in buildings with thin film PV
Limitations from stakeholder needs	Buildings with certain climate needs (datacenters) may be inelligible for thin film rooftop pv due to heat flux
Operation and support labor	
requirements	periodic cleaning and checking adhesion
Necessary Funding Streams:	
Integration	Installation costs of PV and associated power systems
Necessary Funding Streams: Continued	
Support	periodic cleaning and checking adhesion
Continued feedback and improvement	Need process to reassess thin film pv application if increased cooling costs or complaints become cumbersome.

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
h		

Title
Title
Title (if known)

B42. Project Information Form for Project 42: Optimized Cooling for Concentrated Photovoltaic Systems

timized	Cooling for	Concentrated	l Photovoltaic Syste	ems	
Other Names	, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Dr. Sanjeev Sathe	831-656-6288	sbsathe@nps.edu	PI	FY15 FY17
POC2	Dr. Knox Millsaps				Base / Installation
POC3	Dr. Dan Nussbaum				NPS
hnolog	y Description	n			
			ented in this research project		
			ented in this research project		
Provide a bri	ef description of the te	chnology being impleme		n promise for highest cell leve	l efficiencies) w.r.t Cost, Efficiency or Reliabilit
Provide a bri	ef description of the te	chnology being impleme		n promise for highest cell leve	l efficiencies) w.r.t Cost, Efficiency or Reliabilit
Provide a bri Find Optimiz	ef description of the te	chnology being impleme		n promise for highest cell leve	l efficiencies) w.r.t Cost, Efficiency or Reliabilit
Provide a bri Find Optimiz	ef description of the te red Cooling Solutions fo Energy-grids	chnology being impleme	taic System (currently showing high	n promise for highest cell leve	l efficiencies) w.r.t Cost, Efficiency or Reliabilit
Provide a bri Find Optimiz	ef description of the te red Cooling Solutions fo Energy-grids three different techno	chnology being impleme	taic System (currently showing high	n promise for highest cell leve	l efficiencies) w.r.t Cost, Efficiency or Reliabilit
Provide a bri Find Optimiz for the DoD E Select up to	ef description of the te red Cooling Solutions fo Energy-grids three different technol Type 1	chnology being impleme	taic System (currently showing high	n promise for highest cell leve	l efficiencies) w.r.t Cost, Efficiency or Reliabilit

Anticipated Benefits of this Technology

icipate	d Benefits of this Technology
	Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)
mproved P\	'efficiency
Fossil Fuel C	onsumption
	ribe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
Renewable	
ist and desc	ribe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management
	a Improved efficiency or effectiveness of existing renewable generation
	comproved capability to estimate for or enewable systems
ower Cons	Imption
	ribe any benefits this technology has or may have on installation power consumption
ower Mode	ling & Management
	ribe any benefits this technology has or may have on installation power modeling, management, or investment decisions
peration a	nd Support Requirements
st and desc	ribe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy
frastructu	e.
	ance, Independence, & Resiliency ribe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from
	or non-disruption of critical systems
otential	Reduced reliance on outside energy suppliers
yber Secur	tv
	ribe any benefits this technology has or may have on the cyber security of installation energy infrastructure
osts	
	ribe any benefits this technology has or may have on installation energy costs that aren't described above
emonstrate	a Improved decision support tools to inform future investments or funding requirements
econd Orde	r Impacts
'hat additio	anal benefits, information, feedback, or control does this technology offer to the installation energy end user?
otential	Improved energy access in remote facilities
/hat additio	anal benefits, information, feedback, or control does this technology offer to the installation energy manager?
hat additio	anal benefits, information, feedback, or control does this technology offer to future R&D efforts?
ther	

Technology Demonstration Results

What ware the most significant obstacles accountered in this technology demonstration project?
What were the most significant obstacles encountered in this technology demonstration project?
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Page 2
What would you describe as the greatest benefit(s) of having completed this demonstration project?
Improved understanding of design-space tradeoffs for different PV cooling systems
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
what specific adaptations (in any) would be required to make the commerciany available technicitogy more suitable for wavy-specific use?
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
Improved power output from PV systems
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
improved understanding of design space tradeoffs reduces risk of incorporating sub-optimal solutions
What new skills, competencies, or experience were gained within the Navy workforce during this project?

Tashualasulutasutian				
Technology Integration				
Maturity of the technology from the				
	Limited availability of COTS PV cooling solutions			
Maturity/suitability of specific systems				
used in this project				
Integration with Neuropeoific systems				
Integration with Navy-specific systems Environmental or Installation-specific				
challenges	Environmental conditions may limit effectiveness of cooling solutions			
chanenges	Environmentar conditions may mint electivelless of cooling solutions			
Accessibility of required components	high cost of cooling solutions creates restrictions on ROI used to justify cooling projects			
Accessionity offequired components	ingreese of cooling solutions creates restrictions on Koruseu to justify cooling projects			
Process Challenges				
Certification or Approval requirements				
Initial Funding or Resource Allocation				
issues	high up-front cost of implementing solutions			
Continued Funding or Resource				
Allocation issues				
Contracting / Procurement	Contractor support required to implement cooling solutions			
Stakeholder Challenges				
Impact on and Approval of certain				
stakeholders				
Limitations from stakeholder needs	Existing PV installations may be built in a way that precludes installing cooling systems			
Operation and support labor				
requirements				
Necessary Funding Streams: Integration				
Necessary Funding Streams: Continued				
Support	Possible periodic maintenance requirements			
Support	i osiore periodie municendite requirements			
Continued feedback and improvement				
ern Involvement				
item involvement				

Intern Name	Year (if known)	Where are they now? (if known)

Tech papers		
Author(s)	Title	
I	· · · · ·	
Journal Articles, Publication	ns	
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	
LT Robert Riley		
LT Derek Fletcher		
LT Matt Hayes		

B43. Project Information Form for Project 43: Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion

Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion					
Other Names, Abriviations, etc:					
Contacts Name Phone Email Role Period of Period and Perio					
Technology Description					
Provide a brief description of the technology being implemented in this research project					
Use X-band radar and computer modeling to predict wave forces on a wave-energy generating system and apply controls to maximize power generation					
Select up to three different technology types to categorize this project Technology Type 1 Renewable Generation					
Technology Type 2 Modeling & Optimization Technology Type 3					
Anticipated Benefits of this Technology					
Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration) Increased energy generation and ROI from wave energy generation					
Fossil Fuel Consumption List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use					
Image:					
Renewable Energy List and describe any benfts this technology has or may have on installation renewable energy generation, storage, integration, or management Potential Improved efficiency or effectiveness of existing renewable generation					
Potential Improved capability to estimate ROI of renewable systems					
Power Consumption List and describe any benefits this technology has or may have on installation power consumption					
Power Modeling & Management List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions					
Operation and Support Requirements List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.					
Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems					
Cyber Security List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure					
Costs List and describe any benefits this technology has or may have on installation energy costs that aren't described above					
Second Order Impacts What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?					
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?					
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?					
Other					

echnology Demonstra	tion Results			
	les encountered in this technology demonstration project?			
Contracting challenges and changes to				
	er the implementation, operation, or effectiveness of the demonstrated technology?			
Delays in experimental validation				
demonstrated method for improving	est benefit(s) of having completed this demonstration project? efficiency of wave energy generation			
	Id be required to make the commercially available technology more suitable for Navy-specific use?			
prepackaged solution to implementin	g effective wave energy generation			
Once operationally mature, what ben improved efficiency of wave energy ge	efits and/or drawbacks would this technology have over other (mature) alternative technologies? neration mechanisms			
What advances or observations were	nade in this demonstration project that could help justify continued investment in this technology?			
What new skills, competencies, or exp Improved modeling skills	erience were gained within the Navy workforce during this project?			
chnology Adoption C	onsiderations			
Technology Integration				
Maturity of the technology family	technology and with mature enough for wide code dealeyment			
Maturity/suitability of specific system	technology not yet mature enough for wide-scale deployment			
used in this project	further testing needed			
Integration with Navy-specific system Environmental or Installation-specific	possible adaptations needed to integrate with Navy bouy characteristics			
challenges	Complications arriving from using radar systems at naval facilities,			
Accessibility of required components				
Process Challenges				
	s approval needed for radar applications			
Initial Funding or Resource Allocation				
issues Continued Funding or Resource	site-specific calibrations may be needed, requiring extra funding for labor			
Allocation issues				
Contracting / Procurement	Possible contracter support may be needed to integrate radar data with bouy controls			
Stakeholder Challenges				
Impact on and Approval of certain stakeholders	non-interference with other shore-based radar applications at naval bases			
Limitations from stakeholder needs	bouy controls may increase maintenance requirements of wave-energy systems, collaboration needed with maintainers			
Operation and support labor requirements	bouy controls may increase maintenance requirements of wave-energy systems, collaboration needed with maintainers			
Necessary Funding Streams:				
Integration Necessary Funding Streams: Continue				
Support	long term maintenance condsiderations			
	feedback needed from maintenance crews and energy managers			
tern Involvement				
Intern Name Year	(if known) Where are they now? (if known)			
eferences				
Tech papers Author(s)	Title			
Journal Articles, Publications Author(s)	Title			
NPS Student Theses Author(s)	Title (if known)			
B44. Project Information Form for Project 44: Valuation and Financing for Energy Storage

