Assessing and Improving the Operational Resilience of Critical Infrastructures and Missions

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SERDP ◆ ESTCP
SYMPOSIUM
2018 | Enhancing DoD's Mission Effectiveness

Naval Postgraduate School (NPS)
America's National Security Reseach University

1909 Founded at U.S. Naval Academy

1951 Moved to Monterey, CA
Operations Research Curriculum

- Facilities of a graduate research university
- Faculty who work for the U.S. Navy, with clearances
- Students with fresh operational experience

FY2017:

- 65 M.S. and 15 Ph.D. programs
- 612 faculty
- 1432 resident students includes (166 international / 47 countries)
- 909 distributed learning students

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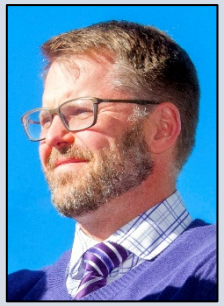
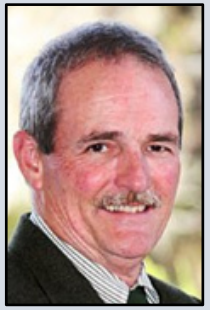
NPS Center for Infrastructure Defense (CID)



David Alderson
Associate Professor, OR
Director, CID
Ph.D., Stanford University, 2003



Gerald Brown
Distinguished Emeritus Professor, OR
Member, National Academy of Engineering
Ph.D., U.C.L.A., 1974

W. Matthew Carlyle
Professor & Chair, OR

Ph.D., Stanford University, 1997

Robert Dell
Professor, OR

Ph.D., S.U.N.Y. Buffalo, 1990

Daniel Eisenberg
Research Assistant Professor, OR

Ph.D., Arizona State University, 2018

Javier Salmerón
Associate Professor, OR

Ph.D., Universidad Politécnica (Spain), 1998

NPS Energy Academic Group (EAG)

Dan Nussbaum
Visiting Professor, OR
Chair, NPS Energy Academic Group

Ph.D., Michigan State Univ., 1971

Alan Howard
Deputy Director, NPS Energy Academic Group

MBA/MIM in International Management, 2000

Jack Templeton
Program Manager, NPS Energy Academic Group

MSM Defense Systems Analysis, NPS, 2013

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Our View on Critical Infrastructure Defense and Resilience

- We have been **studying critical infrastructure for decades**
- View domestic infrastructure through the eyes of adversaries
- Conducted over 150 "red team analyses" to attack our own infrastructure and determine effective hardening and defenses
- Find out whether systems are robust or extremely fragile
- Our techniques answer the following questions:
  - **Effects-Based Planning:** What infrastructure should we target?
  - **Mission Assurance:** How to invest limited resources to survive disruption?

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Our Approach: System Interdiction Models

- One player is trying to ensure the "operation" of a system.

  We call this player the *operator* or *defender*.

- Another player is trying to *interdict* that operation.

  We call this player the *attacker*.

- Player behavior is a decision, not a random event.
- We can be operator/defender or attacker, based on context.

Attacker-Defender (AD)

Defender-Attacker-Defender (DAD)

Investments in hardening, redundancy, etc., limited by budget.	Attacks limited by capability of the "attacker" and installed defenses	Optimal operation of the system, even after loss of components

Reference: Alderson, D.L., G.G. Brown, W.M. Carlyle. 2014. "Assessing and Improving Operational Resilience of Critical Infrastructures and Other Systems." A. Newman, J. Leung, eds., *Tutorials in Operations Research: Bridging Data and Decision*. Institute for Operations Research and Management Science, Hanover, MD, 180-215.

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Our Approach: Model System Function as *flows*.

Technical Models → Installation Mission Needs

- Shortest-path problems
- Max-flow problems
- Min-cost network flow problems
- Multi-commodity flow problems
- Project scheduling problems
- Linear programs
- Integer-Linear programs
- Nonlinear programs
- Nonlinear-Integer programs

- Electricity
- Fuels
- Drinking Water
- Sewage / Water Treatment
- Transportation & Mobility
- Telecommunications

Our techniques scale to realistic size and fidelity, and work with any new or standard model used by system operators.

