ENERGY ACADEMIC GROUP
NAVAL POSTGRADUATE SCHOOL

SURGE

ENERGY ACADEMIC GROUP QUARTERLY NEWSLETTER SUMMER 2020

Highlights

OPERATIONAL ENERGY

Meeting the Challenges of the Department of the Navy Operational Energy Goals

Operational demonstration of the Office of Naval Research (ONR)-sponsored Laser Weapon System (LaWS) (U.S. Navy Photo)

By James C. Caley
Director for Operational Energy, Department of the Navy

THE FOCUS OF NATIONAL STRATEGY has transitioned from one on counter-insurgency operations to global deterrence and competition with peer and near-peer competitors. In order to be successful, the Chief of Naval Operations and the Commandant of the Marine Corps have asked the Services to focus on concepts like Distributed Maritime Operations and Littoral Operations in Contested Environments. The impact on the Naval Operational Energy challenges has been significant. Meeting those challenges require the Department of the Navy (DoN) to enhance the lethality and effectiveness of forces through energy resilience, operational reach, and time on station of forward presence naval forces.

The Department of the Navy operational energy challenges are myriad. The naval fuel distribution system is characterized by critical assets and single points of failure along static lines of communication. Fuel demand is projected to increase by as much as 15% between now and 2030 as a result of increased demand of weapons systems, increasing force structure, and increased demands of distributed maritime operations. For example, our ability to distribute fuel beyond the oiler into the littorals and contested environments needs to be addressed through an integrated naval approach. Deployed expeditionary forces requirements in electricity have gone up more than 26%, and advanced weapons systems and sensors will more than double electrical demand on our ships.

To solve these problems, the DoN should consider the following recommendations.

Future power must be shared

Future warfighting requires more power at all levels. Our Marines and SEALs and other expeditionary forces require power for radios, computers, electronic warfare capability and

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FROM THE CHAIR

Dan Nussbaum, Chair of the Energy Academic Group

I HAVE BEEN THINKING ABOUT THE IMPACT OF COVID-19 on the energy space… (Haven't we all?). Normally, economics is an easy thing. The clearing price of an economic good, say energy, is at that point at which supply and demand are in equilibrium. So, what's going on in today's energy markets? There's been a huge increase in supply (OPEC + cuts) and a simultaneous destruction of demand (COVID-19 and its impacts). Therefore, as expected, prices have collapsed. So what and what now?

There are lots of articles that have come out on this energy issue. I have read probably 40 articles and attended 10 webinars, all on the topic of "*wither energy in the COVID-19 era?*". As you would guess, all of them say, as befits the comments of good economists, that increased supply and decreased demand will lead to lower prices, and it will end when, well… it depends. In other words, "on one hand, and on the other hand". As one of our previous presidents said, "Please get me a one-handed economist!"

> **The one thing that I can see is that we are a far cry from the "peak oil" story that we had heard only five or so years ago.**

The one thing that I can see is that we are a far cry from the "peak oil" story that we had heard only five or so years ago. Now, it may be "peak demand" rather than "peak supply", but we will have to wait to see how that works out. At the moment there appears to be an enormous level of supply on the market. Meanwhile, here are articles/webinars that you can read and watch on your own on this timely and important topic:

The Role of Energy Efficiency in COVID Stimulus Packages, IEA webinar, April 30, 2020, **https://youtu.be/s9KuJhQB2Xw**

COVID-19 Energy Forum Special Issue of the International Association of Energy Economists (IAEE), **https://www.iaee.org/documents/2020EnergyForumSI.pdf**, which includes 37 interesting articles.

I'd be interested in your comments. Happy reading and browsing!

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more. The traditional method of powering those devices with discrete batteries and generators has resulted in increasing carried loads and logistics support requirements. Furthermore, future weapons systems and sensors require significant additional power exceeding the capabilities of today's ships and aircraft. Fitting more power generation and storage on the platforms is not a reasonable solution. Sharing networked power can enable directed energy capabilities such as lasers, more effective radars, and other electronic warfare capabilities.

Fuel distribution needs to meet the demands of a distributed and contested warfighting environment.