	and Financi	0 0/	age		
Other Names,	, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Dustin Talley	805-982-5987	lustin.talley@navy.mil	PI	FY16 FY17 Base / Installation
POC2 POC3	Ming Liu Ken Ho				EXWC
hnolog	y Descriptio	n			
Provide a brie	ef description of the te	echnology being implemented	n this research project		
	nancial model that cap rdable" under current		ergy storage projects that woul	d not be accounted for under	current eROI model to make energy storage
Select up to t	three different techno	logy types to categorize this pro	oject		
Technology Ty	ype 1	Energy Storage			
Technology T		Decision Support			
echnology T	ype 3				
icipate	d Benefits o	f this Technology			
Bottom Line	Up Front: Describe the	biggest anticipated benefit of su	ccessfully implementing this te	echnology operationally (ma	be different from demonstration)
New ROI mod	lel would enable increa	ased funding for energy storage p	rojects, enabling future efforts	that would otherwise be una	ttainable
Fossil Fuel Co					
List and descr	ribe any benefits this te	chnology has or may have on in	stallation fossil fuel consumptio	on or backup power generato	r use
Renewable E					
		chnology has or m <mark>ay</mark> have on in		ieration, storage, integration	ormanagement
Potential		pport capabilities for investing			
Potential	Improved capability	to estimate ROI of renewable sys	tems		
Power Consu	-	aha alami has ar mau have an in	tellation neuros consumption		
Potential		chnology has or may have on in		tanding of now or concumpti	on limite
rotential	Increased ability to e	stimate full value of electricity s	torage, therefore clearer unders	standing of power consumpti	on minus
anner Mada	ling 8 Management				
	ling & Management				
ist and descr	ribe any benefits this te	chnology has or may have on in			sions
List and descr	ribe any benefits this te	chnology has or may have on in more accurate capacity and clea			sions
List and descr	ribe any benefits this te				sions
List and descr	ribe any benefits this te				sions
List and descr	ribe any benefits this te				sions
List and descr Potential	ibe any benefits this te New model provides	more accurate capacity and clea			sions
List and descr Potential Operation an	ibe any benefits this te New model provides	more accurate capacity and clea	rer costs, allowing for more effi	cient fund distribution	
List and descr Potential Operation and List and descr	ibe any benefits this te New model provides d Support Requireme ibe any benefits this te	more accurate capacity and clea	rer costs, allowing for more effi	cient fund distribution	sions t and operate installation energy
List and descr Potential Operation and List and descr	ibe any benefits this te New model provides d Support Requireme ibe any benefits this te	more accurate capacity and clea	rer costs, allowing for more effi	cient fund distribution	
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List and descr Potential Operation and List and descr	ibe any benefits this te New model provides d Support Requireme ibe any benefits this te	more accurate capacity and clea	rer costs, allowing for more effi	cient fund distribution	
List and descr Potential Operation and List and descr infrastructure	d Support Requireme ibe any benefits this te	nts	rer costs, allowing for more effi	cient fund distribution	
List and descr Potential Operation an List and descr infrastructure Energy Assura	ibe any benefits this te New model provides d Support Requirementibe any benefits this te e. ance, Independence, a	more accurate capacity and clea nts cchnology has or may have on th & Resiliency	rer costs, allowing for more effi	cient fund distribution	t and operate installation energy
List and descr Potential Operation an List and descr infrastructure Energy Assura List and descr	ibe any benefits this te New model provides d Support Requireme ibe any benefits this te e. ance, Independence, ibe any benefits this te	nts cchnology has or may have on th & Resiliency cchnology has or may have on in	rer costs, allowing for more effi	cient fund distribution	
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List and descr Potential Operation an List and descr infrastructure Energy Assura List and descr	ibe any benefits this te New model provides d Support Requireme ibe any benefits this te e. ance, Independence, ibe any benefits this te	nts cchnology has or may have on th & Resiliency cchnology has or may have on in	rer costs, allowing for more effi	cient fund distribution	t and operate installation energy
List and descr Potential Operation an List and descr infrastructure Energy Assura List and descr	ibe any benefits this te New model provides d Support Requireme ibe any benefits this te e. ance, Independence, ibe any benefits this te	nts cchnology has or may have on th & Resiliency cchnology has or may have on in	rer costs, allowing for more effi	cient fund distribution	t and operate installation energy
List and descr Potential Operation an List and descr Infrastructure Energy Assura	ibe any benefits this te New model provides d Support Requireme ibe any benefits this te e. ance, Independence, ibe any benefits this te	nts cchnology has or may have on th & Resiliency cchnology has or may have on in	rer costs, allowing for more effi	cient fund distribution	t and operate installation energy

Costs	
list and desc Potential	cribe any benefits this technology has or may have on installation energy costs that aren't described above Improved decision support tools to inform future investments or funding requirements
Potential	mproved decision support tools to morn future investments of futuring requirements
	-
econd Ord	er Impacts
Nhat additi	onal benefits, information, feedback, or control does this technology offer to the installation energy end user?
Nhat additi	onal benefits, information, feedback, or control does this technology offer to the installation energy manager?
What additi	ional benefits, information, feedback, or control does this technology offer to future R&D efforts?
What additi	onal benefits, information, feedback, or control does this technology offer to future R&D efforts?
What additi	onal benefits, information, feedback, or control does this technology offer to future R&D efforts?
	onal benefits, information, feedback, or control does this technology offer to future R&D efforts?
Other	
	Improved ability to justify funding for future energy storage projects
Other	
Other	
Other Potential	Improved ability to justify funding for future energy storage projects
Other Potential	
Dther Potential	Improved ability to justify funding for future energy storage projects gy Demonstration Results
Other Potential hnolog What were t	Improved ability to justify funding for future energy storage projects

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Going against an established process makes implementing new metrics more difficult
What would you describe as the greatest benefit(s) of having completed this demonstration project?
Demonstrate an improved process for assessing the potential value of energy storage projects, which will make it easier for future PIs to receive funding for innovative e storage efforts
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Defense sector and private industry have different priorities and motivations when implementing energy storage technologies, which commercial energy models would
to be adapted to represent the Navy's needs
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
This new energy storage value assessment process would improve access to energy storage technologies on installations
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
Promoting new energy valuation methodology will improve installations' access to technologies that improve energy resilience

What new skills, competencies, or experience were gained within the Navy workforce during this project?

	Technology Integration				
	Maturity of the technology fa	amily	New energy va	luation system has yet to be tested in real world case studies	
	Maturity/suitability of specifi		0,		
	used in this project		N/A		
	Integration with Navy-specifi	ic systems	Inputs into en	ergy valuation tool amy be subjective or vary by installation needs	
	Environmental or Installation	n-specific			
	challenges		Installations w	vith different functions or priorities may value energy differently	
	Accessibility of required com	ponents	Possible lack o	f data required for accurate assessments	
	Description of the Harmonian				
	Process Challenges	•			
	Certification or Approval requ	uiromonto	New POI meth	od for energy storage investments would require official approval/adoption	
	Initial Funding or Resource A		New Rommeth	ou or chergy storage investments would require onicial approval/adoption	
	issues		new eROI met	hod requires labor for accurate assessment of installation energy assets	
	Continued Funding or Resour	rce			
	Allocation issues		Energy valuati	on and resiliency assessments will need to be updated over time	
	Contracting / Procurement		Accurate ener	gy infrastructure assessments may require coordinating with contractors responsible for infrastructure	
	Stakeholder Challenges				
	Impact on and Approval of ce	ertain	Newstand	even u el cette e se estate estate esta esta esta foresta u el construccione esta esta esta la construcción de	
	stakeholders	•	New stored en	ergy valuation metrics may make other infrastructure improvement projects less desirable	
	Limitations from stakeholder	r needs	Time required	to gather data and perform evaluation limit potential depth of energy valuation analysis for new projects	
	Operation and support labor	-	innerequireu		
	requirements		New energy va	luation metrics will need to consider the O&S costs of supporting new energy storage projects	
	Necessary Funding Streams:	•			
	Integration		Time and labo	r required for new assessment of energy projects	
	Necessary Funding Streams: C	Continued			
	Support		Periodic study	may be needed to ensure new energy valuation metrics are updated as Navy needs change over time	
			Case studies n	eeded to validate new energy resiliency valuation method	
Int	ern Involvement	t			
	Please list any interns who we	ere involve	d in this projec	t, as well as the year(s) they worked and where they are now (if known).	
	If necessary, use an "x" to repr	resent any i	nterns whose	names are unknown.	
	Intern Name	Year (i	fknown)	Where are they now? (if known)	
_	<i>.</i>				
ке	ferences				
	Please list any technical pape	ers, publicat	tions, or these	that resulted from this project.	
	Tech papers		Tale		
	Author(s)		Title Internal NAVFAC deliverable report		
			Internal NAVE		
	Journal Articles, Publication	is			
	Author(s)		Title		
	NPS Student Theses				
	Author(s)		Title (if known)	

