



I am going to provide a brief overview by focusing on each of the six framing topics identified here (see also Figure 1):

- What are we trying to accomplish?
- How do we measure success?

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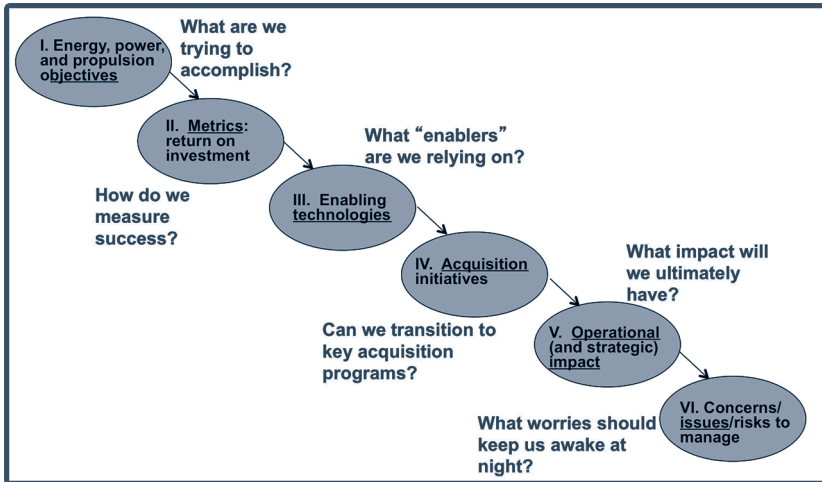
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- What technology enablers are we relying on?
- Can we transition these technology enablers into key acquisition programs?
- What operational and strategic impacts are we ultimately going to have?
- What can go wrong with our plans?



**Figure 1. Adapting Ship Operations to Energy Challenges— Overview (See Appendix for Details)**

In the paragraphs that follow, I'll briefly address the key elements of each of these important topics. Additional supporting details are provided in the Appendix to this presentation.

## WHAT ARE WE TRYING TO ACCOMPLISH?

Stated strategic objectives include strengthening energy security at Navy, joint, and national levels and achieving secure, sufficient, reliable, sustainable energy that reflects future mission requirements, force structure, and operating tempos. Other broad objectives are to conserve energy and reduce greenhouse gas emissions. Stated operational objectives include enhancing combat capability and achieving a reduced logistics tail through the required operational and technological innovations that result in hopefully saving time, money, and lives.

Another broad objective is to diversify energy sources for enhanced resilience. Stated technical objectives include energy efficient acquisition, rapid adoption of technology as an early adopter, and improved tactics, techniques, and procedures (TTPs) and associated testing and adaptation of viable alternative energy sources.

## HOW DO WE MEASURE SUCCESS?

Now let us turn to potential metrics for judging progress and success in this area. At a recent Military Operations Research Society special meeting on power and energy (P&E), it was agreed that a consistent methodology and framework was lacking but was definitely needed if the analysis community is to address P&E to the same extent that we address other important system performance measures. Modeling and simulation tools need to be updated accordingly. The fully burdened cost of fuel (FBCF) or energy (FBCE) needs to be understood better; it needs to be decomposed, defined, and standardized so that we can talk on a common playing field across the services and other DoD and government entities. Our analytic methods will need to include energy efficient Key Performance Parameters (KPPs) as well as the FBCF. Bottom line: we need to provide a more balanced view of total ownership cost, risk, and capabilities for P&E to help support decision makers in this area.

## WHAT TECHNOLOGY ENABLERS ARE WE RELYING ON?

Now let us look at the enabling technologies that the Navy is currently focusing on. This is just a short list of some of the things that are being addressed: improved prime mover efficiencies, hybrid electric drive (HED), alternative fuels, high-capacity energy storage, improved hull forms, advanced propellers, efficient energy and power conversion, improved power generation, high-energy and pulsed-power load development, all-electric ship power control and distribution, and, in some cases, possibly nuclear power and propulsion. You are going to hear a lot more about these topics from our panelists.

## CAN WE TRANSITION THESE TECHNOLOGY ENABLERS INTO KEY ACQUISITION PROGRAMS?

So what are some of the corresponding acquisition initiatives? I think you may have heard about some of these. LHD-8 *Makin Island* has been fitted with an electric auxiliary propulsion system. HED will be going on the USS *Truxtun* (DDG-103) as a proof of concept very soon. You have heard about increased use of biofuels, and time-phased goals have been stated. A variety of other fleet energy efficiency and conservation initiatives have been started. These include the energy dashboard, Smart Voyage Planning, synthetic training, incentivized energy conservation, and a variety of other measures to reduce power propulsion demands.

One of the areas of keen interest is the integrated power system (IPS). We have seen commercial IPSs being put on logistic ships, and a military IPS is being incorporated onto the DDG-1000. A number of research and development initiatives are underway, and a roadmap has been developed for the next-generation IPS. The goal is to provide substantial benefit to warfighting, including providing power to enable future missions with high power demand. We will hear more about some of these from the panelists.

