



# Advanced Power Systems for Enhanced Capability and Fuel Economy

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# Agenda



- *Fuel and Capability : Navy Leadership Perspective*
- *The Situation*
- *War Fighting Needs Drives Power Systems*
- *The Problem*
- *Technology Similarity: Land and Sea*
- *The Challenge: Irregular Sources and Loads*
- *The Solution*
- *Technology Approach*
- *Conclusions*
- *Acknowledgments*

# ***Fuel and Capability – Leadership Perspective***



**“simply rely too much on...depleting stocks of fossil fuels...”**

**“goal has got to be increased warfighting capability”**

**“in every case, adoption of new energy tech has led to a strategic advantage for the country”**



**“remove barriers that will inhibit our ability to get enhanced capability into the hands of our Sailors quickly”**

**“increase our energy security and operational effectiveness by reducing our reliance on fossil fuels”**

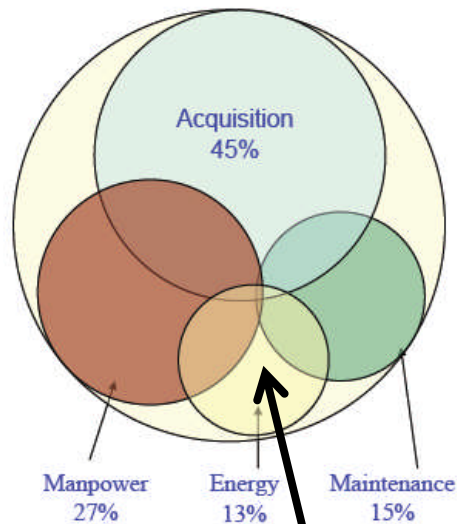


**“We’re roughly two percent of all the oil that is consumed in the United States. We ought to move ahead, and it isn’t just the military that has to [change], we all have to do it, but the military can serve as an early adopter.”**

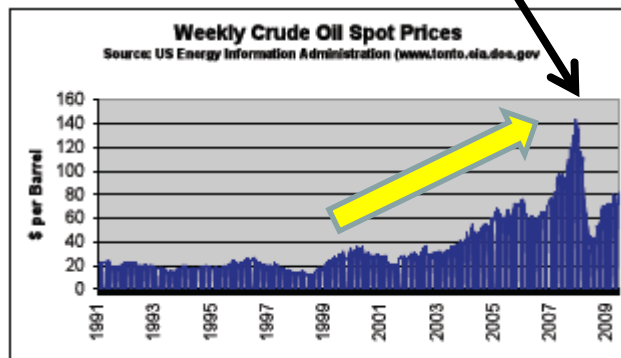


# The Situation

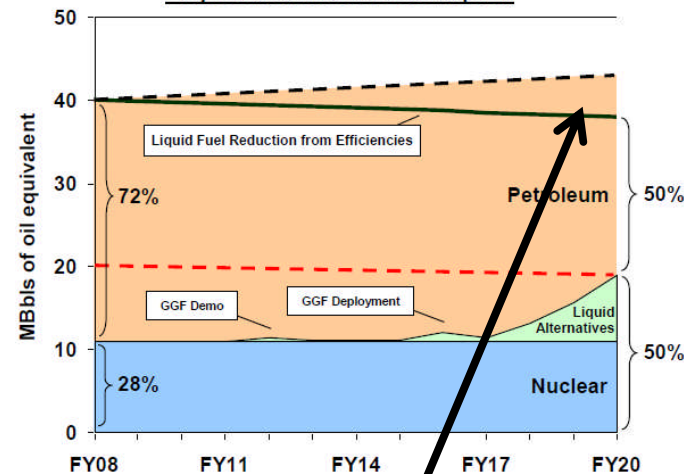
Typical Surface Combatant  
Total Ownership Cost



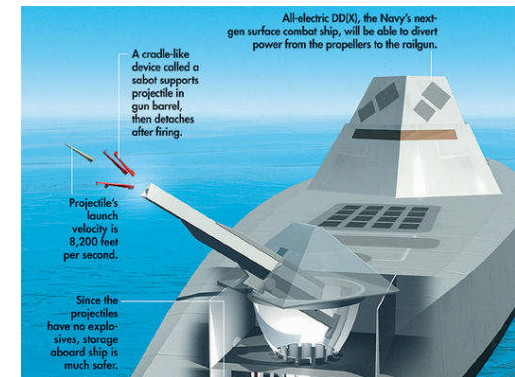
**Energy is a substantial  
And growing cost element**



Projected Afloat Fuel Consumption



**Consumption reduction  
critical to controlling cost  
and maintaining capability  
in light of new load  
requirements.**