Transportable Micro-grid with Storage Relocatable Microgrid with Storage Other Names, Abriviations, etc: Contacts Name Phone Email Role Period of Performance Paul Kistler POC1 805-982-1387 paul.kistler@navy.mil FY1 Base / Installation POC2 Bruce Garret Scott Miller POC3 NBVC Port Hu **Technology Description** Provide a brief description of the technology being implemented in this research project Create and demonstrate portable microgrid system that can be controlled in a cyber secure manner, integrate emerging energy storage technologies Select up to three different technology types to categorize this project Technology Type 1 Technology Type 2 Technology Type 3 Anticipated Benefits of this Technology Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration) adaptable, portable microgrid to reduce energy demand and allow islanding to provide energy assurance Fossil Fuel Consumption List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use emonstrated Integrated alternative-powered backup power systems nstrate Reduced frequency of backup generator use emonstrate Reduced requirement for backup generators to assure power Renewable Energy List and describe any benefits this technology has or may have on installatio energy generation, storage, integration, or management nstrated Integrated or expanded renewable energy storage Improved capability to integrate renewables into larger grid strate nonstrated Improved decision support capabilities for investing in renewable systems **Power Consumption** List and describe any benefits this technology has or may have on installation power consumption Potentia Incorporated energy storage to reduce peak power demand Power Modeling & Management List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions **Operation and Support Requirements** List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems Automated backup systems for critical systems Reduced reliance on outside energy suppliers Increased energy storage capability for independent operation Improved islanding capability to isolate and protect critical systems

B45. Project Information Form for Project 45: Transportable Micro-Grid with Storage

Cyber Securit List and descr	
	y ibe any benefits this technology has or may have on the cyber security of installation energy infrastructure
	J
Costs	
List and descr	ibe any benefits this technology has or may have on installation energy costs that aren't described above
Second Orde	r Impacts
	nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
	Improved energy access in remote facilities
What additio	nal benefits, information, feedback, or control does this technology offer to the installation energy manager?
What addition	nal benefits, information, feedback, or control does this technology offer to future R&D efforts?
windt duurtio	או סבורות, והוסוווומנוסוו, וכבשטמנא, סו בטוונוסו שטבא גוווא גברווווסוטצע טוופו נט ושנשו פיזמני פווטו גאי
Other	
chnolog	y Demonstration Results
What were th	e most significant obstacles encountered in this technology demonstration project?
Project delay:	did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
What would y	you describe as the greatest benefit(s) of having completed this demonstration project?
allows testing	g various microgrid components in specific applications/settings
What specific	
Mostly a matt	adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
	adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? ter of finding which specific (combinations of) COTS components work together to meet Navy needs
Once operatio	ter of finding which specific (combinations of) COTS components work together to meet Navy needs
	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
This program	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? will allow testing components before implenting operationally and possibly discovering bugs
This program	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? will allow testing components before implenting operationally and possibly discovering bugs es or observations were made in this demonstration project that could help justify continued investment in this technology?
This program	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? will allow testing components before implenting operationally and possibly discovering bugs
This program What advance	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? will allow testing components before implenting operationally and possibly discovering bugs es or observations were made in this demonstration project that could help justify continued investment in this technology?
This program What advance	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? will allow testing components before implenting operationally and possibly discovering bugs es or observations were made in this demonstration project that could help justify continued investment in this technology?
This program What advance	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? will allow testing components before implenting operationally and possibly discovering bugs es or observations were made in this demonstration project that could help justify continued investment in this technology?
This program What advance examples of n What new ski	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? will allow testing components before implenting operationally and possibly discovering bugs es or observations were made in this demonstration project that could help justify continued investment in this technology? nicrogrids that had issues due to lack of test bed lls, competencies, or experience were gained within the Navy workforce during this project?
This program What advance examples of m What new ski	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? will allow testing components before implenting operationally and possibly discovering bugs es or observations were made in this demonstration project that could help justify continued investment in this technology? nicrogrids that had issues due to lack of test bed
This program What advance examples of m What new ski	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? will allow testing components before implenting operationally and possibly discovering bugs es or observations were made in this demonstration project that could help justify continued investment in this technology? nicrogrids that had issues due to lack of test bed lls, competencies, or experience were gained within the Navy workforce during this project?
This program What advance examples of m What new ski	ter of finding which specific (combinations of) COTS components work together to meet Navy needs onally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? will allow testing components before implenting operationally and possibly discovering bugs es or observations were made in this demonstration project that could help justify continued investment in this technology? nicrogrids that had issues due to lack of test bed lls, competencies, or experience were gained within the Navy workforce during this project?

NPS Student Theses Author(s)

Title (if known)

echnology Adoption Co	onsiderations			
Technology Integration				
Maturity of the technology family	specific components are mature, but in what combination			
Maturity/suitability of specific systems				
used in this project				
Integration with Navy-specific systems	not yet			
Environmental or Installation-specific				
challenges	integration with existing infrastructure, fire protection, potential for environmental toxins			
Accessibility of required components	issues getting complete data from manufacturors, proprietary nature of battery technology details required for approvals			
Process Challenges				
Process chanenges	Certifications/approvals for Li-Ion batteries, infrastructure upgrades, interconnect agreement with utility company, everything will be			
Certification or Approval requirements				
Initial Funding or Resource Allocation				
issues	installation site-specific funding streams dealing with energy resiliency			
Continued Funding or Resource	, , , , , , , , , , , , , , , , , , ,			
Allocation issues	Periodic battery replacements, trading components			
	Challenges in construction contracting process, occasional upgrades to increase capability, parts manufacturors can go out of			
Contracting / Procurement	business			
Stakeholder Challenges				
Impact on and Approval of certain				
stakeholders	Must get approval for batteries			
Limitations from stakeholder needs				
Operation and support labor				
requirements				
Necessary Funding Streams:				
Integration				
Necessary Funding Streams: Continued				
Support	battery maintenance and replacement			
Continued feedback and improvement	expect to continually upgrade to add testing capability			
tern Involvement				
Intern Name Year (ifknown) Where are they now? (if known)			
eferences				
Tech papers Author(s)	Title			
Journal Articles, Publications Author(s)	Title			

B46. Project Information Form for Project 46: Modular Micro-gird (M2G) System

odular Mic	ro grid (M2	G) System			
Other Names, Abr	iviations etc.	M2G			
other Names, Abi	Withons, etc.	M20			
Contacts POC1 Ro	Name	Phone Phone	Email	Role	Period of Performance
	bert Okwera taka Sugiyama	805-982-5177 805-982-1608	robert.okwera@navy.mil yutaka.sugiyama@navy.mil		FY16 FY19 Base / Installation
	ark Tukeman				EXWC
chnology [Description				
Provide a brief de	escription of the tech	nology being implement	ed in this research project		
	oped with V2G export se of the utility grid po		ge (Li-ion/BMS) alone with conventiona	l backup diesel gen	set to robustly serve critical connected loads while
Select up to three	e different technolog	y types to categorize this	project		
Technology Type		Renewable Generation	• •		
Technology Type 2		Energy Storage			
Technology Type		Microgrids, Islanding, Is			
nticipated I	Benefits of t	his Technoloខ្	ξγ		
Bottom Line Up F	ront: Describe the big	gest anticipated benefit c	of successfully implementing this techn	ology operationall	y (may be different from demonstration)
Improved energy	security through stan	dardized microgrids inco	rpating renewable generation and stora	ge with conventio	nal diesel backup
Fossil Fuel Consu					
			n installation fossil fuel consumption or	backup power gen	nerator use
		ossil fuel backup power sy owered backup power sys			
	duced frequency of ba				
		r backup generators to as	sure power	_	
Renewable Energ		ology has or may have or	installation renewable energy generation	ion storage integr	ration or management
		ntegrate renewables into		ion, storage, mees	
		generation capability (w			
Demonstrated Int	egrated or expanded i	renewable energy storage			
Power Consumpt	ion				
		nology has or may have or	installation power consumption		
		rage to reduce peak powe			
Power Modeling	& Management				
		nology has or may have or	n installation power modeling, manager	ment, or investmer	nt decisions
Operation and Su	pport Requirements				
			the labor, materials, training, or contr	racting needed to s	upport and operate installation energy
infrastructure.					
Energy Assurance	, Independence, & R	esiliency			
List and describe	any benefits this tech	nology has or may have or	installation energy assurance and resil	iency, such as islan	ding or isolation capability, recovery from
	on-disruption of critic				
		ems for critical systems			
	duced reliance on out	0/ 11	ntonoration		
Demonstrated Inc	reased energy storage	capability for independe	ant operation		

List and describe	e any benefits this technology has or may have on the cyber security of installation energy infrastructure
Costs	
	e any benefits this technology has or may have on installation energy costs that aren't described above
	any betteres that sections of may have on machine the gy costs that are to escribe above
Demonstrated Re	eutreu wear and tear on mechanical systems
	npacts I benefits, information, feedback, or control does this technology offer to the installation energy end user?
	benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additional	
What additional	benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additional	benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additional	benefits, information, feedback, or control does this technology offer to the installation energy end user?
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What additional	benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additional What additional What additional What additional	benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additional What additional What additional What additional	benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additional	benefits, information, feedback, or control does this technology offer to the installation energy end user?

