# Why Energy?

*A Programmatic Perspective of the US Navy's Afloat Energy Challenges*

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# Agenda



- Why is Energy Important?
- How is the US Navy Surface Fleet Doing?
- Navy Energy R&D Programs of Record
- Machinery Plant Arrangements and Impact on Energy
- Major Technical Areas and Challenges
- Concluding Remarks

# Why is Energy Important?

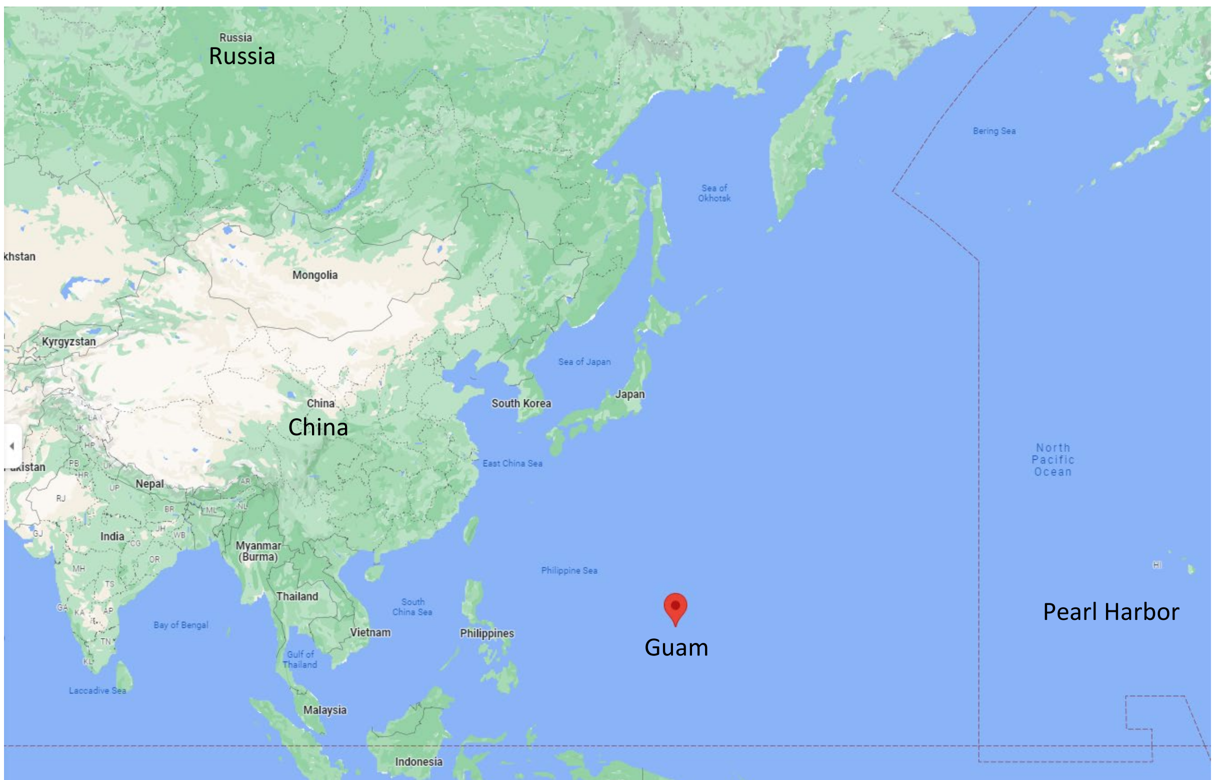


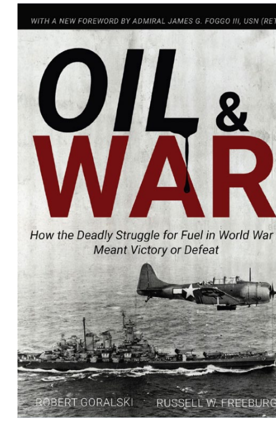
4 major reasons why we should care about power and energy on ships

- Fuel Wins Wars
- Combat System Integration
- Energy = $$$
- Climate Change Impacts on DoN

# Fuel Wins Wars

- Renewed focus on **near peer and peer competition**.
- Peer competitors will challenge logistics in ways not seen in several decades. This includes **fuel**.
- Supply >= Demand … or operations are degraded or fail altogether




By Robert Goralski and Russell W. Freeburg (1987)

HOW?