## WHAT OPERATIONAL AND STRATEGIC IMPACTS ARE WE ULTIMATELY GOING TO HAVE?

The expected operational and strategic impacts of these various energy, power, and propulsion initiatives will be important, so I will examine them briefly here. We are taking the 80,000-foot-high strategic impact view, realizing that the Navy is just a part of an overall national and hopefully international effort. Obviously, the number one desired impact is to have more reliable supplies of energy. But when you think about recent foreign policy areas that have caused us grief, becoming more energy diverse will reduce the demand for petroleum and thereby engender fewer questionable alliances, fewer oil supply entanglements, less energy supply blackmail, and fewer perturbations to our national economy caused by oil price volatility.

As for the operational impacts on the Navy, we would like to see increased ship range, endurance, and tactical reach; a less vulnerable and burdensome logistics tail for ships; a reduction in the FBCF, which is part of our total ownership cost reduction program; and increased power and growth flexibility for next-generation weapons systems. Like Rear Admiral Philip Cullom, I will also cite the observation from the 2009 Global War Game summary that sea logistics lanes and bases are potentially an “Achilles’ heel” for the Navy.

## WHAT CAN GO WRONG WITH OUR PLANS?

What are the principal concerns or risks associated with successfully implementing the various energy-related initiatives that I have described? First of all, it occurs to me that without credible tools for computing metrics like the FBCF or total ownership costs, which admittedly have to be calculated out many years, decision makers will be very reluctant to make acquisition decisions in favor of ship energy, power, and propulsion initiatives whose payoff, whose return on investment (ROI), is many years away. So we need to improve our tools so that we can properly support decision makers in this area.

Second, there is obviously a very significant need to monitor the technology readiness levels of many of the energy efficiency technologies and to carefully manage risk in this whole area. Third, I believe that the Navy, and the DoD as a whole for that matter, would benefit significantly from diversity in its fuel and energy sources. If one thing does not pan out as planned, something else will be available to take its place. It is obviously hard to predict the future, but you can bet that some of the alternative fuel sources will have their own set of vulnerabilities and dependencies.

## APPENDIX

- I. Energy, power, and propulsion objectives
  - Strategic objectives
    - Partner with other services, government, industry, and academia to strengthen energy security at Navy, joint, and national levels
    - Protect access to energy sources for our nation and our allies (i.e., secure, sufficient, reliable, sustainable energy)

- Maintain a long-term perspective regarding energy security, accounting for future mission requirements, force structure, and operational tempo
- Conserve energy, develop alternative energy options, secure energy distribution, and reduce greenhouse gas emissions
- Operational objectives
  - Employ energy efficiency as a force multiplier for both enhanced combat capability and a reduced logistics tail
  - Reduce full logistics tether through operational and technological modifications
  - Reduce operational risks for logistics while saving time, money, and lives, enhancing both operational flexibility and sustainability
  - Rely on diversified energy sources for enhanced military operation efficiency/resilience
- Tactical (and technical) objectives
  - Incorporate energy requirements into all phases of system development and acquisition, i.e., energy efficient acquisition
  - Rapid adoption of technology and improved TTPs for energy efficiency
  - Spearhead early testing and adaptation of viable alternative energy sources, e.g., alternative fuels seamlessly interchanged with petroleum-based fuel

## II. Potential metrics—ROI

From a Recent Military Operations Research Society (MORS) special meeting on P&E:

- A consistent methodology/framework (e.g., data, metrics, terminology, logic) is needed to address P&E with regard to operational effectiveness across the spectrum of required models
- Modeling and simulation tools should be updated accordingly to keep pace with developing P&E technologies
- The elements of FBCF\* or FBCE should be decomposed, defined, and standardized to provide a common understanding (e.g., for the force protection/attrition part of FBCF)

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\*Definition according to the Office of the Deputy Under Secretary of Defense Acquisition and Technology is: “FBCF is the commodity price *plus* the total

- Analytic methods are required to derive energy efficiency KPPs\*\* and FBCF and should be employed to set capability and cost metrics (objectives/thresholds) for acquisition programs
  - Bottom line: Analytic tools and metrics are needed to provide a balanced view of total ownership costs, risks, and capabilities for P&E in support of decision makers
- III.** Illustrative enabling technologies for energy/power/propulsion
- Improved prime mover efficiencies, e.g., combined diesel and gas turbine plants and podded propulsion for new ship designs
  - HED for greater efficiency at low speeds and low electric loads
  - New/alternative fuels, e.g., sustainable non-petroleum-based fuel
  - Rechargeable high-capacity energy storage, e.g., advanced battery and capacitors to enable ultrahigh P&E densities
  - New/improved hull forms and designs for greater efficiencies at various speeds and increased range/endurance
  - Advanced propeller designs/improved propulsive efficiency
  - Efficient P&E conversion, e.g., high-power-density electrical power conversion and thermal management
  - Improved power generation, e.g., advanced gas turbine engines/generators, high-efficiency/reliable/high-power-density fuel cell systems
  - High-energy and pulsed-power load development for advanced combat systems
  - All-electric ship power control and distribution, i.e., integration of ship service electrical power and propulsive power for greater overall efficiency by using same distribution system (e.g., for pulsed-power switching and control system in support of advanced weapon systems)
  - Nuclear power/propulsion

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life cycle cost of all people and assets required to move and protect fuel from the point of sale to the end user.” Note: FBCF use in life cycle operations and support has been codified in DoD 5000.02.