Technology Demonstration Results

conology Demonstration Results
What were the most significant obstacles encountered in this technology demonstration project?
Southern California Edison interconnect agreement, managing grid stability, balancing an ad-hoc modular approach
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
FAUE
What would you describe as the greatest benefit(s) of having completed this demonstration project?
Demonstrate the feasibility of a robust modular microgrid featuring PV, storage, and backup diesel generation
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Create a standard interconnect agreement for working with utilities, standardize battery storage processes
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
This system would be more robust than alternative microgrid designs
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
What new skills, competencies, or experience were gained within the Navy workforce during this project?
chnology Adoption Considerations
Technology Integration
Maturity of the technology family Mature individual components, but still needs further testing as a complete system
Maturity/suitability of specific systems
used in this project Mature individual components, but still needs further testing as a complete system
Integration with Navernetific output
Integration with Navy-specific systems Specific utility or infrastructure interconnect requirements may pose challenges Environmental or Installation-specific
challenges
Accessibility of required components Difficult to acquire batteries
Process Challenges
r locas chancings

L

Certification or Approval requirements	Battery acquisition and utility interconnect agreements
Initial Funding or Resource Allocation	
issues	Funding for equipment and labor for installation
Continued Funding or Resource	
Allocation issues	funding for maintenance and periodic battery replacement
Contracting / Procurement	contracting labor needed to install specialty equipment

Stakeholder Challenges Impact on and Approval of certain stakeholders Require approval from PW Limitations from stakeholder needs Possible system maintenance limitations Operation and support labor requirements Possible system maintenance limitations Necessary Funding Streams: Integration Need to identify funding stream for acquisition and installation Necessary Funding Streams: Continued Support Need to identify funding stream for maintenance

Continued feedback and improvement Need to establish process for monitoring energy use of microgrid and extra maintenance costs

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Christopher Phelps		

-

References

Tech papers		
Author(s)	Title	
Journal Articles, Publications		
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B47. Project Information Form for Project 47: Wind Effects on Sun-Tracking PV Cell Solar Panels

d Effects on Sun Tracking PV Cell Solar Panels					
Other Nam	nes, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performan
POC1	M. S. Chandrasekhara	650-604-4269	mchandra@nps.edu	Co-PI	FY16 FY
POC2	Randall Olsen	619-553-8713	randall.olsen@navy.mil	Co-PI	Base / Installation
POC3					NPS, Miramar MCAS
nology	Description				
•.	•	technology heing in	nlemented in this research proje	ct	
•.	•	technology being in	nplemented in this research proje	ct	
Provide a	brief description of the		· · · ·		e structual loads caused by winds and sto
Provide a	brief description of the		· · · ·		re structual loads caused by winds and sto
Provide a l	brief description of the		· · · ·		re structual loads caused by winds and sto
Provide al	brief description of the	a to design structura	l components of sun-tracking PV sy		te structual loads caused by winds and sto
Provide al	briefdescription of the nd load data and use dat s to three different techr	a to design structura	l components of sun-tracking PV sy gorize this project		e structual loads caused by winds and sto
Provide al obtain wir conditions	brief description of the ind load data and use dat s to three different techr y Type 1	a to design structura	I components of sun-tracking PV sy gorize this project tion		e structual loads caused by winds and stc

Anticipated Benefits of this Technology



Technology Demonstration Results

Site access, panel fabrication dela	ys due to contracting process, coordination issues with PW
, , , , , , , , , , , , , , , , , , , ,	,
In what ways did these obstacles	inder the implementation, operation, or effectiveness of the demonstrated technology?
delays in project progress	r age z
What would you describe as the g	reatest benefit(s) of having completed this demonstration project?
	, scale models verified in wind tunnel tests; improved understanding of structural requirements
What specific adaptations (if any)	would be required to make the commercially available technology more suitable for Navy-specific use?
Once operationally mature, what	benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
	benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
	benefits and/or drawbacks would this technology have over other (mature) alternative technologies? weather events, but at increased costs
mproved survivability in extrem	e weather events, but at increased costs
mproved survivability in extrem What advances or observations w	e weather events, but at increased costs ere made in this demonstration project that could help justify continued investment in this technology?
mproved survivability in extrem What advances or observations w	e weather events, but at increased costs
mproved survivability in extrem What advances or observations w	e weather events, but at increased costs ere made in this demonstration project that could help justify continued investment in this technology?
mproved survivability in extrem What advances or observations w	e weather events, but at increased costs ere made in this demonstration project that could help justify continued investment in this technology?
mproved survivability in extrem What advances or observations w	e weather events, but at increased costs ere made in this demonstration project that could help justify continued investment in this technology?
mproved survivability in extrem What advances or observations w	e weather events, but at increased costs ere made in this demonstration project that could help justify continued investment in this technology?
mproved survivability in extrem What advances or observations w Designs have proven successful in	e weather events, but at increased costs ere made in this demonstration project that could help justify continued investment in this technology? scale model wind tunnel tests, need further verification of full size components
mproved survivability in extrem What advances or observations w Designs have proven successful in	e weather events, but at increased costs ere made in this demonstration project that could help justify continued investment in this technology?
mproved survivability in extrem What advances or observations w Designs have proven successful in	e weather events, but at increased costs ere made in this demonstration project that could help justify continued investment in this technology? scale model wind tunnel tests, need further verification of full size components
mproved survivability in extrem What advances or observations w Designs have proven successful in	e weather events, but at increased costs ere made in this demonstration project that could help justify continued investment in this technology? scale model wind tunnel tests, need further verification of full size components
mproved survivability in extrem What advances or observations w Designs have proven successful in	e weather events, but at increased costs ere made in this demonstration project that could help justify continued investment in this technology? scale model wind tunnel tests, need further verification of full size components

Technology Integration	
Maturity of the technology family	Designs still require testing at full scale
Maturity/suitability of specific	
systems used in this project	Design of wind-resistant PV arrays may impose constraints on where these PV systems can be installed
Integration with Navy-specific	
systems	
Environmental or Installation-	
specific challenges	Technology may still need to address retrofitting existing PV arrays to reduce wind loads
Accessibility of required	
components	Acquisition challenges yet to be met if these improved designs are to be deployed at larger scales

Process Challenges	
Certification or Approval	
requirements	
Initial Funding or Resource	
Allocation issues	new wind-resistant PV system design may incur a higher up-front cost to integrate new systems
Continued Funding or Resource	
Allocation issues	
Contracting / Procurement	PI still needs to identify a supplier or means to mass produce the improved PV systems

Stakeholder Challenges

Impact on and Approval of certain	
stakeholders	
Limitations from stakeholder	
needs	
Operation and support labor	
requirements	Maintenance and operation funding
Necessary Funding Streams:	
Integration	funding for installation or modification of existing systems
Necessary Funding Streams:	
Continued Support	
Continued feedback and	
improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
John Hernandez	2014-2015	
Gaston Ragazzo	2016	
Youseff Elkassis		

References

Tech papers		
Author(s)	Title	
Journal Articles, Publicati	ions	
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	
LCDR C J Wagner		

B48. Project Information Form for Project 48: Grid Stability in High Penetration Renewables

Grid S	tabi	lity in High P	enetration Rer	newables		
Othe	er Names	, Abriviations, etc:				
Co	ontacts	Name	Phone	Email	Role	Period of Performance
	POC1	Bruce Garrett	805-982-5615	bruce.garrett@navy.mil	PI	FY16 FY18
	POC2 POC3	Ken Ho Bob Love				Base / Installation
r	-005	BOD LOVE				10r.uu - ui
Геchn	olog	y Description	n			
Prov	ide a bri	ef description of the te	chnology being implemen	ted in this research project		
Use r	mobile p	ower quality meters to	assess the performance of p	ower infrastructure in terms of its a	bility to handle the stress	es of high penetration renewable energy sources
Sele	ct up to t	three different techno	logy types to categorize th	is project		
	nology T		Renewable Integration			
	nology T		Energy Management &			
	nology T		Implementation, Integ			
Antici	pate	d Benefits of	f this Technolo	gy		
Bott	om Line	Up Front: Describe the	biggest anticipated benefit	of successfully implementing this to	echnology operationally (may be different from demonstration)
Incre		· ·				w to mitigate these effects to improve energy
		onsumption				
				n installation fossil fuel consumption	on or backup power gener	rator use
Pote			f backup generator use			
Pote	intial	Reduced requirement	t for backup generators to a	ssurepower		
Rene	ewable E	nergy				
			chnology has or may have c	n installation renewable energy ger	neration, storage, integrat	ion, or management
Pote			or effectiveness of existing re			
Pote	ntial	Improved decision su	pport capabilities for inves	ting in renewable systems		
Pow	er Consu	umption				
			chnology has or may have c	n installation power consumption		
				F		
-						
		ling & Management				desisions
	intial		to optimize grid configura	n installation power modeling, mai	nagement, or investment	decisions
	ntial		nd monitoring of installatio			
	ntial		capabilities for energy infra			
Pote			tion to inform energy infras			
		d Support Requiremer				
			chnology has or may have c	on the labor, materials, training, or o	contracting needed to sup	port and operate installation energy
infra	structur	e.				
		ance, Independence, &				
				n installation energy assurance and	resiliency, such as islandi	ng or isolation capability, recovery from
		or non-disruption of cri				
	ntial		ion to prevent cascading bla			
Pote	ntial	improved capability t	to restore grid functionality	/ aπer outages		

Cyber Security List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs	
List and des	ribe any benefits this technology has or may have on installation energy costs that aren't described above
Potential	Increased ability to diagnose need for preventative maintenance
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additi	What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?			
Potential	Increased awareness of energy use			
What additi	onal benefits, information, feedback, or control does this technology offer to the installation energy manager?			
Potential	Real-time monitoring of energy systems			
Potential	Improved documentation of infrastructure			
What additi	onal benefits, information, feedback, or control does this technology offer to future R&D efforts?			
Potential	Improved access to energy use data			

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Page 2
What would you describe as the greatest benefit(s) of having completed this demonstration project?
Improved understanding of how to prevent damage to shore power systems and mitigating the effects of instabilities caused by intermittent renewable energy sources. Improved understanding of JBPHH electrical infrastructure performance
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
This project helps researchers understand the nature and depth of the problem, but does not yet propose full solutions
What new skills, competencies, or experience were gained within the Navy workforce during this project?