Supply OR Demand

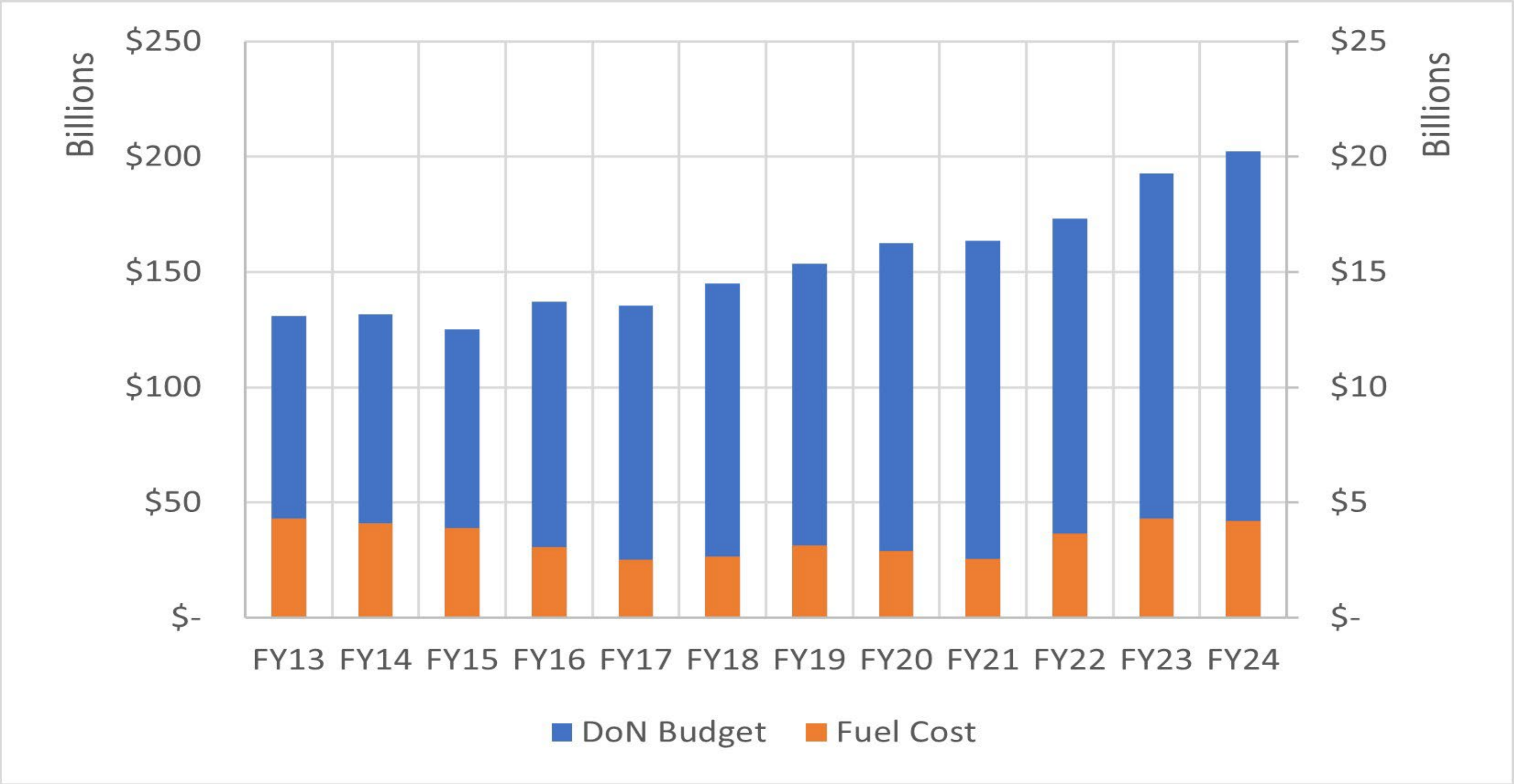
# Combat System Integration

HELIOS Laser Depiction, Credit Lockheed Martin Corporation


SPY-6 AMDR Radar, Credit Naval Sea Systems Command

- Average electric load on USN combatants is expected to double from present day to 2040. All other things remaining the same, this would shift power generation fuel consumption from roughly 30% of total fuel consumption to 47% of total fuel consumption.
- Lasers and other game changing combat systems require high electrical power in very short time periods, stressing traditional power generation and distribution architectures.

# Energy = $$$




- Fuel costs account for approximately 1.5-3% of the Navy's total budget in a given year.
- 10-year average fuel costs are approximately $3.5B per year.

15% Fuel Savings in FY22 would = 7 F-35s, 11 Tomahawk Cruise Missiles, and a $500k bonus

# Climate Change Impacts on DON

## Test Capability Degradation

Pu'uloa RTF


Piney Island BT-11

**Climate Issue:** Erosion & Flooding

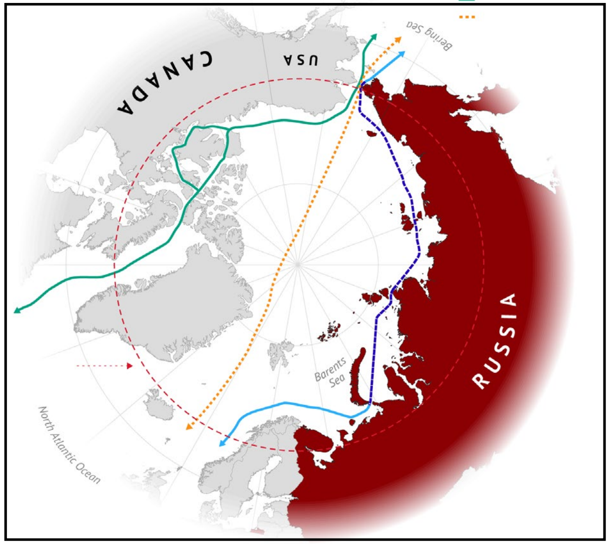
**DoN Impact:** Test Site Capabilities

- Pu'uloa Range Training Test Facility, MCB Hawaii – Erosion
- Piney Island Bombing Target-11, NCAS Cherry Point, NC – Flooding

**Potential Solutions**

- Resilient Natural Structures (Pu'uloa)
- Sediment Deposition (Piney Island)