Navy oilers may be the backbone of naval capability, but are not optimized for performing their mission in high risk environments, or worse yet, under fire. Both the Navy and the Marine Corps are examining fuel distribution within the range of enemy threat accomplished in smaller, lower profile, risk-worthy platforms.

Advanced energy storage is a key enabler for unmanned systems, isolated forces, and efficient and effective power management of directed-energy weapons.

The Navy and Marine Corps are in need of dependable, energy/power-dense, safe, and affordable batteries to meet these growing demands. Leveraging commercial investment in domestic grid electrification and the automotive sector, and enhanced standardization and commonality, are potential opportunities.

These considerations are offered as the DoN works towards establishing coordinated, Service-specific, measurable objectives to ensure naval operational challenges are addressed and integrated. There surely will be more to follow.

LEARN MORE
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TS Golden Bear in Vallejo, California (California State University Maritime Academy photo)

ENERGY RESEARCH

Waste Heat Recovery on the Training Ship *Golden Bear*

NAVAL POSTGRADUATE SCHOOL (NPS) faculty made a recent visit to California State University Maritime Academy, Cal Maritime, to research waste heat recovery (WHR) for energy efficiency on surface ships.

Energy Efficiency and Navy Combat Power

The capacity to integrate future high-power weapons demands ship energy systems that support the maximum operational reach *and* lethality that warfighters can apply. Common renewable energy technologies are not feasible due to spatial constraints and survivability considerations. However, WHR system retrofits have shown potential.

Why WHR?

There are *theoretical limits* on the performance of *heat engines*. "Heat engines" receive heat (often from fuel combustion), convert *some* heat to work (usually in the form of a rotating shaft), then reject the remaining heat to the environment. Theoretical limits on thermal efficiency establish that a heat engine will not convert *all* received heat into work. However, the rejected or "waste" heat can be *recovered* for another "low end" heat engine to receive.

NPS Professor Larraza and LT Denzel Reina, USN—a graduate student studying mechanical engineering at NPS—are considering how WHR systems could be included in future ship design as well as in retrofit to existing ships.

WHR Research and Analysis

The recent tour of Cal Maritime's 500-foot Training Ship *Golden Bear* featured its Organic Rankine Cycle (ORC) WHR system. NPS professor Andres Larraza leads research and analysis efforts analyzing WHR system approaches, like ORC and others. The objective: determine the best options, feasibility, and barriers to improved operational capabilities and implementation.

Professor Larraza and LT Denzel Reina, USN—a graduate student studying mechanical engineering at NPS—are considering how WHR systems could be included in future ship design as well as in retrofit to existing ships. Alternative WHR systems, including thermoelectric and thermoacoustics technologies, are also being studied.

LEARN MORE
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OPERATIONAL ENERGY

Vertical Wiper Blades Reduce Aircraft Drag, Tests Show

By Corrie Poland, Air Force Operational Energy (SAF/IEN)

KC-135 Stratotanker (U.S. Air Force photo by Master Sgt. Keith Reed)

Article originally published April 20, 2020. Provided by the U.S. Air Force Air Combat Command and reprinted with permission.

AERODYNAMICS TESTING on the KC-135 Stratotanker confirmed vertically mounted wiper blades reduce aircraft drag by approximately 1 percent during cruise conditions, potentially saving the Air Force $7 million annually in associated fuel costs.

Across the KC-135 fleet, blades are positioned horizontally on the windshield as part of the aircraft's original 1950s design. However, as the understanding of aviation aerodynamics advanced, research indicated placing the wipers vertically (when not in use) could improve aerodynamic efficiency and optimize fuel use.

Commercial airliners first demonstrated the concept on the McDonnell Douglas MD-11, a jet airliner primarily used by the cargo industry, proving that retro-fitting the blades vertically could decrease costly drag by 1.2 percent.

As part of the effort to increase the capability of legacy aircraft, the Advanced Power and Technology Office (APTO), part of the Air Force Research Laboratory (AFRL), identified the KC-135 as a candidate for the modification in 2019 citing its horizontal wiper design and significant fuel use.

According to 2019 data from the Air Force Total Ownership Cost database, the KC-135 fleet consumed over 260 million gallons last year, accounting for almost 14 percent of total Air Force aviation fuel use.