-		
	Technology Integration	
	Maturity of the technology family	unknown maturity of technologies used to counter the instability effects of intermittent distributed energy sources
	Maturity/suitability of specific systems	
	used in this project	
	used in this project	
	Integration with Navy-specific systems	
	Environmental or Installation-specific	
	challenges	Integrating specific systems to improve grid stability will vary from base to base
	chancinges	integrating specific systems to improve give stability with vary non-base to base
	Accessibility of required components	
	Process Challenges	
	riocess chanenges	
	Certification or Approval requirements	Approvals / permitting required to tap into power grid
	Initial Funding or Resource Allocation	
	issues	
	Continued Funding or Resource	
	Allocation issues	
	Contraction (Decomposite	
	Contracting/Procurement	
	Stakeholder Challenges	
	Impact on and Approval of certain	
	stakeholders	Results to be shared with NAVFAC energy managers to coordinate on implementing proposed solutions
	Limitations from stakeholder needs	
	Operation and support labor	
	requirements	
	Necessary Funding Streams:	
	Integration	
	Necessary Funding Streams: Continued	
	Support	Continued support necessary to adapt grid as more renewables installed
	Continued feedback and improvement	
	continued leeuback and improvement	
Int	ern Involvement	
	Intern Name Year (if known) Where are they now? (if known)
Ro	ferences	
ne		
	Tech papers	
		TAL
	Author(s)	Title
		And
	Journal Articles, Publications	
	Journal Articles, Publications	

Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	
	Title (if known)	

B49. Project Information Form for Project 49: Nanolubricant HVAC Refrigerant

olubrication HVAC	Refrigerant			
Other Names, Abriviations, etc:				
Contrato Norro	Dis a se	Exc. 11	Dala	
Contacts Name POC1 Paul Kistler	Phone 805-982-1387	Email paul.kistler@navy.mil	Role	Period of Performa
POC1 Paul Kistler POC2 Mark Kedzierski	805-982-1387	<u>paul.kistler@navy.mii</u>		
				Base / Installation
POC3				TBD, NIST Lab
hnology Descriptio	n			
Provide a brief description of the te		ted in this research project		
	ennology being implement			
est nanolubricant refrigerants in wa	aterside chillers with typica	al COP ratings to determine operating	gefficiencies and discove	r potential maintenance issues
elect up to three different techno	logy types to categorize th	is project		
Fechnology Type 1	Implementation, Integ	ration, Adaptation		
Technology Type 2	Other			
Fechnology Type 3				
icipated Benefits of	f this Technolo	øv		
		of successfully implementing this tec efficiencies of chiller systems with ty		may be different from demonstration)
		n installation fossil fuel consumption		
Renewable Energy List and describe any benefits this ter	chnology has or may have o	on installation renewable energy gene	eration, storage, integrat	ion, or management
Power Consumption				
ist and describe any benefits this te				
Potential Reduced installation	power consumption throu	gh improved end-user efficiency		
, Power Modeling & Management				
	chnology has or may have o	on installation power modeling, mana	agement, or investment o	decisions
Operation and Support Requiremen				
ist and describe any benefits this ten nfrastructure.	chnology has or may have o	on the labor, materials, training, or co	ontracting needed to sup	port and operate installation energy
Energy Assurance, Independence, & List and describe any benefits this te disruptions, or non-disruption of cri	chnology has or may have o	on installation energy assurance and r	esiliency, such as islandi	ng or isolation capability, recovery from
	·			
and the second				

List and desti	be any benefits this technology has or may have on the cyber security of installation energy infrastructure
Costs	
	be any benefits this technology has or may have on installation energy costs that aren't described above
Potential	Improved decision support tools to inform future investments or funding requirements
Second Order	Imparts
	nal benefits, information, feedback, or control does this technology offer to the installation energy end user?
What addition	al benefits, information, feedback, or control does this technology offer to the installation energy manager?
What addition	al benefits, information, feedback, or control does this technology offer to future R&D efforts?
Other	
hnology	y Demonstration Results
What were the	e most significant obstacles encountered in this technology demonstration project?
I imited nume	er of nanolubricant manufacturers. Difficult funding transfer process, NIST (national institute of science n technology) is doing lab testing for us, but Nav
	one work with them creating a big process with lawyers and contractors to transfer funds
never really do	
never really do	one work with them creating a big process with lawyers and contractors to transfer funds did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
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never really do In what ways o huge project o What would y Energy savings	ane work with them creating a big process with lawyers and contractors to transfer funds did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? leavs Page 2 ou describe as the greatest benefit(s) of having completed this demonstration project? swith payback period of 2 years?
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never really do In what ways of huge project d What would y Energy savings What specific Process to avo Once operatio	ane work with them creating a big process with lawyers and contractors to transfer funds did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? lelays Page 2 ou describe as the greatest benefit(s) of having completed this demonstration project? swith payback period of 2 years? adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? id voiding warranties on HVAC equipment with new nanolubricant refrigerant mally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
never really do In what ways of huge project d What would y Energy savings What specific Process to avo Once operatio	ane work with them creating a big process with lawyers and contractors to transfer funds did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? lelays Page 2 ou describe as the greatest benefit(s) of having completed this demonstration project? swith payback period of 2 years? adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? id voiding warranties on HVAC equipment with new nanolubricant refrigerant mally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
never really do In what ways of huge project d What would y Energy savings What specific Process to avo Once operatio	ane work with them creating a big process with lawyers and contractors to transfer funds did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? lelays Page 2 ou describe as the greatest benefit(s) of having completed this demonstration project? swith payback period of 2 years? adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? id voiding warranties on HVAC equipment with new nanolubricant refrigerant mally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
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never really do In what ways of huge project of What would y Energy savings What specific Process to avo Once operatio Potential of vo What advance	ane work with them creating a big process with lawyers and contractors to transfer funds
never really do In what ways of huge project of What would y Energy savings What specific Process to avo Once operatio Potential of vo What advance	ane work with them creating a big process with lawyers and contractors to transfer funds did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? lef as Page 2 ou describe as the greatest benefit(s) of having completed this demonstration project? with payback period of 2 years? adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? id voiding warranties on HVAC equipment with new nanolubricant refrigerant inally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? biding warranties on HVAC equipment, but this can be mitigated through a recent legislative process
never really do In what ways of huge project of What would y Energy savings What specific Process to avo Once operatio Potential of vo What advance	ane work with them creating a big process with lawyers and contractors to transfer funds
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never really do In what ways of huge project of What would y Energy savings What specific Process to avo Once operatio Potential of vo What advance significant HV.	ane work with them creating a big process with lawyers and contractors to transfer funds Id these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Id a page 2 ou describe as the greatest benefit(s) of having completed this demonstration project? iwith payback period of 2 years? adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? id voiding warranties on HVAC equipment with new nanolubricant refrigerant inally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? piding warranties on HVAC equipment, but this can be mitigated through a recent legislative process is or observations were made in this demonstration project that could help justify continued investment in this technology? AC energy savings
never really do In what ways of huge project of What would y Energy savings What specific Process to avo Once operatio Potential of vo What advance significant HV.	ane work with them creating a big process with lawyers and contractors to transfer funds
never really do In what ways of huge project of What would y Energy savings What specific Process to avo Once operatio Potential of vo What advance significant HV.	ane work with them creating a big process with lawyers and contractors to transfer funds Id these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Id a page 2 ou describe as the greatest benefit(s) of having completed this demonstration project? iwith payback period of 2 years? adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? id voiding warranties on HVAC equipment with new nanolubricant refrigerant inally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? piding warranties on HVAC equipment, but this can be mitigated through a recent legislative process is or observations were made in this demonstration project that could help justify continued investment in this technology? AC energy savings
never really do In what ways of huge project of What would y Energy savings What specific Process to avo Once operatio Potential of vo What advance significant HV.	ane work with them creating a big process with lawyers and contractors to transfer funds Id these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology? Id a page 2 ou describe as the greatest benefit(s) of having completed this demonstration project? iwith payback period of 2 years? adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? id voiding warranties on HVAC equipment with new nanolubricant refrigerant inally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? piding warranties on HVAC equipment, but this can be mitigated through a recent legislative process is or observations were made in this demonstration project that could help justify continued investment in this technology? AC energy savings