## Expanded Arctic Theater




**Climate Issue:** Ice Cap Melt

**DoN Impact:** New Northern Border

- New shipping lanes
- New border
- Extended operations in artic conditions

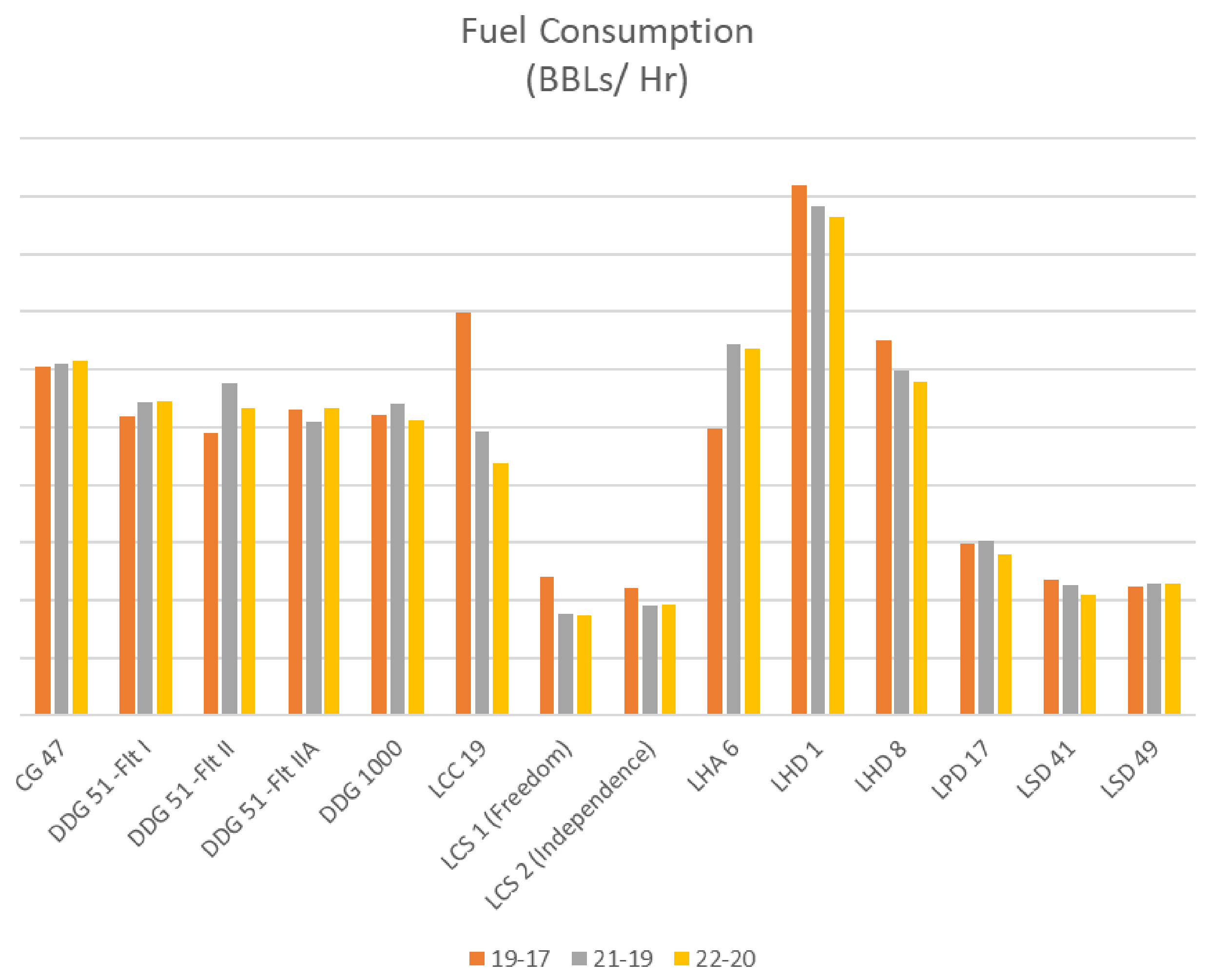
**Potential Solutions**

- Arctic Patrols
- Arctic Defensive Bases
- Improved thermal insulation for Arctic Operations

# How is the US Navy Surface Fleet Doing?



This chart shows the annual fuel consumption rates by ship class from 2017 to 2022 in 3 year averages. This data is normalized by operational hours therefore capturing changes that both operational practices and ship modifications provide.



# Ship Comparison: LSD-42 vs LPD-27

| LSD-42 | CLASS | LPD-27 |
|---|---|---|
| Germantown | NAME | Portland |
| 8 February 1986 | COMMISSION | 13 February 2016 |
| 0.73 | FUEL BURN (BBL/HR/1000TONs) | 0.55 |

**EFFICIENCY GAIN: 25.4%**

**Primary Technological Advancements: Stern Flaps, Bulbous Bow, and More Efficient Diesel Engines**

# Ship Comparison: LHD-1 vs LHD-8

| | | |
|---|---|---|
| LHD-1 | CLASS | LHD-8 |
| Wasp | NAME | Makin Island |
| 29 July 1989 | COMMISSION | 24 October 2009 |
| 1.06 | FUEL BURN (BBL/HR/1000TONs) | 0.71 |

**EFFICIENCY GAIN: 21.9%**

**Primary Technological Advancements: Hybrid Electric Drive System**

# Technological Growth & Stagnation



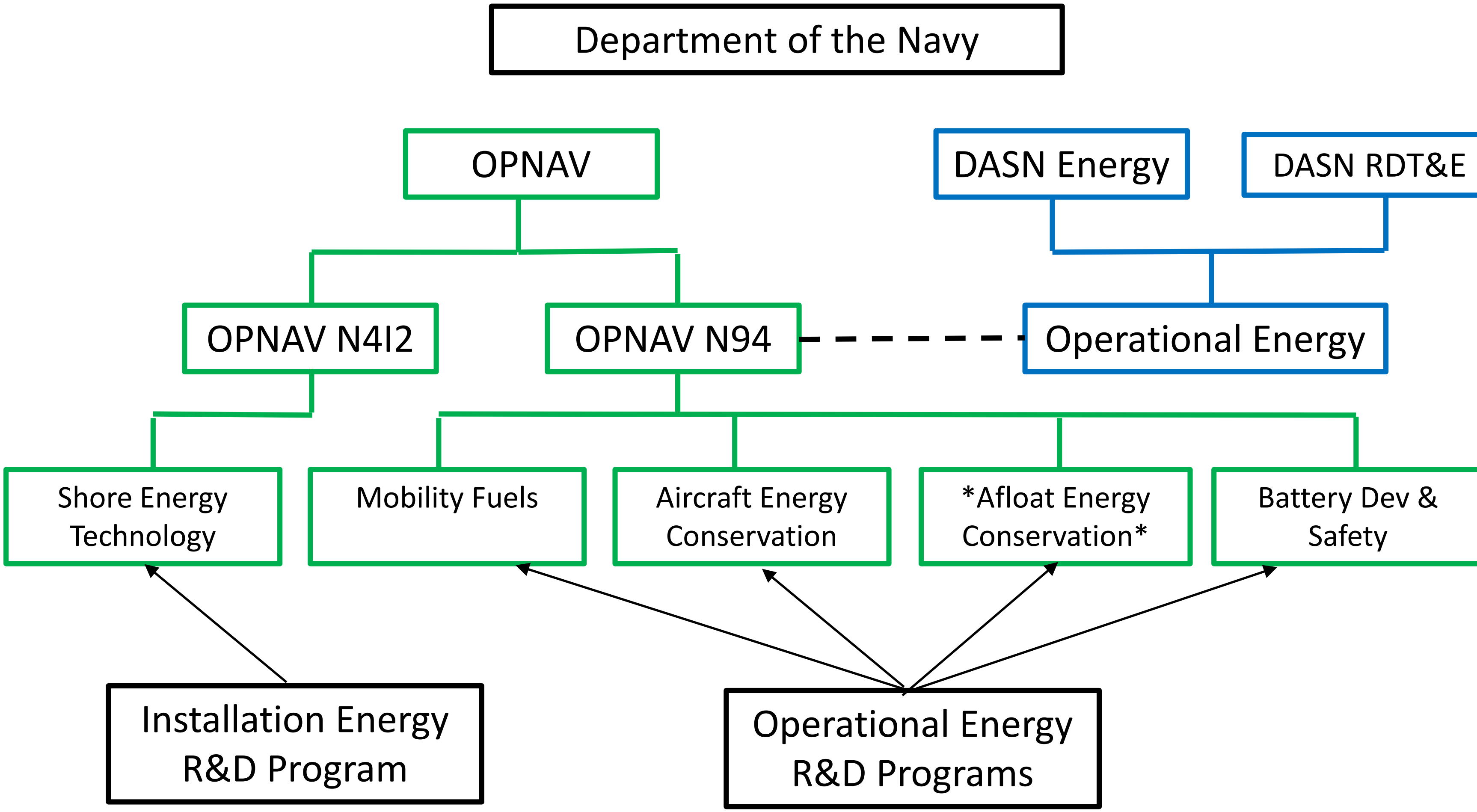
- Areas of Technological Growth and Efficiency Gains
  1. Integrated Power Systems & Hybrid Electric Drive
  2. Hydrodynamic Hull Appendages (e.g. Stern Flaps)
  3. Higher Efficiency Chillers
  4. Electronic Fuel Injection Systems for Diesel Engines
  5. Electrical Power Distribution Architectures
  6. Solid State Lighting