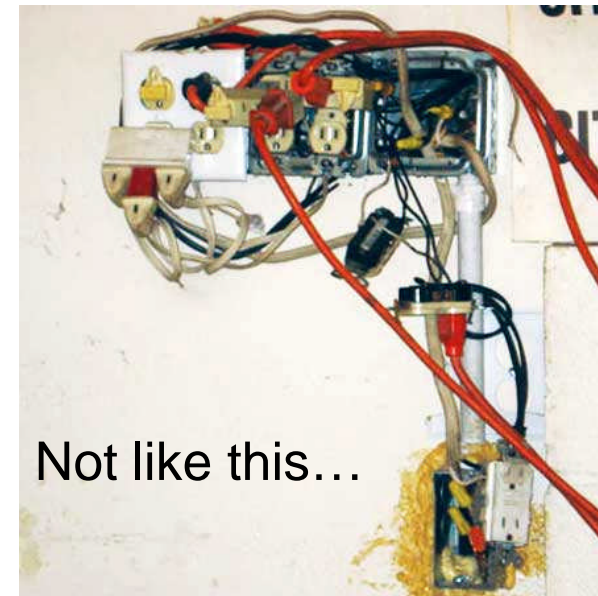


# Looking Forward

**New threats and technology development are leading to better and more power hungry solutions in sensors and weapons.**



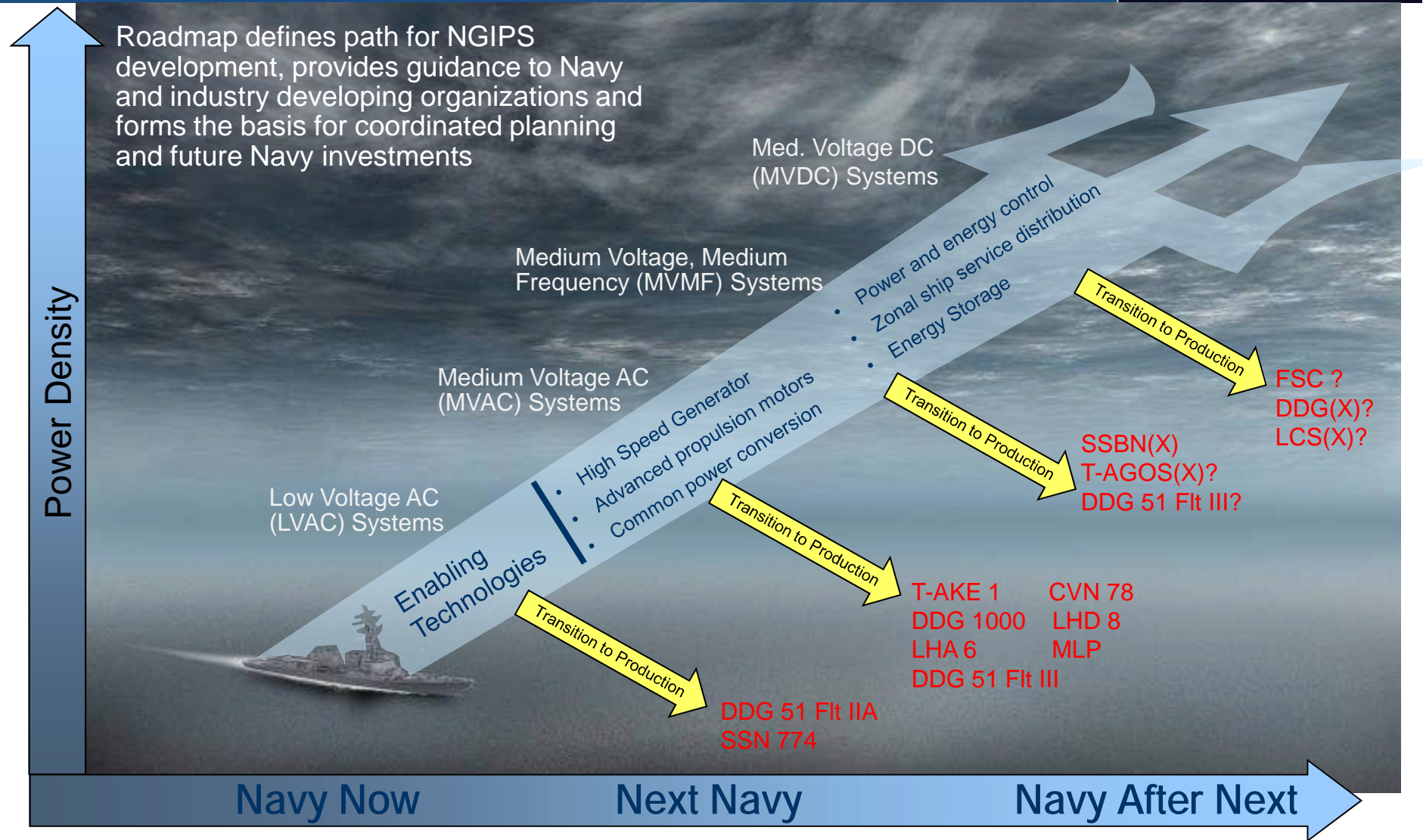
How do you address this on both current and future platforms?