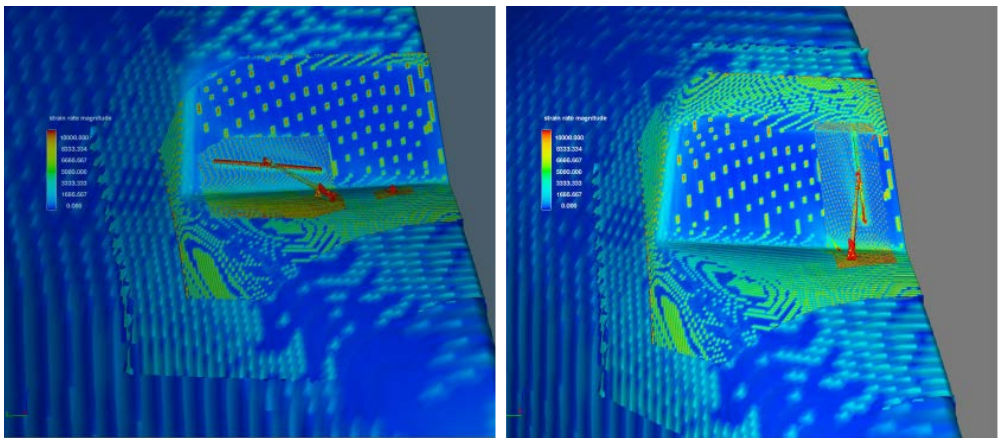
> **"While 1 percent efficiency may not seem like a lot, it equates to millions of dollars in fuel savings each year, which can then be re-invested into other programs."**

"We're partnering with the Southwest Research Institute, the Air National Guard, and the Air Force Operational Energy office to validate the concept and determine actual efficiency gains," said Ed Clark APTO aviation program lead overseeing the initiative.

The team of researchers and aeronautical engineers employed a KC-135 from Rickenbacker Air National Guard Base in Ohio, to conduct comprehensive ground testing on the airframe. Using computational fluid dynamics (CFD), they were able to model how air flows over the nose and windshield of the aircraft during flight, simulating both vertical and horizontal wiper positions.

The CFD models enabled the Rickenbacker team to visualize areas on the airframe that produce higher drag (shown in red in the photo on page 5) and identify potential efficiencies. According to the report, data showed a reduction in drag of 0.8 percent for re-positioning the blade vertically, and 0.2 percent for the slimmer wiper design.

"This is a significant milestone for us. Over several months, we performed thousands of flight configurations



Computational fluid dynamics analysis, conducted by Air Force Research Laboratory and Southwest Research Institute, shows the nose of a KC-135 Stratotanker, as the wiper blades are positioned horizontally, left, and vertically, right. The red indicates an area of high aerodynamic drag. (U.S. Air Force photo)

during CFD testing to prove efficiency gains on the KC-135," Clark remarked. "Now, we're ready to move onto airworthiness testing and certify its use with the [Federal Aviation Administration]."

The team plans to further refine the wiper design and layout over the coming months, with the next phase scheduled for summer 2020. They have also partnered with Delta Airlines, who plans to leverage some of the lessons learned on the KC-135 effort to assess the potential of utilizing vertical wipers on their Boeing 767 fleet.

"While 1 percent efficiency may not seem like a lot, it equates to millions of dollars in fuel savings each year, which can then be re-invested into other programs," explained Daniel Pike, acquisition manager and chief of future operations for Air Force Operational Energy, whose office is helping to fund the initiative. "When you combine the results of optimization efforts across multiple aircraft, you start to understand how much of an impact this could have."

As the Air Force seeks to improve the range and capability of its legacy aircraft, researchers and subject matter experts from APTO and the Operational Energy office are exploring several ways to increase efficiency through optimized operations, modern technology, and drag reduction initiatives.

LEARN MORE

For more information on energy optimization efforts in the Air Force, visit: **safie.hq.af.mil/OpEnergy**

Defense Energy Seminar Series

NPS' academic programs in Defense Energy are supplemented by a seminar series which provides a forum for leading voices within the field, practitioners, and other Defense Energy influencers. These professionals give presentations, engage in brown bag discussions, and facilitate informal gatherings that encourage Defense Energy faculty and students to discourse over current issues in Defense Energy, supplementing classroom teaching with practical, professional experiences. The Defense Energy Seminars Series is a permanent part of NPS' Defense Energy program, and a key to its real-world relevance.