- Areas of Stagnant Technology and Efficiency Gains
  1. Weather Boundary Insulation
  2. HVAC System Design and Components
  3. Power and Energy Monitoring and Awareness
  4. Waste Heat Recovery

NAVSEA NAVAL SEA SYSTEMS COMMAND

# Navy Energy R&D Programs of Record

FERDP
NAVSEA 05T
Technology Office




*The "Afloat Energy Conservation" project is known as the Fleet Energy Research and Development Program (FERDP)

# FERDP Overview

**FERDP Mission: To enhance lethality, resilience, reach, and sustainment of warfare systems through more effective generation, use and distribution of energy on existing and future surface fleet assets by developing and transitioning energy and maintenance improvements.**

**FERDP Vision: Converting U.S. Navy Surface Ships from Mustang GTs® to Mustang Mach-Es®**

## Focus Areas:

- Auxiliary Systems
- Electrical Systems
- Energy Monitoring & Assessment
- Heating, Ventilation & Air Conditioning (HVAC)
- Hull Hydrodynamics
- Hull Husbandry
- Power Generation & Storage
- Propulsion Systems
- Thermal Management

**Program Sponsors: OPNAV N94/N4**

# FERDP Vision Explanation

## Converting U.S. Navy Surface Ships from Mustang GTs® to Mustang Mach-Es®

The FERDP vision uses a car analogy to illustrate the program's overarching goal of improving the way the U.S. Navy designs, builds, and modernizes its Fleet. The Mustang Mach-E® is one example of how car manufactures are drastically changing the way they design cars to give customers a greater return on their investment. The Mustang Mach-E packs more of a punch than its predecessor from decades ago, while reducing the ownership cost of the vehicle. The table below provides a set of specifications for a legacy Mustang GT®, the new Mustang Mach-E®, and the correlation to U.S. Navy Ships.

| | 1990 MUSTANG GT® | | 2021 MUSTANG MACH-E® | | U.S. NAVY SURFACE SHIP |
|---|---|---|---|---|---|
| **Range** | 272 miles | | 300 miles | | Extending the range of surface ships means more time on station and less time refueling |
| **Efficiency** | 18.5 MPG | | 102.4 MPGe | | Great efficiency allows ships to stay on station longer and devote more energy to warfighting systems |
| **Annual Fuel Cost (Based on 12,000 miles)** | $1,784 | | $553 | | Reducing the operational cost of ships frees up funding for building and maintaining the fleet |
| **Performance** | **Horsepower** 225 HP | **Torque** 300 ft-lbs | **Horsepower** 332 HP | **Torque** 417 ft-lbs | Ships can become more efficient without sacrificing performance, such as top speed and firepower |
| **Visual Aids** | Analog gauges with real time power and speed information | | 10.2" digital cluster & 15" touch screen with historic, real time, and projected vehicle performance | | Providing ship operators with near real-time energy information allows operators to make more informed decisions and fight more effectively |
| **Power On Board** | 12-volt power via cigarette lighter | | Wireless phone charging pad and available auxiliary power point outlets to power electronic device | | Additional on-board power enables future combat system upgrades |