Executing the NGIPS Technology Development Roadmap Paramount

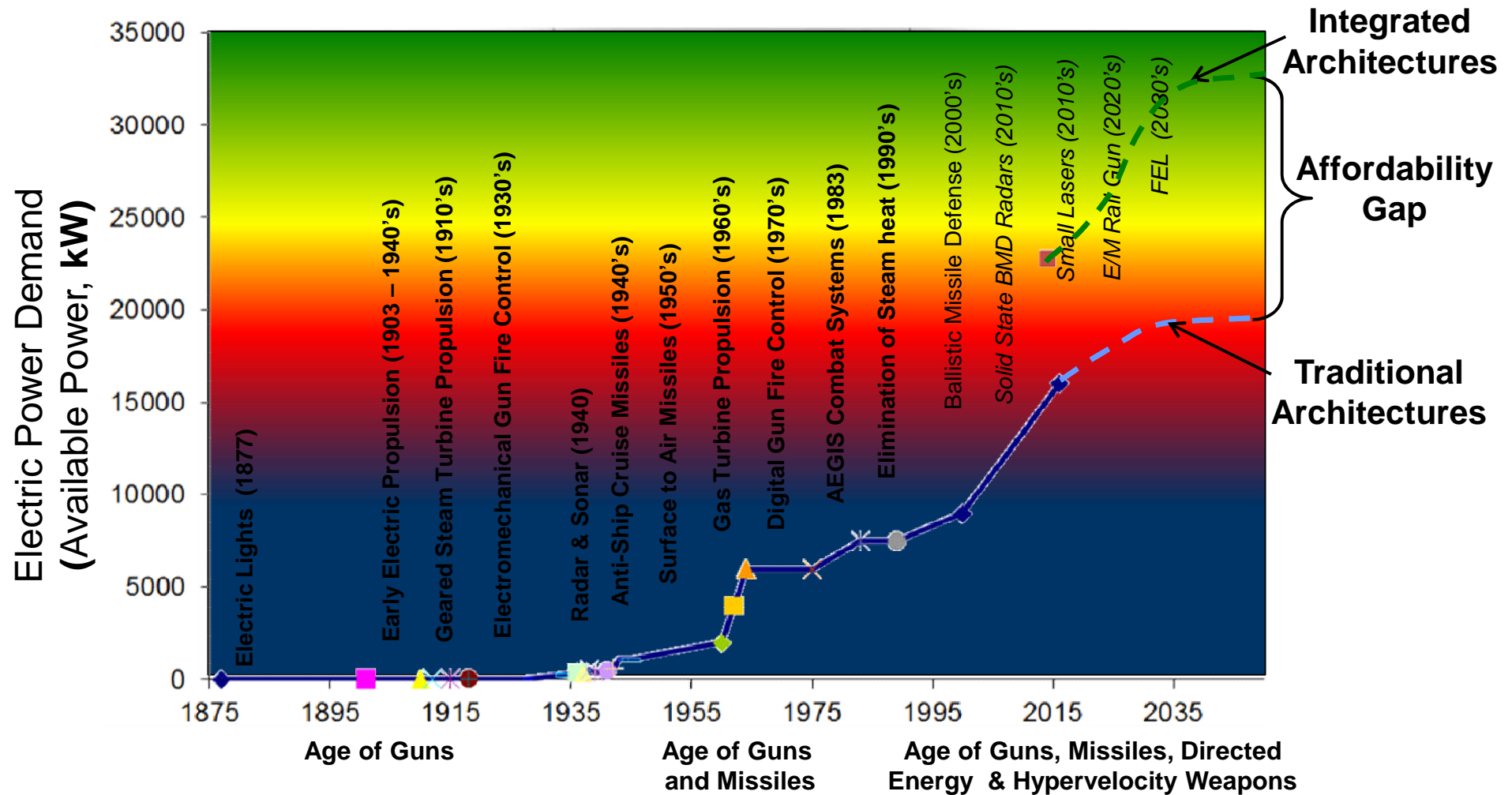


# Next Generation Integrated Power System (NGIPS) Technology Development Roadmap (TDR)



*“Directing the Future of Ships Power”*

# War fighting Needs Drive Power Systems



Integrated Architectures meet requirements at lower cost

# The Problem

## National Power & Energy

- ♦ **Critical to**
  - National security
  - Economic growth
  - Public health & safety
- ♦ **Current/Future demands**
  - **Greater reliability/resiliency**
    - Increased situational awareness
    - Faster response to faults/failures
    - Higher intrinsic reliability
  - **More flexibility**
    - Shift from centralized to market driven command and control
  - **Increased energy security**
    - Shift away from dependence on foreign oil