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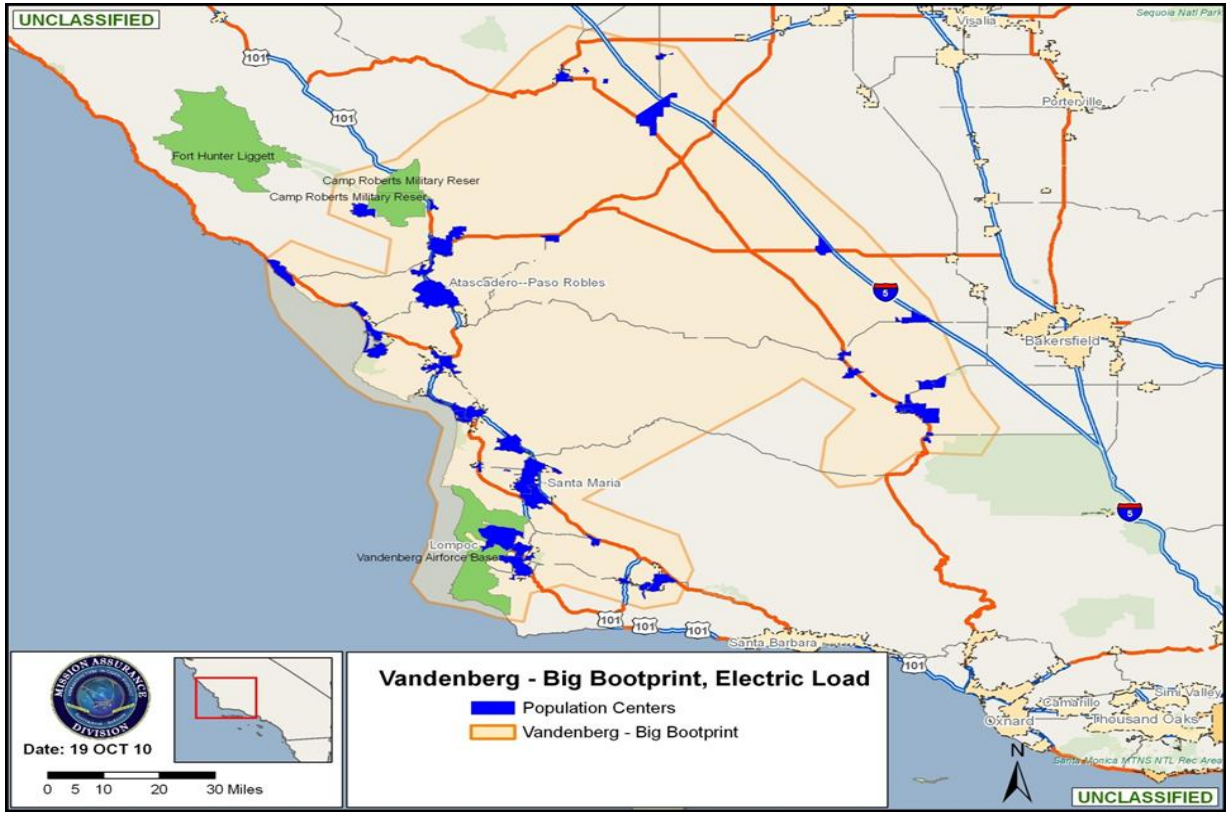
Resilient Islands & Installations: Vandenberg AFB



Integrating Knowledge of Military & Civilian Systems

- 100s buses
- 100s HV trans. lines
- ~100 transformers
- ~50 substations
- ~50 generating units (~5,000 MW)
- ~100 demand points (~1,500 MW)

Reference: Salmerón, J., Alderson, D., and Brown, G., 2011, Resilience Report: Electric Power Infrastructure Supporting Mission Assurance at Vandenberg Air Force Base (U), Center for Infrastructure Defense Technical Report NPS-OR-11-008, December. *Distribution authorized to U.S. Government Agencies and their contractors due to military infrastructure content until 31 Dec 2021. Other requests for this document shall be referred to Assistant Secretary of Defense for Homeland Defense and Americas' Security Affairs.*

Prepared for: Mission Assurance Division (MAD), Office of the Assistant Secretary of Defense for Homeland Defense and Americas' Security Affairs (OASD-HD&ASA), Naval Surface Warfare Center, 6149 Welsh Road, Suite 203, Dahlgren VA 22448

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Resilient Islands & Installations: US Virgin Islands