# FERDP Past Successes

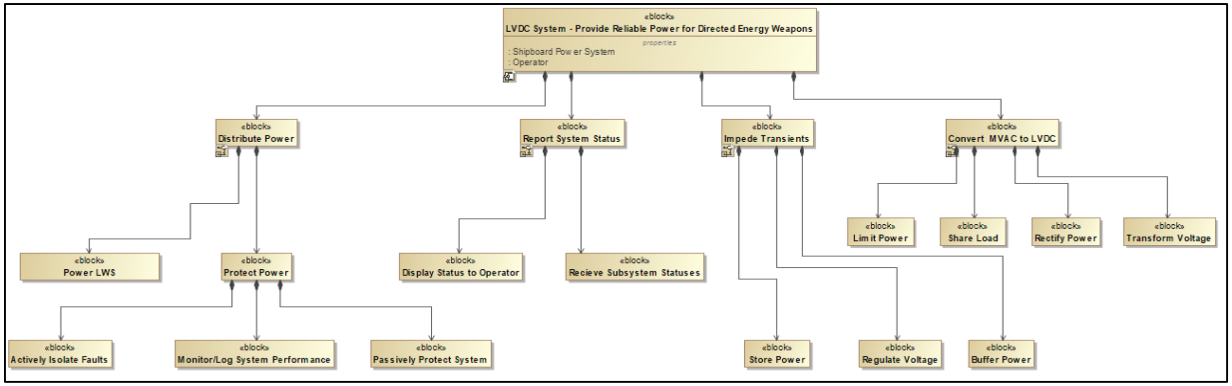


## Examples of past FERDP Projects include the following:

<u>Amphib Stern Flaps</u>

<u>Solid State Lighting</u>

<u>Medium Voltage Direct Current vs Low Voltage Direct Current Study</u>

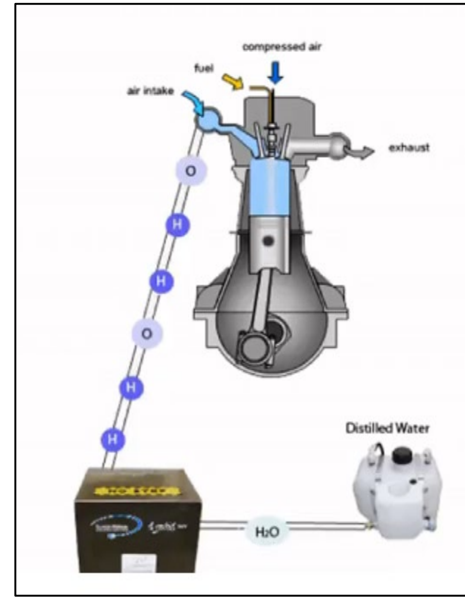


# Current FERDP Initiatives

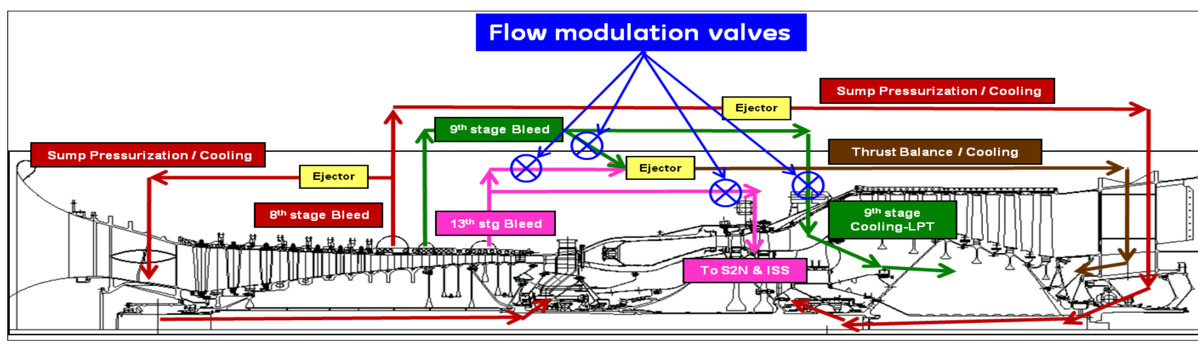
## Examples of current FERDP initiatives include the following:

High Efficiency Super Capacity Chiller Upgrade on LHD-1 Class

Diesel Engine - Hydrogen Enhanced Combustion T&E




Gas Turbine - Fuel Efficiency Concepts Test & Evaluation



# Machinery Plant Architecture and Impact on Energy Requirements

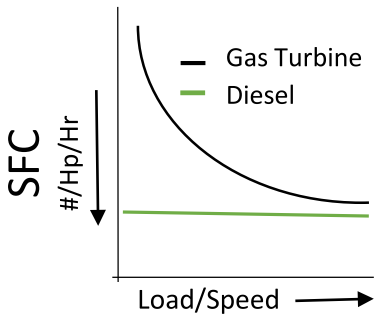
Arguably the biggest impact on a vessel's overall fuel consumption & ability to accommodate large combat and noncombat system loads.

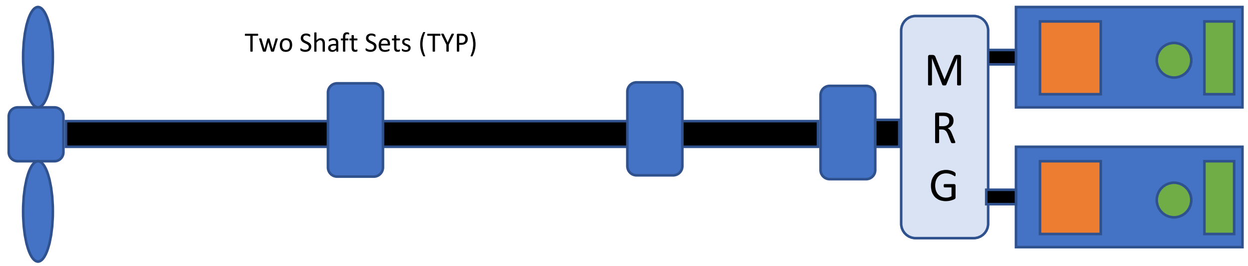
One of the most difficult aspects of a ship to modify once in service.

The following slides cover four overarching machinery plant types and when they are most appropriate:

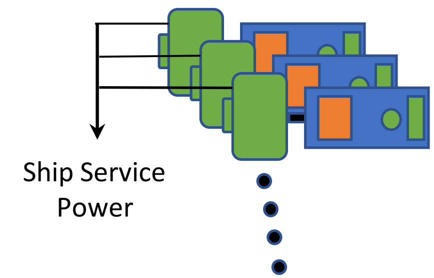
- Mechanical Drive
- Hybrid Electric Drive (HED)
- Integrated Power System (IPS)
- Integrated Power and Energy Storage System (IPES)