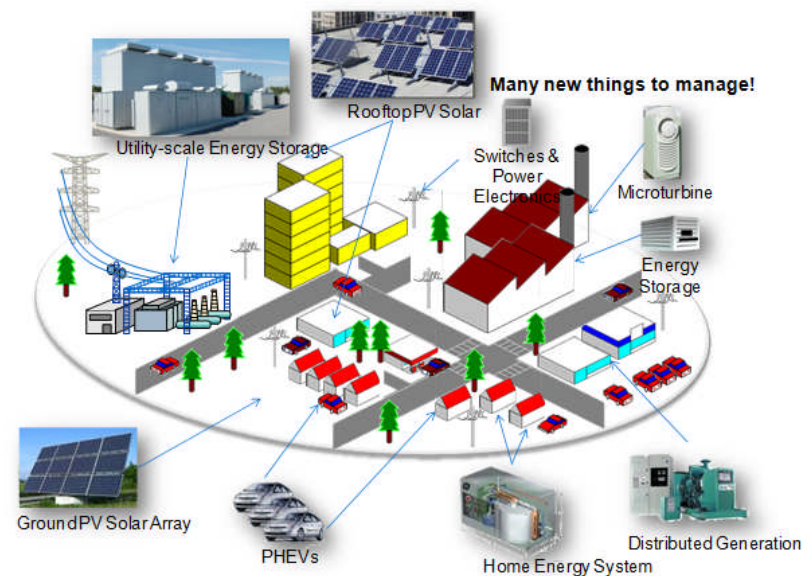
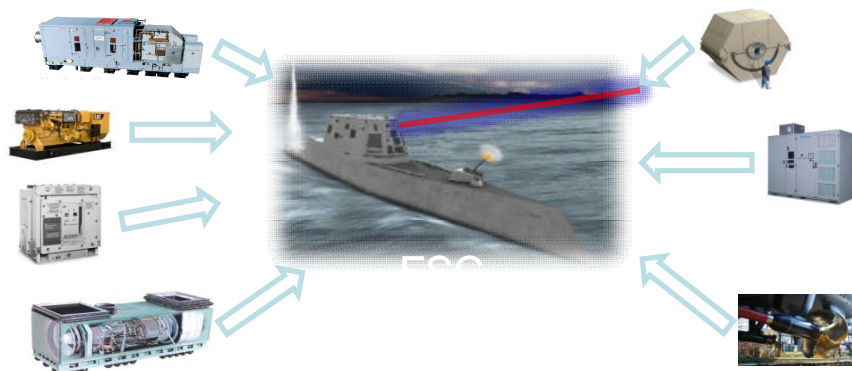
## Military Power & Energy

- ♦ **Critical to**
  - Power projection
  - Base security & operations
  - Warfighter health & safety
- ♦ **Current/Future demands**
  - **Greater reliability/resiliency**
    - Increased situational awareness
    - Faster response to faults/failures
    - Higher intrinsic reliability
  - **More flexibility**
    - Shift toward IPS and HED
    - Shift toward increased automation for command and control
  - **Increased energy security**
    - Shift away from dependence on foreign oil
    - Reduce risk to Warfighter

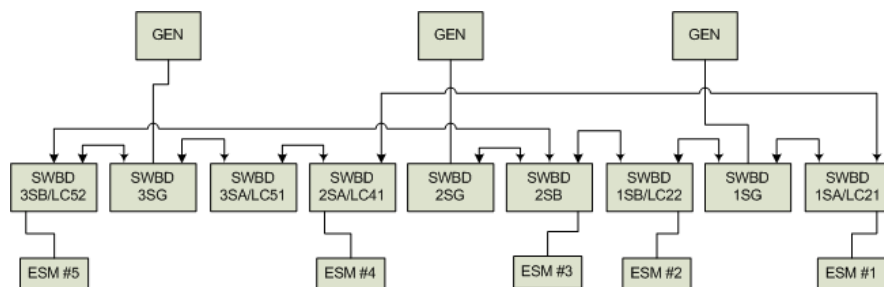
*The Military and National power and energy systems face many of the same challenges*