Technology Adopti	on Considera	ations
Technology Integration		
Maturity of the technology fa	mily new technol	ogy requires vetting to avoid voiding warranties
Maturity/suitability of specif		ogy requires verting to avoid volding warrances
used in this project		
Laboration with No. 199	Describber of	
Integration with Navy-specifi Environmental or Installation		intenance considerations
challenges	r speerne	
Accessibility of required com	ponents few nanolub	ricant refrigerant manufactureres available
Process Challenges		
		uirements to integrate new refrigerants that may potentially void chiller warranties, implementation would require a
Certification or Approval req		ified Facilities Criteria guide/specs
Initial Funding or Resource A issues		tially be purchased from ops/maintenance budget
Continued Funding or Resou		
Allocation issues	possible mai	ntenance funding considerations
Contracting / Procurement	only one par	volubricant refrigerant manufacturer known
Contracting / Procurement	only one har	olubricant refrigerant manufacturer known
Stakeholder Challenges		
Impact on and Approval of ce		
stakeholders	PW buy-in n	eeded to install new nanolubricant refrigerant
Limitations from stakeholder	needs	
Operation and support labor		
requirements	possible mai	ntenance considerations
Necessary Funding Streams:	n and to fund	DWAima to install your officerent
Integration Necessary Funding Streams: 0		PW time to install new refrigerant
Support		
Continued feedback and imp	rovement	
ntern Involvement	t	
Intern Name	Year (if known)	Where are they now? (if known)
References		
Technener		
Tech papers Author(s)	Title	
	inde	
for an all for the second s	_	
Journal Articles, Publication Author(s)	s Title	
Author(s)	nue	
NPS Student Theses Author(s)	Title (if know	
	intie (il know	mp

B50. Project Information Form for Project 50: Tunable White LED

nable White LED				
Other Names, Abriviations, etc:				
Contacts Name	Phone	Email	Role	Period of Performan
POC1 Paul Kistler	805-982-1387	paul.kistler@navy.mil	PI	FY17 FY1
POC2 Konstantinos Papa	amicha			Base / Installation
POC3 Bang Duong				NAVFAC EXWC
hnology Descripti	on			
Provide a brief description of the	e technology being impleme	nted in this research project		
		re lighting controls can be implem ntrols giving personnel control ove		vity, even at lower light levels which can pro onment.
Select up to three different tech	nnology types to categorize t	his project		
Technology Type 1	Implementation, Inte	gration, Adaptation		
Technology Type 2	Other			
Technology Type 3				
	<u></u>			
ticipated Benefits	of this Technolo	рgy		
	pectral and CCT properties of			(may be different from demonstration) re productive at potentially lower lighting
Fossil Fuel Consumption				
List and describe any benefits thi	s technology has or may have	on installation fossil fuel consump	otion or backup power gene	rator use
Renewable Energy List and describe any benefits thi	s technology has or may have	on installation renewable energy g	generation, storage, integra	tion, or management
Power Consumption				
List and describe any benefits thi	s technology has or may have	on installation power consumption	on	
Potential Reduced installati	on power consumption throu	ugh improved end-user efficiency		
Potential Reduced installati	on power consumption throu	ugh building control automation		
Power Modeling & Managemen	t			
		on installation power modeling, n	management, or investment	decisions
Operation and Support Require		and the labor of a state of a labor to be a		and the state of t
	s technology has or may have	on the labor, materials, training, c	or contracting needed to sup	pport and operate installation energy
infrastructure.				
Energy Assurance, Independence	e. & Resiliency			
		on installation energy assurance a	nd resiliency, such as island	ing or isolation capability, recovery from
disruptions, or non-disruption o		and the standard standards and the standards and standards a		
disruptions, or non-disruption o	reneledi systemis			

	e any benefits this technology has or may have on the cyber security of installation energy infrastructure
i	
Costs	
List and describ	e any benefits this technology has or may have on installation energy costs that aren't described above
Second Order I	npacts
	•
Second Order In What additiona	mpacts I benefits, information, feedback, or control does this technology offer to the installation energy end user?
	•
	•
What additiona	•
What additiona	I benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additiona	I benefits, information, feedback, or control does this technology offer to the installation energy end user?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?
difficulties in approving lighting control systems, difficulties in attempting to involve UC Davis, contracting vehicles, RMF (risk management framework, cybersecurity)
because of required approvals, don't have the people, funding, facilities to go through the RMF process
because on required approvais, don't have the people, failuting, facilities to go through the twin process
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
delays, 5 month delay to determine if project would be considered "human testing"
delay, 5 month delay to determine in project would be considered internal resting
What would you describe as the greatest benefit(s) of having completed this demonstration project?
will give info on lighting if people will dim light when at certain colors/hues, give experience with tunable LED, assuming people dim bluer lights will use less energy,
theoretical savings of up to 20% compared to undimmed LED
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
no necessary
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
Increased installation costs due to control systems
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
not yet
What new skills, competencies, or experience were gained within the Navy workforce during this project?
learning what is required for RMF

Technology Integration	
Maturity of the technology family	Tunable LEDs are readily commercially available
Maturity/suitability of specific systems	
used in this project	
Integration with Navy-specific systems	Cyber requirements may preclude certain systems based on control architecture
Environmental or Installation-specific	
challenges	Personal lighting preference may vary
Accessibility of required components	
Process Challenges	
Certification or Approval requirements	Got to go through site approval, safety plans, public works, contracting
Initial Funding or Resource Allocation	
issues	most energy projects are alternative-financed, need to convince that it is a good (profitable) technology.
Continued Funding or Resource	
Allocation issues	
Contracting / Procurement	ESPC or UESC (Utility Energy Saving Contract), contractor or utility is responsible for operation/maintenance
Stakeholder Challenges	
Impact on and Approval of certain	will need to be a change to unified facilities criteria (UFC) for lighting design, currently requires maximum cct of 4100k, minimum

stakeholders	illumination requirements, 30-18 ft-candles
Limitations from stakeholder needs	
Operation and support labor	
requirements	requires less labor that replacing flourescent tubes (longer life), but slightly different skill set
Necessary Funding Streams:	
Integration	Requires additional time to calibrate lighting to individuals' needs
Necessary Funding Streams: Continued	
Support	
Continued feedback and improvement	Need to evaluate energy savings from new lighting after user calibration

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers		
Author(s)	Title	
Journal Articles, Publica	tions	
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B51. Project Information Form for Project 51: Waste Heat Recovery from Gas Turbine Exhaust

ste Hea	at Recovery	From Gas Turb	oine Exhaust		
Other Names,	, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Garth Hobson	831-656-2888	gvhobson@nps.edu	PI	FY18 FY19
POC2	Doug Seivwright			Co-PI	Base / Installation
POC3					NPS
hnolog	y Descriptio	n			
	•		nted in this research project		
Provide a brie	ef description of the to	echnology being impleme	inted in this research project	e the efficiency of gas turb	pine systems
Provide a brie Develop a wa	ef description of the to	echnology being impleme	luids (CO2 Brayton cycle) to improv	e the efficiency of gas turb	pine systems
Provide a brie Develop a wa	ef description of the to ste heat recovery syste three different techno	echnology being impleme m using organic working fl	luids (CO2 Brayton cycle) to improv	e the efficiency of gas turb	pine systems
Provide a brie Develop a was Select up to t	ef description of the to ste heat recovery syste three different techno ype 1	echnology being impleme m using organic working fl plogy types to categorize ti	luids (CO2 Brayton cycle) to improv	e the efficiency of gas turb	pine systems

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration) Improved energy efficiency and lowered fuel costs in a scalable system **Fossil Fuel Consumption** List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use Reduced natural gas needed for heating or installation operation otentia Improved efficiency of fossil fuel backup power systems otentia Renewable Energy List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management trated Added renewable energy generation capability (wind, solar, etc) **Power Consumption** List and describe any benefits this technology has or may have on installation power consumption Reduced installation power consumption through improved distribution efficiency Power Modeling & Management List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions **Operation and Support Requirements** List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure Energy Assurance, Independence, & Resiliency List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems Reduced reliance on outside energy suppliers Cyber Security List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure Costs List and describe any benefits this technology has or may have on installation energy costs that aren't described above Second Order Impacts What additional benefits, information, feedback, or control does this technology offer to the installation energy end user? What additional benefits, information, feedback, or control does this technology offer to the installation energy manager? What additional benefits, information, feedback, or control does this technology offer to future R&D efforts? Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?	
Optimization of non-recuperated CO2 thermodynamic cycle, integration of industrial hardware in a scaled demonstrator	
n what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?	
Page 2	
What would you describe as the greatest benefit(s) of having completed this demonstration project?	
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?	
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?	
What new skills, competencies, or experience were gained within the Navy workforce during this project?	