# Mechanical Drive



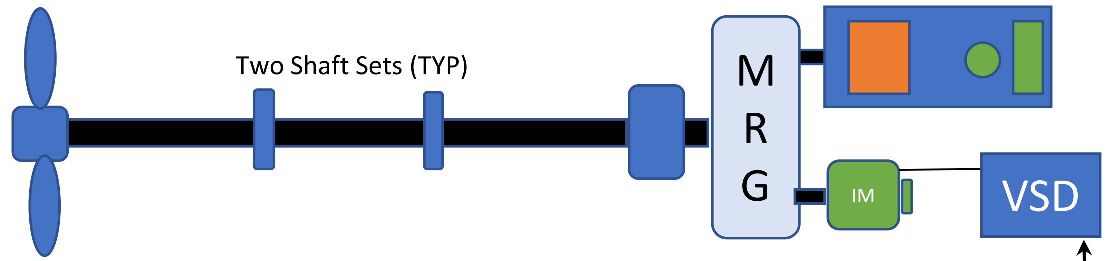



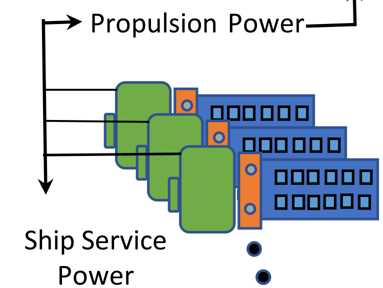

- **Independent Mechanical Propulsion** and **Ship Service Power** systems are the most prevalent in the fleet and provide the base line comparison for improved fuel performance.
- The Main Engines provide full propulsion power and Electric Generators provide ship service power.
    - DDG 51 Class: 4 GE LM2500 Gas Turbines (2/shaft) and three RR Generator Sets
    - LPD 17 Class: 4 Main Diesel Engines for propulsion and 5 Diesel Generator Sets for ships service power.
    - LHD1 Class: Geared Steam Turbines for Propulsion and 5 Steam Turbine Generator Sets for Ships Service Power. The Steam is Provided by two Main Boilers.
- **Least complex** arrangement from an electric power management and controls standpoint.

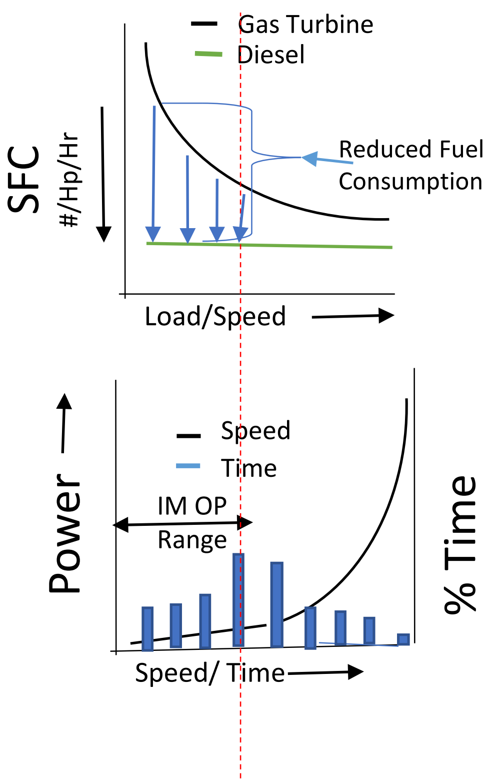



**Most suitable and efficient when ship service power is significantly lower than propulsion load and most time is spent at or near full propulsion power.**

# Hybrid Electric Drive



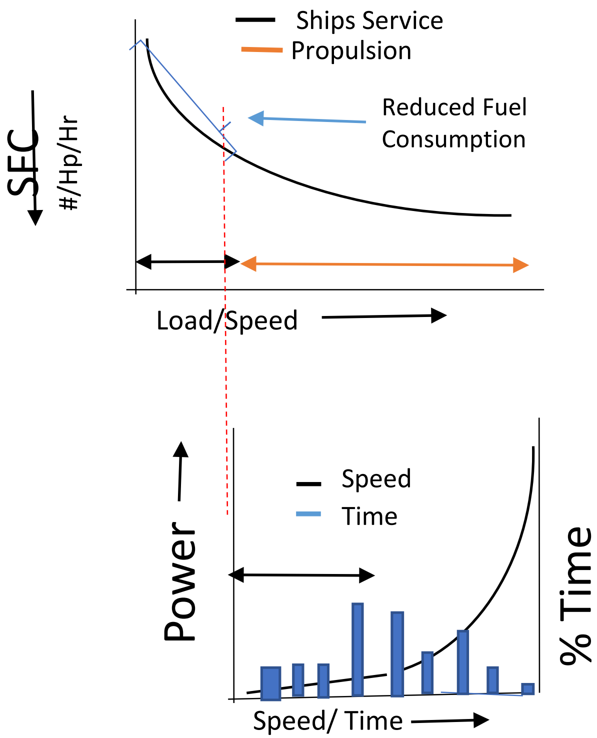



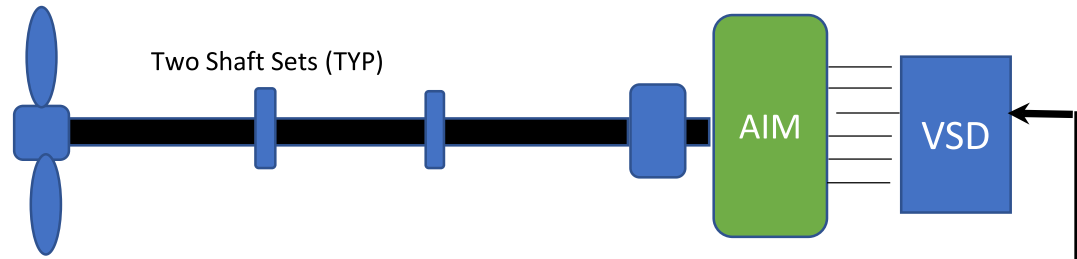




- Includes an Induction Motor (IM) and Variable Speed Drive Unit (VSD) **convert electrical power to mechanical (shaft) power**.
- Takes advantage of excess Ships Service Power capacity as well as the **improvement in Specific Fuel Consumption (SFC)** between that of the Main Engine at low power and Generator sets at higher power.
  - Fielded on LHD-8 and the LHA-6 Class Amphibious Assault ships as well as on the DDG-103.
  - The LHD-8 system saved approx. **$18M in fuel during its initial deployment** in 2011 compared to earlier LHD-1 Class ships.