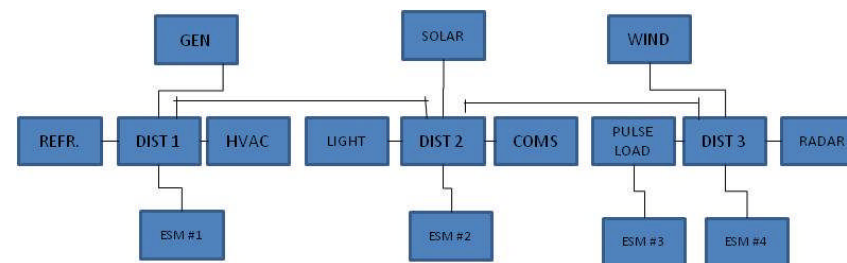
# Technology Similarity – Land and Sea



## At Sea

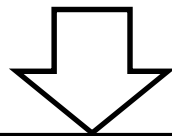


## On Land

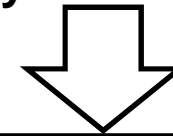


# Technological Needs Are Similar

**Safe, efficient systems  
are critical to adoption  
and widespread use**



**Multiple-rate, high  
power/energy systems  
with appropriate thermal  
Characteristics are  
necessary for adoption**



## Commercial



Storage at Grids Edge



Transportation

## Military



Ships



Subs



Aircraft

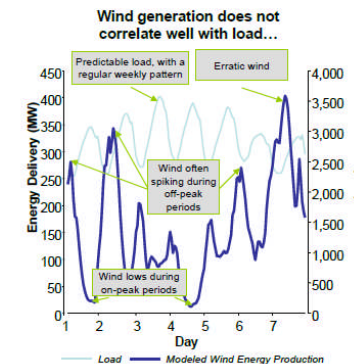


Vehicles

## Commercial



Grid Stabilization



## Military



High Rate Weapons & Sensors



Forward Operating Bases



Generator Ride Through

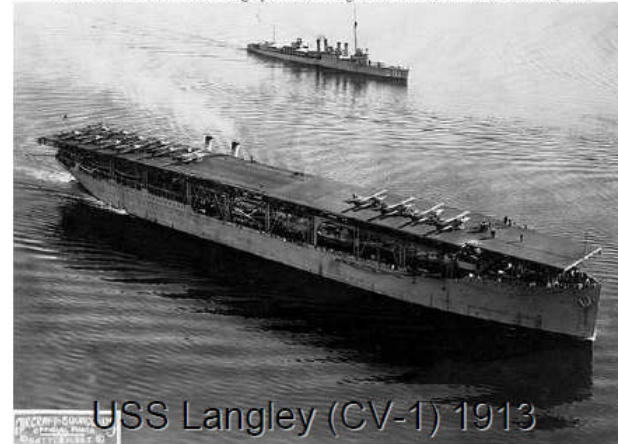


# USN History of Electric Ships: Micro grids Nothing New to the Navy

Photo # NH 63407 USS Trenton reefing top sails, circa the mid-1880s



Photo # NH 81279 USS Langley off San Diego, California, with USS Somers, 1928



USS Archerfish (SS-311) 1945

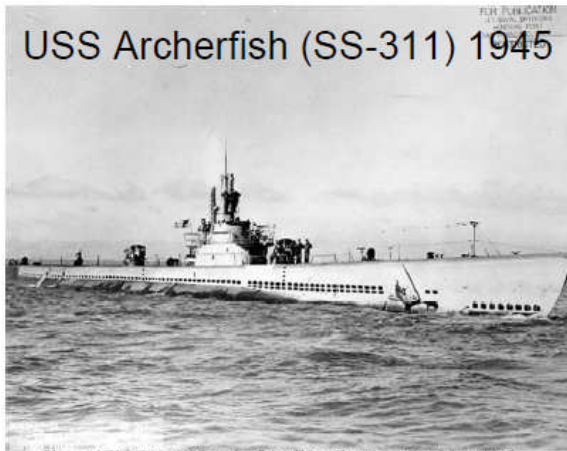


Photo # NH 96816 USS Archerfish off San Francisco, CA, 5 June 1945

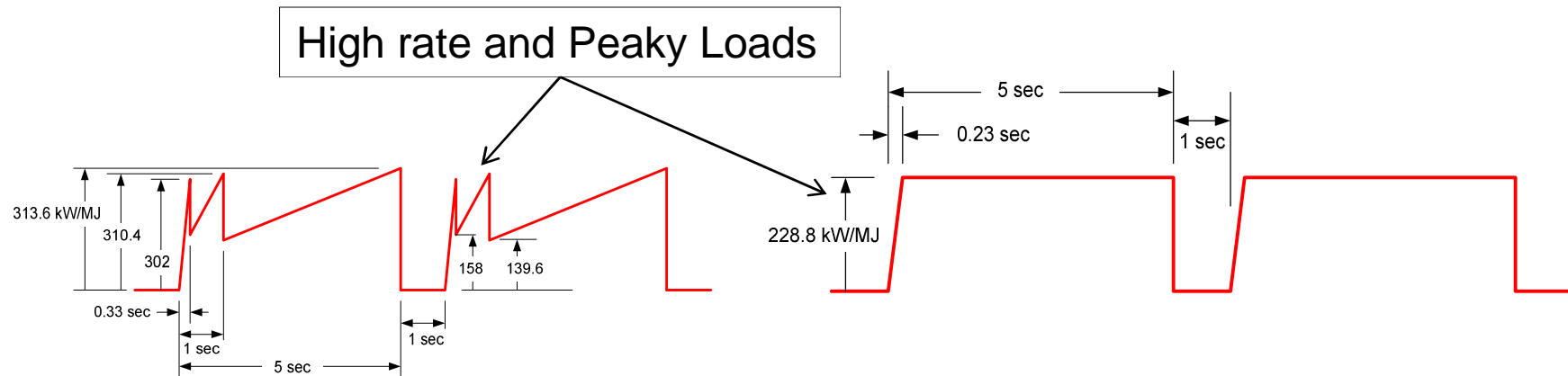