<u>0</u>		
Technology Integration		
Maturity of the technology f	amily waste heat re	covery technology mature on utility scale applications but not building scale.
Maturity/suitability of speci		
used in this project		
Integration with Navy-speci		
Environmental or Installatio		
challenges	Certain instal	lations are using centralized steam heating systems that may need to be replaced
Accessibility of required con	nponents Will have to s	ource custom advanced heat exchangers (non COTS item)
Process Challenges		
		ill be a very involved process for large scale operations, environmental permitting for natural gas systems
Initial Funding or Resource		
issues Continued Funding or Resou	large upfront	cost
Allocation issues		
Contracting / Procurement	Procurement	of advanced heat exchangers (non-COTS item)
Stakeholder Challenges Impact on and Approval of c	ortain	
stakeholders		ignificant infrastructure work to integrate waste heat recovery systems
stationacis	They requires	Builden under andere
Limitations from stakeholde	er needs operations or	climate will constrain when upgrades can take place.
Operation and support labo	r	
requirements		
Necessary Funding Streams:		
Integration	Continued	
Necessary Funding Streams: Support	Continued	
Support		
Continued feedback and imp	provement	
tern Involvemen		
Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers	
Author(s)	Title
Journal Articles, Publications	
Author(s)	Title
NPS Student Theses	
Author(s)	Title (if known)
LT Aaron Vandenberg	
LT Coria Buck	

B52. Project Information Form for Project 52: Efficient Implementation of Solid State Transformers (SST)

cient Implementation of Solid State Transformers (SST)					
)ther Names,	, Abriviations, etc:				
Contacts	Name	Phone	Email	Role	Period of Performance
POC1	Todd Weatherfort	831-656-3044	trweathe@nps.edu	PI	FY16 FY17
POC2	Andrew Parker				Base / Installation
POC3	Matthew Porter				NPS, NCSU
nnolog	y Description	n			NF3, NC30
	y Descriptio		ented in this research project		INF3, NC30
	y Descriptio		ented in this research project		NF3, NC30
rovide a bri	y Description	echnology being impleme		pology to control the exchar	nge of power between the microgrid and the
rovide a brientegrate soft	y Description	echnology being impleme		pology to control the exchar	
rovide a brientegrate soft	y Description ef description of the te ware control for "Smar	echnology being impleme		pology to control the exchar	
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Anticipated Benefits of this Technology

	• Up Front: Describe the biggest anticipated benefit of successfully implementing this technology operationally (may be different from demonstration)
improved ei	ergy transfer efficiency and ability to establish mobile microgrids
	er gy transier eniciency and aunity to establish mobile microgrius
Fossil Fuel C	onsumption
	vribe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use
Renewable	
	ribe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management
Demonstrati Potential	ec Improved efficiency or effectiveness of existing renewable generation Improved efficiency or effectiveness of existing renewable energy storage
lealized	Improved capability to integrate renewables into larger grid
otential	Improved capability to estimate ROI of renewable systems
ower Cons	
lealized	ribe any benefits this technology has or may have on installation power consumption Reduced installation power consumption through improved distribution efficiency
ower Mod	eling & Management
	ribe any benefits this technology has or may have on installation power modeling, management, or investment decisions
otential	Power modeling used to optimize grid configuration or expansion
•	nd Support Requirements
	ribe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy
nfrastructu	re. eq Reduced contractor support required to install, maintain, or operate technology
	a recorder of pupped and a second sec
Demonstrat	
otential	Technology is easier to operate than alternative systems
norm Accu	
	rance, Independence, & Resiliency
ist and desc	
ist and desc	rance, Independence, & Resiliency rribe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from
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Technology Demonstration Results

Intract parts availability, SST/MUSE testbed integration, contract execution what ways did these obstacles hinder the implementation, or effectiveness of the demonstrated technology? Bage 2 hat would you describe as the greatest benefit(s) of having completed this demonstration project? Inproved understanding of performance of new solid state devices, improved capability to establish microgrids in remote facilities due to compact size/weight of new chnology hat specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? Itting to ensure standards for reliability, safety are met Ince operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? Inproved capability to establish compact microgrids at remote installations hat advances or observations were made in this demonstration project that could help justify continued investment in this technology?		
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וות מסימורפי סו סטצפו אמנוסויג שביר ווומע פווו מווג מפווסויגרו מנוסוי מיס פרני נוומר כסמים וופיף וטגנוץ כסו מחשפע חויעפג ווופור זו מווג נפרוווסוספץ:	Once operationally matur	e, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
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hat new skills, competencies, or experience were gained within the Navy workforce during this project?	Once operationally matur Improved capability to est	e, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? tablish compact microgrids at remote installations
	Once operationally matur improved capability to est What advances or observa	e, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? tablish compact microgrids at remote installations stions were made in this demonstration project that could help justify continued investment in this technology?
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	Technology Integration					
	Maturity of the technology f		chnology m	ust still be properly vetted to ensure component reliability needs are met		
	Maturity/suitability of speci	ific systems				
	used in this project					
	Integration with Navy-speci	fic systems				
	Environmental or Installatio	on-specific				
	challenges					
	Accessibility of required con	nponents lim	nited numbe	er of vendors		
	Process Challenges					
	Certification or Approval rec	quirements				
	Initial Funding or Resource	Allocation				
	issues		ge compone	ent cost		
	Continued Funding or Resou	urce				
	Allocation issues					
	Contracting / Procurement	Cor	ntracting su	pport needed to acquire and install systems		
	Stakeholder Challenges					
1	Impact on and Approval of c	ertain				
	stakeholders		zh demands	for power quality and reliability that cannot be sacrificed for efficiency		
	Limitations from stakeholde	er needs				
	Operation and support labo					
	requirements		ssible maint	enance/servicability complications		
	Necessary Funding Streams:					
	Integration					
	Necessary Funding Streams:	Continued				
	Support					
	Continued feedback and im	provement Fee	edback need	led to ensure systems are meeting power quality and reliability needs in the field		
	aca recabacit and im	/ enterte l'ete				
nt	ern Involvemen	t				
	Intern Name	Year (if kn	iown)	Where are they now? (if known)		
			,			

References

Tech papers		
Author(s)	Title	
Author(s)	inte	
Journal Articles, Publication	15	
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	
CDR Martino		

B53. Project Information Form for Project 53: HVAC Control by Means of Predicted Percentage of Dissatisfied Method

AC Con	trol by Mean	s of Predicted	Percentage of Diss	atisfied Meth	od
Other Names	s, Abriviations, etc:				
Contacts POC1	Name Arthur Rubio	Phone 619-553-1904	Email rubio@spawar.navy.mil	Role	Period of Performance FY17 FY19
POC2	Alan Williams	015 555 1504			Base / Installation
POC3					SSC PAC Building 111
chnolog	y Description	1			
Provide a bri	ief description of the teo	chnology being impleme	nted in this research project		
Implement P	Predictive Mean Vote (PM	IV) and Predictive Percen	tage Dissatistfied (PPD) to provide hi	gh resolution HVAC contr	ols to optimized energy usage in HVAC systems
· · · · ·		ogy types to categorize th			
Technology		Modeling & Optimizat			
Technology		Energy Management 8	Monitoring		
Technology					
nticipate	d Benefits of	this Technolo	ogy		
Bottom Line	Up Front: Describe the b	piggest anticipated benefi	t of successfully implementing this to	echnology operationally (may be different from demonstration)
			HVAC systems by using smart sensors		
Fossil Fuel C	onsumption				
		hnology has or may have	on installation fossil fuel consumpti-	on or backup power gener	rator use
Potential		eeded for heating or insta			
				-	
Renewable I		hnology has or may have	on installation renewable energy ger	heration, storage, integrat	ion, or management
	-				
Power Cons	umation				
	-	hnology has or may have	on installation power consumption		
Potential			igh building control automation		
			······································		
Power Mode	eling & Management				
		hnology has or may have	on installation power modeling, ma	nagement, or investment	decisions
Potential	Modeling and simulati	ion to inform energy infra	structure investments		
	· ·		on the labor, materials, training, or o	contracting needed to sup	port and operate installation energy
mastructu					
	ance, Independence, &				
	ribe any benefits this tec or non-disruption of crit		on installation energy assurance and	resiliency, such as islandi	ng or isolation capability, recovery from

	cribe any benefits this technology has or may have on the cyber security of installation energy infrastructure
Costs	
	cribe any benefits this technology has or may have on installation energy costs that aren't described above
Potential	Reduced wear and tear on mechanical systems
	•
	er Impacts on al benefits, information, feedback, or control does this technology offer to the installation energy end user?
	•
What additi	onal benefits, information, feedback, or control does this technology offer to the installation energy end user?
What additi What additi	onal benefits, information, feedback, or control does this technology offer to the installation energy end user?
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What were the most significant obstacles encountered in this technology demonstration project?
Design of sensors and communication infrastructure to be compliant with cyber and networking protocols
n what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Page 2
What would you describe as the greatest benefit(s) of having completed this demonstration project?
Decreased energy consumed by HVAC systems and reduced maintenance requirement due to decreased run time
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
what advances of observations were made in this demonstration project that could help justify continued investment in this technology:
What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Integration	
Maturity of the technology family	Design of sensors and communications infrastructure in progress
Maturity/suitability of specific systems	
used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific	
challenges	Cyber concerns regarding wireless sensors
Accessibility of required components	Custom-built solution, needs to be further developed into an off-the-shelf solution
Process Challenges	
	Approval required for wireless transmitting devices
Initial Funding or Resource Allocation	
issues	
Continued Funding or Resource Allocation issues	
Anocación issues	
Contracting / Procurement	Possible contractor labor needed to integrate sensor input into HVAC control systems
Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	impact on building occupant comfort level

Limitations from stakeholder needs	Stakeholder's desire for manual climate control
Operation and support labor	
requirements	periodic maintenance to replace sensor batteries
Necessary Funding Streams:	
Integration	
Necessary Funding Streams: Continued	
Support	periodic maintenance to replace sensor batteries
Continued feedback and improvement	Feedback required to ensure building occupant comfort within allowable percentage satisfied

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Jeremy Poche		
Justin Hartline		