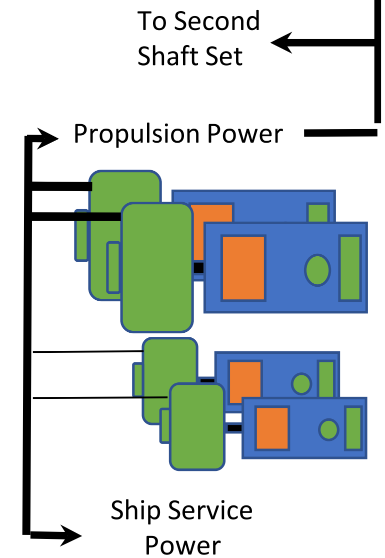
**Most suitable and efficient when ship spends significant time at loiter and slow speed within the induction motor output capability.**

# Integrated Power System



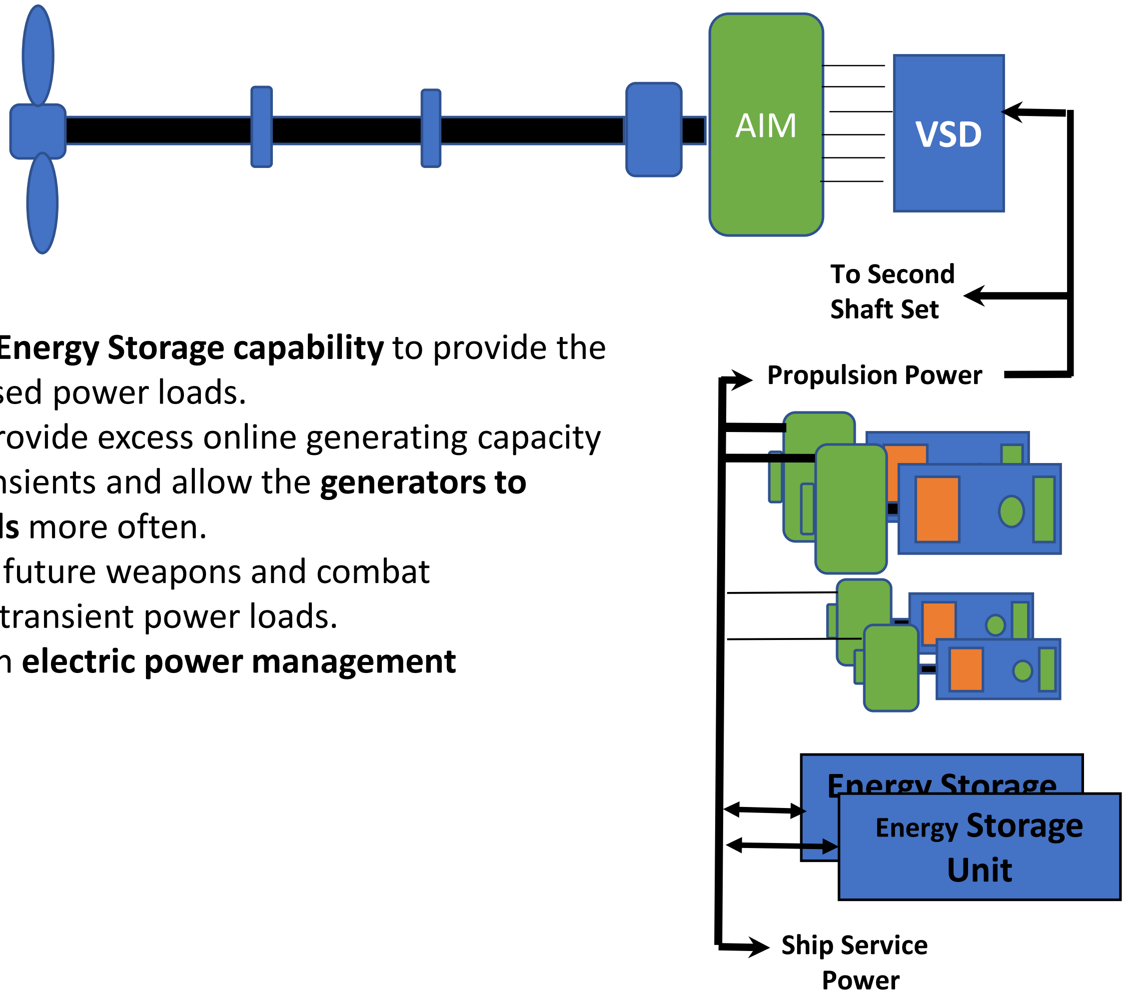




- Common Power Generation System to **provide electrical power** to both the **Propulsion and Ships Service** Power Distribution Systems.
- **Reduces the number of prime movers** on the ship and allows for higher loading of the prime movers reducing Specific Fuel Consumption at any given load point.
- Provides **maximum flexibility** to accommodate a **wide range of speeds** while providing a **significant increase in combat system power** at low and medium speeds.
    - The DDG-1000 is the Navy's only active IPS ship, but the next generation destroyer is also being designed with an IPS.




**Most suitable and efficient when ships service fuel consumption is near propulsion fuel consumption and ship spends significant time at lower speeds**

# Integrated Power and Energy Storage System




- **IPS** with addition of a **fast, reliable Energy Storage capability** to provide the transient response required for pulsed power loads.
- Intended to preclude the need to provide excess online generating capacity needed to mitigate detrimental transients and allow the **generators to operate at more efficient load levels** more often.
- Currently being investigated due to future weapons and combat systems requiring increasingly high transient power loads.
- **Most complex** arrangement from an **electric power management and controls** standpoint.

**Most suitable and efficient when IPS is the optimal solution and significant pulse loading of the electric bus is expected.**

# Major Technical Areas and Challenges

The following technical areas are examples of major challenges and areas of opportunity for the US Navy.

Some are relatively new challenges, and some are old challenges that still represent opportunity space to improve upon in the future.

# Underwater Hull Fouling Control and Mitigation



## Challenge:

- The maritime industry has been fighting the effects of biological growth on ship hulls for centuries.
- Fouled hulls have significant (10+%) impacts on fuel burn rates and reduce top speed.
- Hull/Prop Cleaning programs are costly and only effective when cleaning occurs immediately before ships leave the pier.