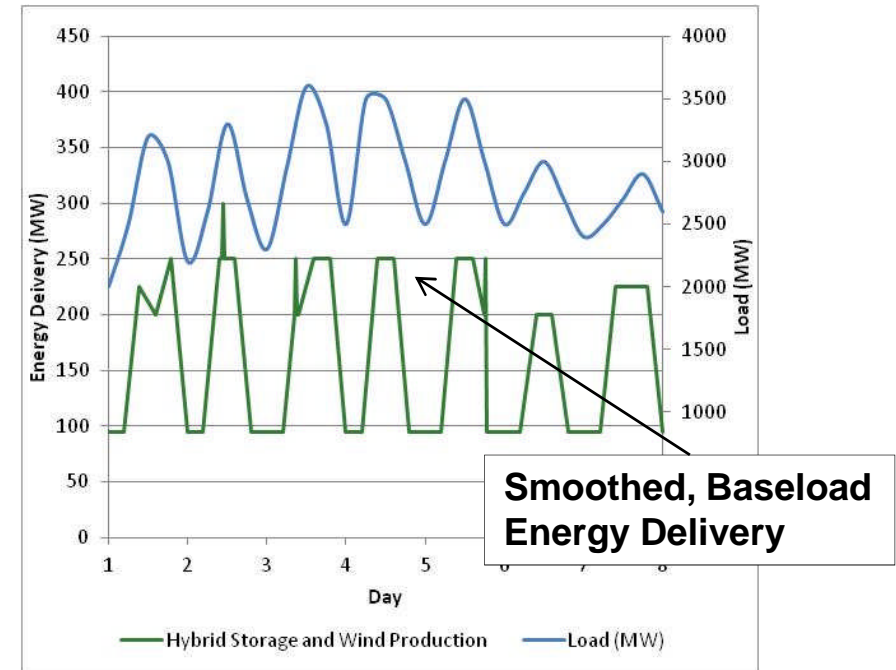
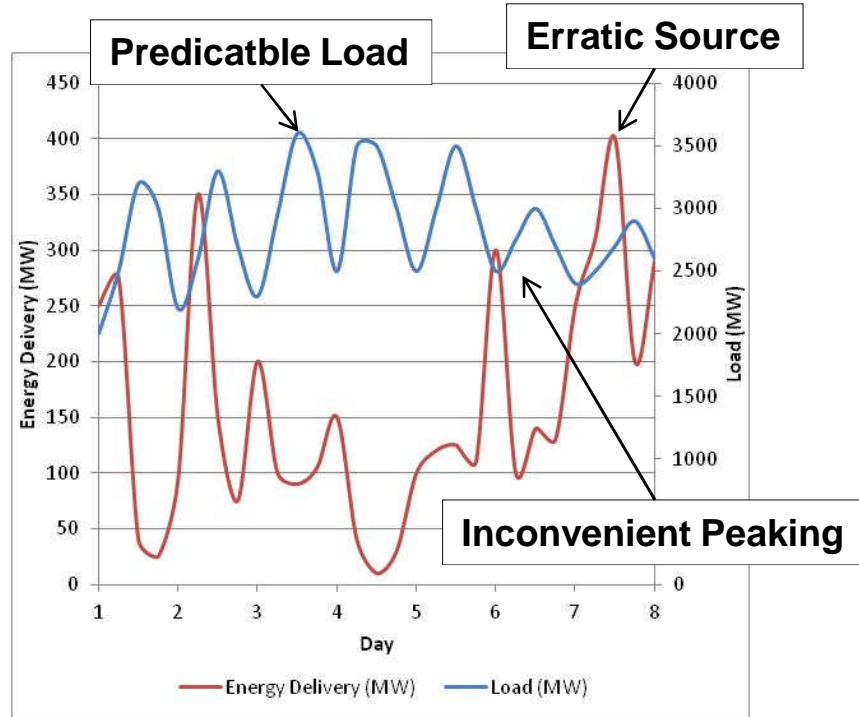
USS New Mexico (BB-40) 1918



The US Navy has over 100 years of history designing and operating shipboard microgrids.



# The Challenge: Irregular Sources And Loads





# The Solution



## National Power & Energy

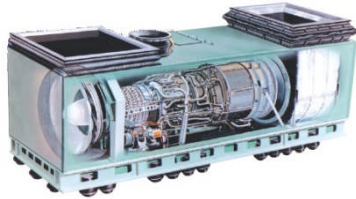
- ♦ **Architecture**
  - SmartGrid
  - HVDC Distribution
- ♦ **Technologies**
  - Alternative Energy Sources
  - Advanced Conductors
  - Hi-temp Superconductors
  - Energy Storage
  - Distributed intelligence & Smart Controls
  - Power Electronics
- ♦ **Acceptance/Deployment**
  - Regulatory Framework
  - Siting & Licensing

## Military Power & Energy

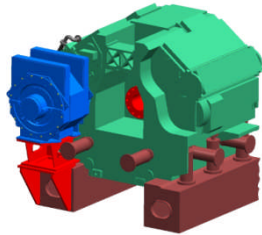
- **Architecture**
  - IPS
  - MVAC, MVHF, MVDC
- **Technologies**
  - Zonal Distribution
  - Power Generation Modules
  - Power Load Modules
  - Power Distribution Modules
  - Power Conversion Modules
  - Energy Storage Modules
  - Power Control Modules
- **Acceptance/Deployment**
  - Technology Insertion & Engineering Roadmap

*For both Military and the National power and energy systems, the recognized solution is transformation*