LEARN MORE

Please see the Calendar of Events in this issue of *Surge* or visit **nps.edu/web/eag/seminars** for upcoming and archived seminars.

RESILIENCE CORNER

A 'Resilience-as-a-Verb' Perspective on COVID-19

By Dan Eisenberg, PhD, Department of Operations Research, NPS

RESILIENCE IS A "NEW" TERM creeping into military directives, but what does it mean and how do we use it to guide decisions? In previous Resilience Corners, we described the 'resilience-as-a-verb' perspective as one way to assess resilience. This perspective focuses less on what your Service has and focuses more on what people do when faced with stressful events. It emphasizes the assessment of the processes that enable resilience, i.e., sensing, anticipating, adapting, and learning (SAAL). (See the Winter 2020 issue of *Surge* for a more detailed explanation of SAAL.)

The SAAL framework provides a baseline for the capabilities necessary for society to return safely back to work.

However, the 'resilience-as-a-verb' perspective stretches far beyond military operations and can inform the current COVID-19 epidemic. A recent article written by resilience experts from the Naval Postgraduate School, the Ohio State University, and Arizona State University demonstrates how the SAAL framework provides a baseline for the capabilities necessary for society to return safely back to work.

Woods et al. (2020) poses a series of four questions—each related to a different SAAL process—that must be answered to safely return to work. The questions are:

Sensing

Can we test/track/isolate new cases that emerge and become new hotspots?

Anticipating

Can we meet all non-COVID-19 patient health needs while sustaining the ability to ramp up care capacity to provide treatments for all those seriously ill from new COVID-19 infections?

Adapting

Can we provide safe and effective treatments to promote recovery and reduce risks for patients seriously ill from COVID-19?

Learning

Have we created the ability to assess immunity and build immunity in the population through antibody testing and vaccines?

Answers to these questions help us assess how well society will be posed to adapt in a future with COVID-19. If sensing processes to test, track, and isolate new cases are unavailable, we will remain reliant on blunt policies for social distancing that affect large populations, rather than targeted policies to manage future outbreaks. If anticipating processes to preposition and surge medical resources are unavailable, we will remain vulnerable as COVID-19 related infections overwhelm limited resources at medical facilities. If adapting processes to develop and quickly implement new remedies are unavailable, we will be unable to produce effective treatments to the virus. If learning processes to assess and build immunity are unavailable, we will not be able to adapt to virus changes over time. Together, if any of the SAAL processes are unavailable, then society will be less capable to adapt to the next virus that disrupts our lives.

LEARN MORE

Email Dan Eisenberg at **daniel.eisenberg@nps.edu** or call 831-656-2358

Notes

Woods, David D., Seager, Thomas P., and Alderson, David L. "When Can We Move Forward from COVID-19? When Four Capabilities Are in Action.". Zenodo, April 10, 2020. doi: http://doi.org/10.5281/zenodo.3748052

25 Years After the "Contract of the Century": The Implications for Caspian Energy

By Ambassador (Ret.) Robert F. Cekuta

WHEN THE AGREEMENT BETWEEN Azerbaijan and an international oil consortium was signed in 1994, it launched the development of the Azeri-Chirag-Guneshli (ACG) oil fields in the Caspian Sea and signaled the region's return as a serious oil supplier. Dubbed "The Contract of the Century," it had implications beyond just an agreement to drill for, produce, and sell oil. The investment boosted the income and helped strengthen the independence of Georgia and Azerbaijan and demonstrated international interest in the region's newly independent countries. It would become the model for future deals and projects, e.g., the Southern Gas Corridor, that would further energy security.

Even 25 years later, the Caspian Basin remains an important supplier. Bordering Iran and Russia and an oil and gas source for Asian and Western markets, the region's geopolitics remains complex. While there might be questions about the likelihood of future international mega-energy projects on the scale of the $40+ billion Southern Gas Corridor, the Caspian region can contribute further to regional and global energy security.

Over 3 billion barrels of oil had been produced in the ACG fields as a result of $33 billion in investments.