References

Tech papers		
Author(s)	Title	
Journal Articles, Publications		
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B54. Project Information Form for Project 54: Develop Energy Use Trends with Innovative Visualization/Analysis

Develo	p Ene	ergy Use Trer	nds with Inn	ovative Visualiza	tion/Analysis	
C	Other Nam	es, Abriviations, etc:				
	Contacts	Name	Phone	Email	Role	Period of Performance
-	POC1	Chris Chen	619-553-6852	chris.s.chen@navy.mil	PI	FY17 FY18
	POC2 POC3	David Borroel Kerrie Trotter				Base / Installation
	r 0C3	incine notier				
Techno	ology	Description				
P	Provide a b	rief description of the	technology being imp	lemented in this research proj	ect	
		or this project is to fuse ge in naval facilities.	existing datasets (i.e. C	IRCUITS, Maximo, INFADS, AMI,	, audit data) to better unde	erstand the factors that have high correlations with
s	elect up t	o three different techr	ology types to catego	rize this project		
	echnology		Decision Support			
	echnology		Other			
-	echnology					
Anticip	ated	Benefits of t		אנא		
E	Bottom Lir	e Up Front: Describe th	ne biggest anticipated I	penefit of successfully impleme	nting this technology oper	rationally (may be different from demonstration)
AA F	use existir					high correlations with energy usage in naval
fi	acilities					
		Consumption	toobaalaanta		an automation and the	
	ist and de	scribe any benefits this	technology has or may	have on installation fossil fuel of	consumption or backup po	ower generator use
				200		
	Renewable					
L	ist and de	scribe any benefits this	technology has or may	have on installation renewable	energy generation, storag	e, integration, or management
_						
P	ower Con	sumption				
		-	technology has or may	have on installation power cor	nsumption	
-						
		deling & Management				
				have on installation power mo	deling, management, or in	vestment decisions
				frastructure investments		
		and Support Requirem		have on the labor materials tr	aining or contracting nee	ded to support and operate installation energy
	otential	Technology is easier to				
_						
		urance, Independence				
	ist and de	scribe any benefits this	technology has or may	nave on installation energy ass	urance and resiliency, such	h as islanding or isolation capability, recovery from

	escribe any benefits this technology has or may have on the cyber security of installation energy infrastructure
	·
Costs	en alte en stan Arabitation de la colore en ante la colore en teste llatter en anno en teste de la colore de la
Potential	escribe any benefits this technology has or may have on installation energy costs that aren't described above Improved decision support tools to inform future investments or funding requirements
Second O	rder Impacts
What add	itional benefits, information, feedback, or control does this technology offer to the installation energy end user?
Potential	Increased awareness of energy use
What add	itional benefits, information, feedback, or control does this technology offer to the installation energy manager?
Potential	
What add Potential	itional benefits, information, feedback, or control does this technology offer to future R&D efforts? Improved access to energy use data
Potential	Induoved access to energy use data
Other	
าโกฐง	Demonstration Results
51059	
	e the most significant obstacles encountered in this technology demonstration project? ng reporting in a way that considered different factors such as floor area, building/facility type, local climate, etc; gaining access to data
n what u	
II wildt w	averdid these obstacles binder the implementation operation or effectiveness of the demonstrated technology?
	ays did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
	ays did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
	ays did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
	ays did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
What wo	raye z
	ays did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
	uld you describe as the greatest benefit(s) of having completed this demonstration project?
	uld you describe as the greatest benefit(s) of having completed this demonstration project?
	uld you describe as the greatest benefit(s) of having completed this demonstration project?
Improved	uld you describe as the greatest benefit(s) of having completed this demonstration project? I capability to compare energy use data across dissimilar buildings in a meaningful way
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Mproved	uld you describe as the greatest benefit(s) of having completed this demonstration project? I capability to compare energy use data across dissimilar buildings in a meaningful way cific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
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Mhat spe	Id you describe as the greatest benefit(s) of having completed this demonstration project? I capability to compare energy use data across dissimilar buildings in a meaningful way cific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use? rationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies? I capability to compare datasets from separate archives with their own formats ances or observations were made in this demonstration project that could help justify continued investment in this technology?

Technology Integration	
Maturity of the technology family	databases are mature, but there is no mature way to format/transfer data between them
Maturity/suitability of specific	
systems used in this project	
Integration with Navy-specific	
systems	Verification & Validation needed to confirm accuracy of data conversion
Environmental or Installation-	
specific challenges	
Accessibility of required	
components	

Process Challenges

r roccus chancinges	
Certification or Approval	
requirements	
Initial Funding or Resource	
Allocation issues	
Continued Funding or Resource	
Allocation issues	
Contracting / Procurement	
Contracting / Procurement	

Stakeholder Challenges

Stakenoluer Challenges	
Impact on and Approval of certain	
stakeholders	
Limitations from stakeholder	
needs	
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	
Necessary Funding Streams:	
Continued Support	funding may be necessary to periodically update data sets
Continued feedback and	
improvement	

Intern Involvement

	Year (if known)	Where are they now? (if known)
Tim Jordon		
Jason Sneddon		

References

Tech papers		
Author(s)	Title	
Journal Articles, Publ	ications	
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

B55. Project Information Form for Project 55: Green Data Center Software Product Evaluation

ireen Data Center Soft	tware Product Eval	uation		
Other Names, Abriviations, etc:				
Contacts Name POC1 Mamadou Diallo	Phone 9494001735 mar	Email nadou.h.diallo@navy.mil	Role	Period of Performance
POC2 Michael August	9494001733			Base / Installation
POC3 Scott Slayback				NACS lab
echnology Description	ı			
Provide a brief description of the tea	chnology being implemented in th	his research project		
			ogies in saving energy in da	ata centers (Microsoft System Center Virtual
Machine Manager on Microsoft Hype Distributed Power Management).	er-V, Eaton Intelligent Power Manag	gement on Citrix XenServer, a	and vSphere Distributed P	Power Management on VMWare vSphere
Select up to three different technol		t		
Technology Type 1	Other			
Technology Type 2 Technology Type 3				
nticipated Benefits of	this Technology			
		essfully implementing this te	chnology operationally (r	may be different from demonstration)
Reduced energy consumption at Nav	y datacenters			
Fossil Fuel Consumption				
List and describe any benefits this tec	chnology has or may have on install	ation fossil fuel consumptio	n or backup power genera	atoruse
Renewable Energy				
List and describe any benefits this tec	chnology has or may have on install	ation renewable energy gene	eration, storage, integrati	on, or management
Power Consumption				
List and describe any benefits this tec				
Potential Reduced installation p	power consumption through impro	oved end-user efficiency		
Power Modeling & Management				
List and describe any benefits this tec	chnology has or may have on install	ation power modeling, man	agement, or investment d	lecisions
Operation and Support Requiremen	ts			
List and describe any benefits this tec		bor, materials, training, or co	ontracting needed to supp	port and operate installation energy
infrastructure.				
Energy Assurance, Independence, &	Resiliency			
	-	ation energy assurance and i	resiliency, such as islandir	ng or isolation capability, recovery from
disruptions, or non-disruption of crit				

	e any benefits this technology has or may have on the cyber security of installation energy infrastructure
osts	
	e any benefits this technology has or may have on installation energy costs that aren't described above
	Reduced wear and tear on mechanical systems
econd Order I	
Vhat additiona	Il benefits, information, feedback, or control does this technology offer to the installation energy end user?
Vhat additiona	al benefits, information, feedback, or control does this technology offer to the installation energy manager?
Vhat additiona	I benefits, information, feedback, or control does this technology offer to future R&D efforts?
Other	
	Demonstration Results
hnology	
hnology	
	most significant obstacles encountered in this technology demonstration project?

What were the most significant obstacles encountered in this technology demonstration project?
n what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?
Page 2
What would you describe as the greatest benefit(s) of having completed this demonstration project?
Virtualized data center Energy Management Testbed for deploying and evaluating energy management systems
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?
Dice operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
mercede activities y maker, what detents and/or unavoacts would this technology have over other (maker) activities activities technologies more data center energy optimization technologies
improved depaidintly to compare data center energy optimization technologies
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
What new skills, competencies, or experience were gained within the Navy workforce during this project?

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers Author(s)		
Author(s)	Title	
Journal Articles, Public	ations	
Author(s)	Title	
NPS Student Theses		
Author(s)	Title (if known)	

Technology Adoption Considerations

Technology Integration	
Maturity of the technology family	
Maturity/suitability of specific systems	
used in this project	It remains to be seen which particular product is best suited for DoD use
	Installations using different hardware or software configurations might benefit more from different specific implementations or
Integration with Navy-specific systems	versions of energy management technology
Environmental or Installation-specific	
challenges	
Accessibility of required components	
Process Challenges	
	Approval required for implementation across DOD data centers
Initial Funding or Resource Allocation	
issues Continued Funding or Resource	
Allocation issues	
Anocation issues	
Contracting / Procurement	
contracting/ Hocarcinent	
Stakeholder Challenges	
Impact on and Approval of certain	
stakeholders	
Limitations from stakeholder needs	Energy management software may not significantly impact data center performance
Operation and support labor	
requirements	
Necessary Funding Streams:	
Integration	
Necessary Funding Streams: Continued	
Support	
Continued feedback and improvement	Continued support needed to implement software updates

LIST OF REFERENCES

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