# Technology Approach



Advanced Generators With Improved SFC



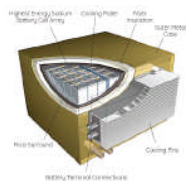
“Hybrid” Generation and Propulsion Systems



High Efficiency Power Conversion and Electrical Architectures



Optimized Generator Loading



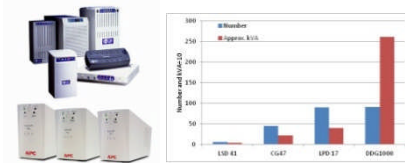
Energy Storage

# Energy Storage Is An Enabler For...

## Energy Surety

Current

- Online storage devices for backup power
- UPS for protection of sensitive devices
- Closed, signature-free energy source

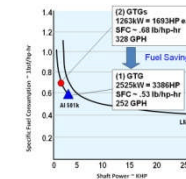


Increasing UPS and Batteries

Short Term

## Fuel Savings

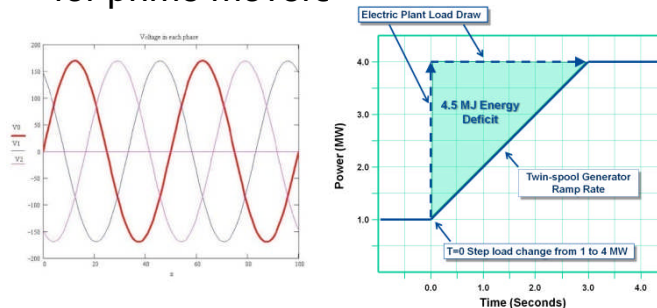
- Single Generator Operations (Shipwide UPS)
- Generator load optimization/scheduling
- Minimization of spinning assets
- Terrestrial distributions (microgrids)



## Power Quality

Medium Term

- Advanced GTG Transient ride-through
- Load changes outside of design space for prime movers

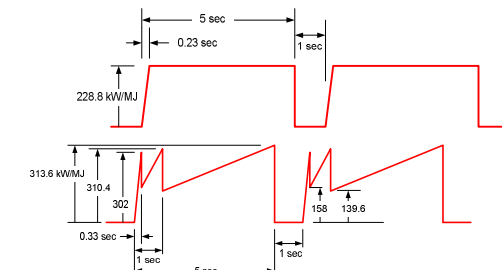
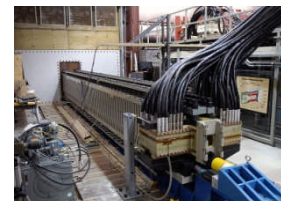


Power Quality Surety Under Two-Spool GTG Application

Long Term

## Advanced Loads

- Pulsed applications
- Highly transient loads
- Cyclic load requirements



Potential EMRG Load Profiles

# Partnering for Transformation...



## GRIDS



- Flywheels
- Flow Batteries
- Compressed Air

## ADEPT

- SiC power semiconductors
- GaN
- Advanced Capacitors
- Advanced magnetic materials
- DC Link converter

## Electrofuels

- Direct Solar fuels

## BEEST

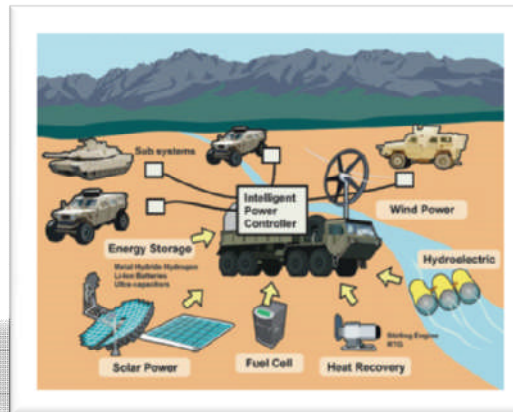
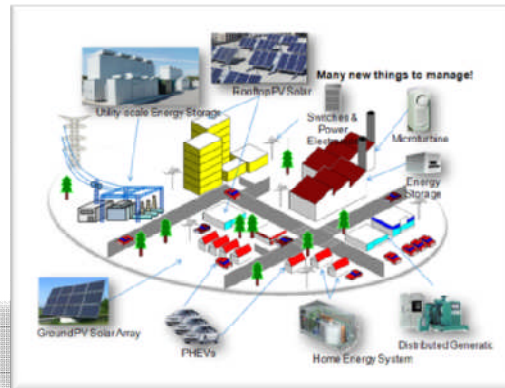
- Vehicle batteries

## BEETIT

- Building cooling systems

## IMPACCT

- Reducing CO<sub>2</sub> Emissions



## Energy Security

- Alternative and renewable energy sources
- Future logistics tools
- Resilient power networks and systems

## Efficient Power & Energy Systems

- Materials, devices and architectures to increase efficiency, and power density for platforms, and reduce weight for personal power
- Efficient power conversion, switching, distribution, control and thermal management
- Engines, motors, generators and actuators
- Electrochemical, thermal and kinetic energy storage

## High Energy & Pulsed Power

- Energy storage power system architectures
- Energy pulsed power switching and control