Revisiting the contract after 25 years reveals its significance: in 1994, Azerbaijan and others in the region recognized the need to be responsive to the concerns of private enterprise to tap, market, and profit from the resources. The contract's provisions were ratified by the country's parliament and enshrined as constitutional law. Thus, the Azerbaijani government sent a strong signal in 1994—a time when most of the former Soviet Union faced chaotic business conditions—that it would take necessary steps for foreign investment. The contract also established that the region's countries need to work together and sparked a model that would help re-establish trans-Eurasian trade links to foster greater regional connectivity.

In 2017, when the ACG contract was renewed for another 25 years, over 3 billion barrels of oil had been produced in the ACG fields as a result of $33 billion in investments. While circumstances continue to change, Caspian oil and gas remain important. The process begun with the 1994 contract continues to be important in world markets, global energy security and the stability of the Caspian region.

The Caspian Basin is an important oil supplier.

LEARN MORE

Ambassador Cekuta's full article is available through the Caspian Policy Center at **https://www.caspianpolicy.org/25-years-after-the-contract-of-the-century-the-implications-for-caspian-energy/**

ENERGY SECURITY

EAG Supports Baltic Defense College Operational Level Energy Security Course

FROM 23–27 MARCH 2020, the Naval Postgraduate School's Energy Academic Group (EAG) partnered with the NATO Energy Security Center of Excellence to execute the Baltic Defense College's Operational Level Energy Security Course. The Baltic Defense College (BDC) is located in Tartu, Estonia and is an English-speaking international institution of Estonia, Latvia, and Lithuania that provides professional military education at the operational and strategic level for military and civilian leaders of the Baltic states, their allies and partners. This was the second time that the EAG supported this event.

While the course was to be a resident program, due to the COVID-19 pandemic, it reverted to a virtual format with Microsoft Teams used as the platform for delivery. While there were many shortfalls due to the virtual format that hampered overall effectiveness as compared to a resident program, the course was nonetheless successful in meeting minimum program objectives.

The aim of the event was to provide participants with knowledge of the importance of energy and energy security in the current geopolitical situation and their influence on military operations. Upon completion of the course, students were able to: interpret NATO's energy security pillars (energy security awareness, critical energy infrastructure protection, and energy efficiency in military operations); analyze the links between energy and crisis (conflict/hybrid) as well as energy and geopolitics; and analyze energy development and vulnerabilities as part of the new challenges to security and the crosscutting nature of emerging threats in the Baltic Sea region.

The EAG Associate Chair, Mr. Alan Howard, provided lectures on Maritime Security and Critical Energy Infrastructure Protection. Mr. Lawrence Walzer, an EAG faculty member, provided presentations on "Energy in Conflict" and "The Terrorist Threat to Critical Energy Infrastructure." Mr. Walzer further developed and presented red and blue cell training exercises for participants to conduct during breakout groups, which were also facilitated with the use of Microsoft Teams.

There were a total 21 participants from the three Baltic states, the United States, Australia, Greece, Italy, and Ukraine. For those interested, the course will again be hosted by the Baltic Defense College next year from 22–26 March 2021.

LEARN MORE

Email Lawrence Walzer at **lmwalzer1@nps.edu** or call 831-656-3777

Operational Energy Research Available on Calhoun

All NPS resident students write a thesis or capstone project report as part of their curricular requirements. Many theses are unclassified and accessible on Calhoun—the Naval Postgraduate School's digital repository for research materials and institutional publications created by the NPS community. To access theses which involve operational energy, please use the following link. New theses are added every quarter.

View operational energy theses available on Calhoun:
https://bit.ly/2A5tQPK

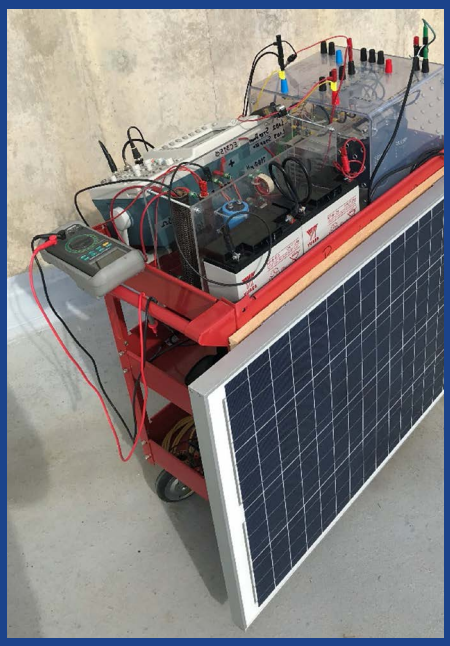
STUDENT ENERGY RESEARCH SPOTLIGHT

Photovoltaic Array Maximum Power Point Tracking Efficiency Analysis using Real-time Hardware-in-the-loop Simulation and Testing