\*\*Energy efficiency KPPs are called out in CJCS 3170.01F to be “selectively implemented”—in other words, slowly applied to programs.

- IV.** Illustrative acquisition initiatives for energy/power/propulsion
- USS *Makin Island* (LHD 8) with an electric auxiliary propulsion system that enables efficient low-speed operations (up to 75% of time deployed)
  - Goal for HED on DDG-51 (USS *Truxtun*) by 2012 (as part of a proof of concept) with potential cost savings at low speeds
  - Increased use of biofuels in fleet with ambitious time-phased goals:
    - 2012: Green Strike Group with all ships certified to run on 50/50 biofuel blend
    - 2016: Green Strike Fleet with all ships containing full load of biofuel plus HED DDG
    - 2020: 50% of Department of the Navy energy consumption will come from alternative energy sources
  - Other fleet energy efficiency and conservation initiatives, e.g.,
    - The energy dashboard to monitor power and fuel consumption
    - Smart Voyage Planning software for all ships
    - Expanded use of synthetic training for ships to reduce fuel consumption
    - Combustion trim loop on L-ships
    - Stern flaps, bulbous bows, hull and propeller coatings, propeller redesign, and other measures to reduce propulsion power demands
    - Incentivized Energy Conservation (I-ENCON) program
  - IPS
    - Commercial IPS on T-AKE 1
    - Military IPS incorporated into DDG-1000
    - Next-Generation IPS (NGIPS) Research, Development, Test & Evaluation, Navy funding to enable, for example, more efficient prime mover operations, opportunities for propulsion efficiency, integration of fuel cell technology for ship applications, and very-high-powered mission systems in the future



- V. Potential operational (and strategic) impact from energy/power/propulsion initiatives
  - Potential strategic impact (as part of an overall national effort) of lessening dependence on foreign oil/energy with very large implications for military/U.S. Navy deployments and utilizations in the future
    - More reliable supplies of energy, i.e., more assured energy access in the future
    - Less contesting for petroleum energy sources between nations
    - Fewer questionable alliances with autocratic regimes to ensure access to their oil supplies
    - Fewer oil supply entanglements influencing our foreign policy (e.g., today's Middle East)
    - Less energy supply blackmail by bad actors empowered by energy (e.g., oil, gas) wealth
    - Less adverse perturbations to our national debt and economy caused by oil price volatility
  - Potential operational impact on Navy of successful energy efficiency efforts
    - Increased ship range and endurance, i.e., expanding tactical reach through efficiency
    - Less vulnerable/burdensome logistics tail for ships—frees up combat forces for key missions (less logistics protection needs), i.e., increased combat flexibility/effectiveness
    - Reduction in FBCF by not over-relying on volatile oil market
    - \$10 increase in barrel of oil increases the Navy fuel bill by about \$300 million
    - Reduced fuel/energy costs could mean more funds available for procurement, training, and maintenance
    - Increased power/growth flexibility for next-generation weapon systems (e.g., very-high-powered radars, electromagnetic rail guns, free-electron laser systems)
  - From a participant at a Naval War College wargame exercise: “Sea control of logistics lanes, as well as defense of related logistics bases, were as important or more important than sea control of the main objective area . . . [i.e., a potential Achilles' Heel]”

- VI.** Concerns/issues/risks to manage related to energy/power/propulsion initiatives
- Analysis/acquisition decision support
    - Need reliable tools to compute FBCF(E)—the current state of the art in this area appears suspect (i.e., insufficient rigor and discipline)
    - Without credible tools for computing FBCF(E) and total ownership cost, decision makers will be reluctant to make acquisition decisions in favor of ship energy, power, and propulsion initiatives whose payoff (ROI) may be many years away
    - It is also not clear whether energy efficiency-related KPPs will be as strongly enforced as other KPPs (related to ship and combat system capabilities), e.g., potentially resulting in the cancellation of a program
  - Many enabling technologies
    - Technology readiness levels (TRLs) for key enabling ship energy, power, and propulsion technologies must be carefully monitored/managed
    - For example, the NGIPS roadmap appears to be a good initial step in prioritizing and tracking related technology developments
  - Alternative (non-petroleum-based) fuels
    - Putting the requisite infrastructure in place in the near- to midterm could be a significant challenge
    - Technical hurdles and economic constraints could greatly limit how rapidly alternative fuel sources can replace (vice augment) fossil fuel-based energy on Navy ships
    - Uncertain whether these alternative fuel sources will pose their own set of vulnerabilities/dependencies (albeit with a smaller carbon footprint)