## Opportunity Space:

- Better hull coatings that minimize/eliminate growth
- Accurate hull fouling prediction methods to optimize cleaning schedules without manpower intensive underwater hull inspections
- Shift from reactive to proactive cleaning enabled by autonomous hull grooming devices


Fouling on Underside of USN Combatant Craft, Credit National Defense Magazine

Autonomous Hull Grooming Robot

GREENSEA ARMACH ROBOTICS

# Combustion Engine Efficiency Improvements



## Challenge:

- The US Navy does not drive the large marine engine market, making efficiency improvements difficult and costly.
- Increase the Low Power efficiency of Gas Turbine Engines.
- Increase power density of diesel engines.

## Opportunity Space:

- Maximize combustion efficiency of fuel by altering the fuel/air mixture. Examples include hydrogen, ammonia, or methanol.
- Improve sensors and data analytics to monitor and optimize engine performance.
- Recovery and reuse of waste heat for combined cycle engines or other purposes.
- Nontraditional prime movers, such as Stirling engines.

Stirling Engine, Credit National Museum of Scotland

Credit Kwanchai Lerttanapunyaporn/EyeEm/Getty

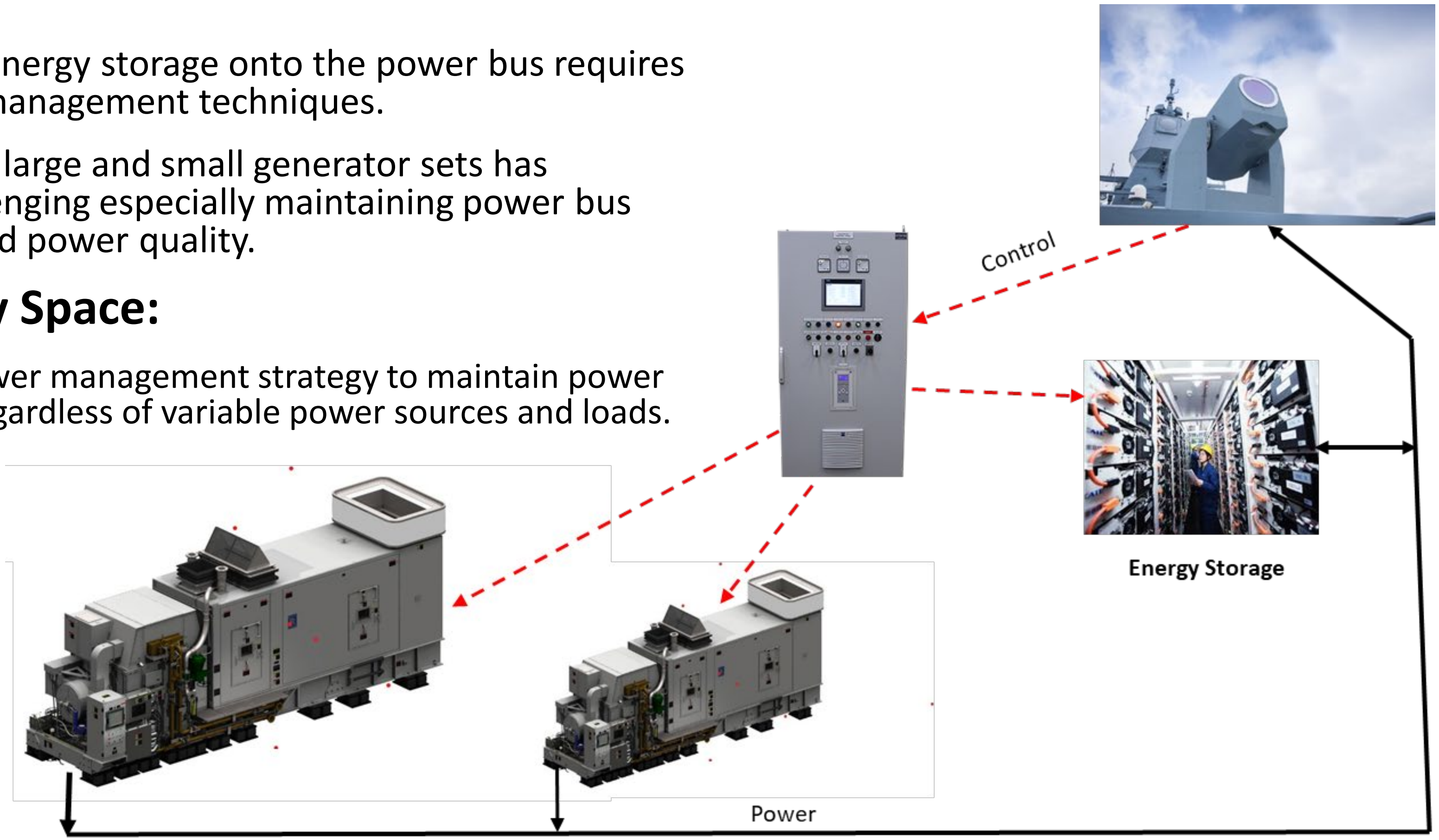
# Electric Power Management

## Challenge:

- Future weapon and combat systems are envisioned to have both increased steady state loads and high pulsed loading which negatively impacts the power bus quality and stability.
- Insertion of energy storage onto the power bus requires new power management techniques.
- Paralleling of large and small generator sets has proven challenging especially maintaining power bus continuity and power quality.

## Opportunity Space:

- Develop a power management strategy to maintain power bus quality regardless of variable power sources and loads.



# Concluding Remarks



- Energy wins wars, saves money, and impacts overall DoD mission success
- The US Navy has made great strides over the past half century, but there is still room for improvement
- There are many R&D programs across the Navy tackling this challenge
- Machinery Arrangement choices have a major impact on life of ship power and energy posture
- Hydrodynamics, noncombat system loads, and combat system loads are also important factors that shouldn't be ignored

**Competing design requirements and priorities makes investing in energy demand reduction initiatives difficult, especially when there isn't a strong ROI. The energy community must sell these technologies effectively in order to be successful.**