By Capt David B. Lorio, USMC

The current United States Navy and Marine Corps' warfighting concepts focus on distributed and decentralized operations to increase the lethality and security of the force as a whole. An amplified reliance on electrical energy to power weapon systems, command and control structures, and other materiel, in conjunction with a distributed force, escalates the logistical requirements for each operational unit. Renewable energy resources, such as solar radiation, may be a means of reducing this logistical burden; however, photovoltaic (PV) arrays must operate at their maximum power point for these systems to be a more effective renewable energy resource technology.

This thesis studies the efficiencies of the controller for a PV power conditioning system implementing the two most common maximum power point tracking (MPPT) algorithms, "Perturb and Observe" and "Incremental Conductance". The system includes a commercial-off-the-shelf PV array; a step-down switching DC-DC converter, engineered from standard energy storage components and an Insulated Gate Bipolar Transistor IGBT; lead-acid batteries as the energy storage system and load; and an Opal-RT real-time simulator for rapid control prototyping. First, a physics-based model of the system was simulated. Then, the efficiency of the MPPT controller, defined by the ratio of power achieved and the maximum theoretical power produced by the PV array considering environmental conditions, was studied and improved through control parameter optimization. Afterwards, the control algorithms were implemented in a physical system using the real-time simulator in a hardware-in-the-loop testing configuration. Lastly, the voltage, current, and power produced by the PV array were studied, measured, and compared to the simulated results. The experimental testing confirmed that the MPPT controller performed as designed and achieved the expected efficiency for the various solar irradiances and temperatures under which it was tested.



Capt Lorio's research included a DC microgrid set up with a PV array, step-down switching DC-DC converter, lead acid batteries as the energy storage system and load, and an Opal-RT real-time simulator for rapid control prototyping.

Capt David B. Lorio, USMC

About the author

Capt David Lorio, USMC, is a student of Electrical Engineering at the Naval Postgraduate School. Contact Dr. Giovanna Oriti at goriti@nps.edu for more information about this research.

ENERGY RESILIENCE

NPS Researchers Lead a New Project on Infrastructure Resilience at Military Installations

By Dan Eisenberg, PhD, Department of Operations Researh, NPS

DOD SERVICES SEEK A BETTER understanding of compound threats to interdependent infrastructure systems on their installations. Military services view infrastructure resilience broadly as a critical system that can, "take a punch, stay standing, and punch back" (MCICOM 2019). This corresponds to the capacity for infrastructure systems to survive events that threaten mission readiness, continue to function and recover in the immediate aftermath of an event for up to 14 days, and adapt to project combat power into the future. All DoD services have similar, lofty goals for infrastructure resilience.

Researchers from the Naval Postgraduate School Center for Infrastructure Defense (CID) and the Energy Academic Group (EAG) are now leading efforts to measure infrastructure vulnerabilities and help make military installations more resilient. The new team led by Dr. Daniel Eisenberg of the CID is comprised of experts across multiple departments including Operations Research and Systems Engineering. They are funded by the Office of the Secretary of Defense Strategic Environmental Research and Development Program to conduct research for the next three years.

Researchers from the Naval Postgraduate School Center for Infrastructure Defense (CID) and the Energy Academic Group (EAG) are now leading efforts to measure infrastructure vulnerabilities and help make military installations more resilient.