# *Conclusions*

- ◆ **The cross between ever-growing electrical load and ever-increasing fuel costs presents a complex issue**
- ◆ **Technologies which can reduce consumption and provide greater power output require specific considerations to implement**
- ◆ **Smart architectures can support complex loads with enhanced efficiency**
- ◆ **Shipboard microgrid architectures have been under construction by the Navy for the last 100 years**
- ◆ **Coordinated approaches can enable commonality and commercial application to reduce cost**

# Acknowledgements



- ♦ **Dr. Timothy McCoy, PMS 320**
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- ♦ **Mr. Donald Hoffman, ONR 331/NSWCCD-SSES**
- ♦ **Mr. John Kuseian, PMS 320/NSWCCD-SSES**
- ♦ **Mr. Nathan Spivey, PMS 320/NSWCCD-SSES**



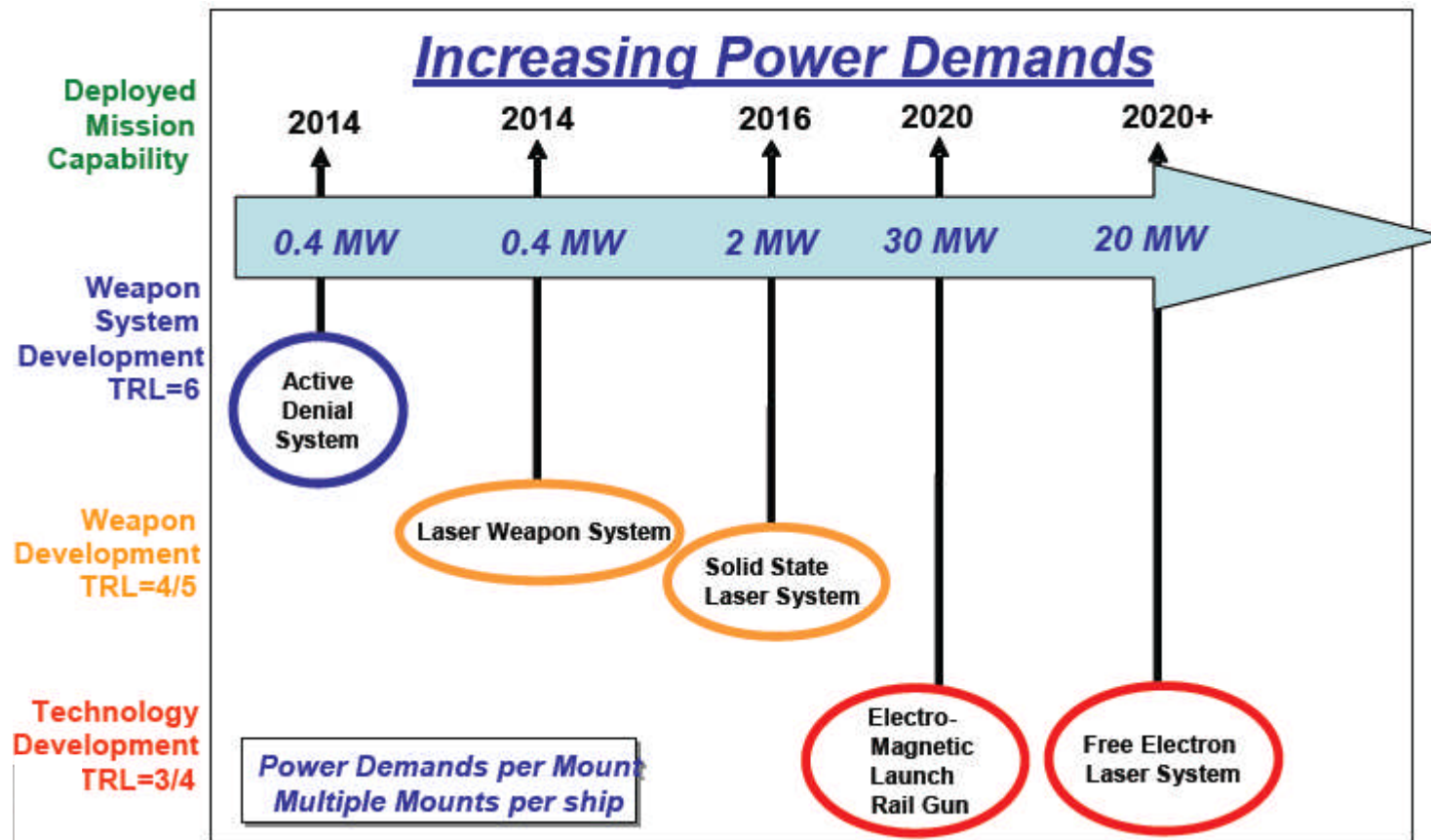
QUESTIONS?

# BACK-UPS





# Growing Sensor and Weapon Load Requirements



Balancing irregular loads with irregular sources (inconsistent and/or lagging transient response) presents a controls and architectural problem for both Shipboard and Terrestrial Microgrids.

# US Navy Surface Fleet Energy Storage Vision