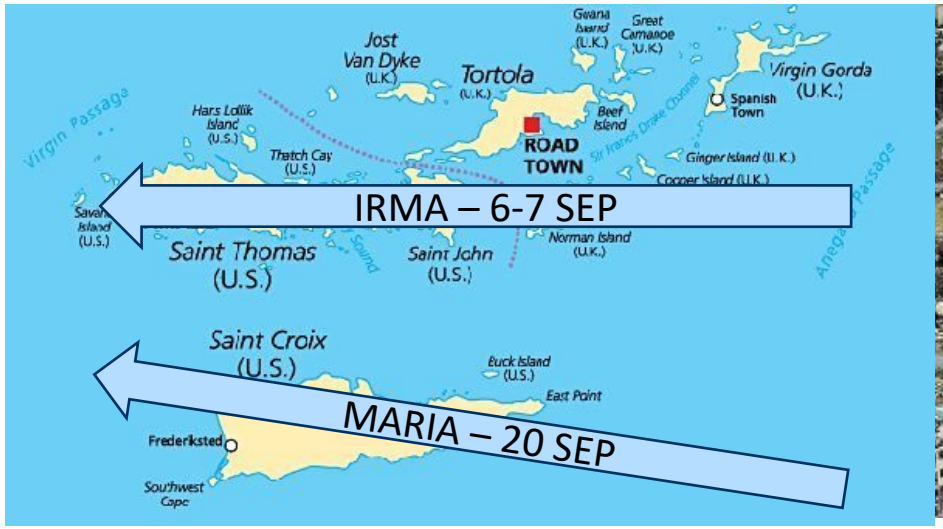
The USVI suffered two Category 5 Hurricanes in September 2017

- Electricity: not 100% restored until March 2018
- Potable water: portions of territory without water for months

FEMA-funded project: Interdependent Infrastructure Resilience

- Interdependent Electric Power & Water Failures (underway)
- Tradeoffs in Local vs. Imported Food Supply (FY-19 & FY-20)

Reference: Bunn, B., 2018. An operational model of interdependent water and power distribution infrastructure systems (Master's Thesis, Monterey, CA; Naval Postgraduate School).



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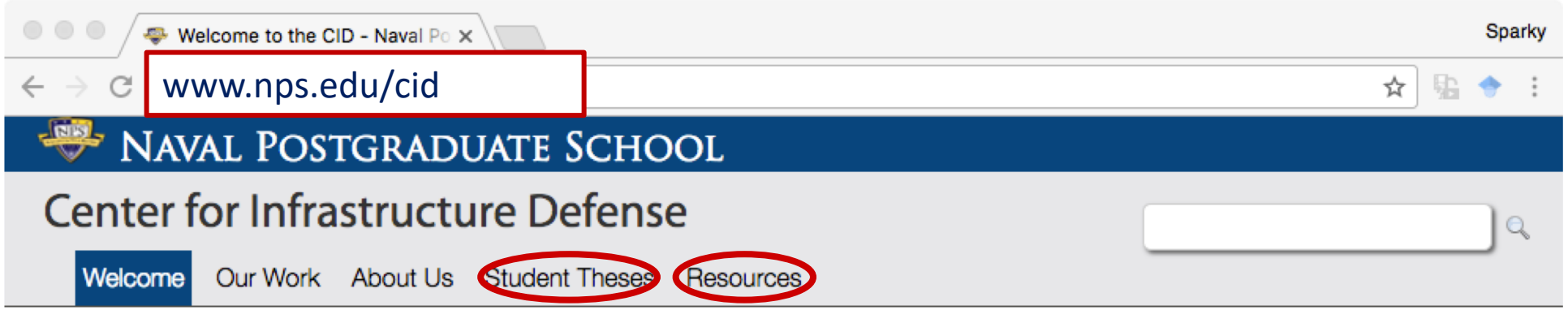
NPS Center for Infrastructure Defense: Ongoing Work



Student Theses

- Electricity, Oil, Gas (7)
- Emergency Planning and Evacuation (4)
- Maritime, Port, and Border Security (3)
- Transport and Logistics (7)
- Communications and Internet (4)
- Food and Agriculture (1)
- Weapons of Mass Destruction (4)
- Military Applications (7)
- Theory (11)

Journal Articles

- Network Interdiction and Attacker-Defender Modeling (8)
- Decision Support and Risk Management (4)
- Energy: Electric Power, Oil, Gas (6)
- Maritime and Port Security (2)
- Evacuation and Emergency Management (3)
- Internet (1)
- Weapons of Mass Destruction (6)
- Military Planning and Logistics (5)

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NPS Center for Infrastructure Defense: Ongoing Work

Questions and Engagement:

- How do installation energy and water resilience practices differ across military services?
- How do energy and water resilience solutions serve civilian vs. military needs?

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