The cross-campus team is focused on developing models that measure the vulnerability of installation infrastructure systems and use these measurements to guide service-wide infrastructure investment and protection. DoD resilience goals align with a broader need across the DoD to understand how the loss of interdependent infrastructure services affects mission readiness. For example, mission critical water, communications, mobility, and food systems often rely on backup generators and uninterruptible power supplies to operate during blackouts. However, these backup systems may fail when needed and are not necessarily designed for 14 days of continuous operation. Mission readiness requires the recovery and functioning of electricity distribution systems, which themselves may rely on interdependent services like water for cooling, communications for control systems, and fuel trucks for operation. Together,

the vulnerability of any infrastructure system directly impacts operations and management of all other critical systems.

Relating system models to service-wide infrastructure investments requires translating measures of vulnerability into measures of infrastructure readiness and installation mission needs.

Currently, there is no standard way to integrate multiple models of electric power, water, transportation, telecommunications, and related systems for resilience analysis. This means there is no way to measure interdependent vulnerabilities and cascading effects. One goal of the project is to develop a standard architecture and runtime infrastructure to federate models used to measure real-world infrastructure operations together and assess their interdependencies. Using this model architecture, Eisenberg and his team plan to develop computational and optimization-based methods for identifying worst-case disruptions in interdependent systems.

Relating system models to service-wide infrastructure investments requires translating measures of vulnerability into measures of infrastructure readiness and installation mission needs. Infrastructure readiness across the DoD is determined by two key performance indicators—the facility condition index (FCI), measuring infrastructure quality and condition and the mission dependency index (MDI), measuring the importance of an asset or facility to military missions. While FCI helps decision-makers understand the likelihood that military infrastructure will survive extreme events like hurricanes, MDI is more relevant for resilience by capturing the capability for infrastructure services to adapt to compound threats.

Eisenberg and his team plan to support DoD resilience goals by linking MDI to the new understanding of infrastructure vulnerability gained through interdependent models. Existing methods for calculating MDI all stem from work by the Naval Facilities Engineering Command (NAVFAC 2018). To calculate MDI for a given infrastructure asset, expert opinion determines how interruptible, relocatable, or replaceable an infrastructure service is within a single facility and among interdependent facilities. The new team at NPS will build on these aspects of MDI—service interruptibility, relocateability, and replaceability—and relate them to worst-case failure assessment methods.

LEARN MORE

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Notes

Marine Corps Installation Command (MCICOM) 2019, "Installation Next: Hawaii-Resilience Symposium Report."

Naval Facilities Engineering Command (NAVFAC) 2018, "CNIC INSTRUCTION 11100.1A: Mission Dependency Index."

Energy Academic Group Welcomes New Team Member

ERIC HAHN joined the EAG in April 2020 as Faculty Associate-Research. Hahn's twenty-year active duty career encompassed shore and ocean facilities, infrastructure, and fixed cyber-physical systems engineering and business management while leading and developing military and civilian, technical, and acquisition support personnel. With the EAG, Hahn will focus his effort on energy systems research, infusing cross-disciplinary work with operational energy and energy efficiency concepts, involving faculty and students from multiple subject areas.

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LCDR USN (Ret) Eric Hahn

Calendar of Events

Summer 2020 Defense Energy Seminar Series
Due to rapidly changing circumstances surrounding the COVID-19 virus, the Defense Energy Seminar Series will be offered exclusively online for the Summer Quarter. Please visit our website at **https://nps.edu/web/eag/seminars** for upcoming seminar dates and all EAG event details.

Interested in Energy-related Thesis Research?

Since 2013, NPS and the EAG supported a plethora of student thesis research in the area of energy. Publicly viewable student theses can be searched from the Resources page of the EAG website at **nps.edu/web/eag/resources**. The EAG's extensive resources, intellectual capital, and connections with multi-disciplinary faculty and energy professionals provide students enhanced support for energy-related research. If interested in energy research, please reach out to the EAG team!

ENERGY ACADEMIC GROUP
NAVAL POSTGRADUATE SCHOOL

Connect with the Energy Academic Group

The Energy Academic Group is located in Quarters D, Bldg 281 on the NPS campus in Monterey, California. A wide range of NPS faculty are affiliated with the energy program, actively participate in energy graduate education, energy executive education, and energy research. For questions, please contact one of the principal EAG faculty members:

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Contribute to an issue of *Surge*

If you would like to contribute an article or have your research/work published in the *Surge* newsletter, please contact Lois Hazard via email at lkhazard@nps.edu.

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