Sizing Power Generation and Fuel Capacity of the All-Electric Warship

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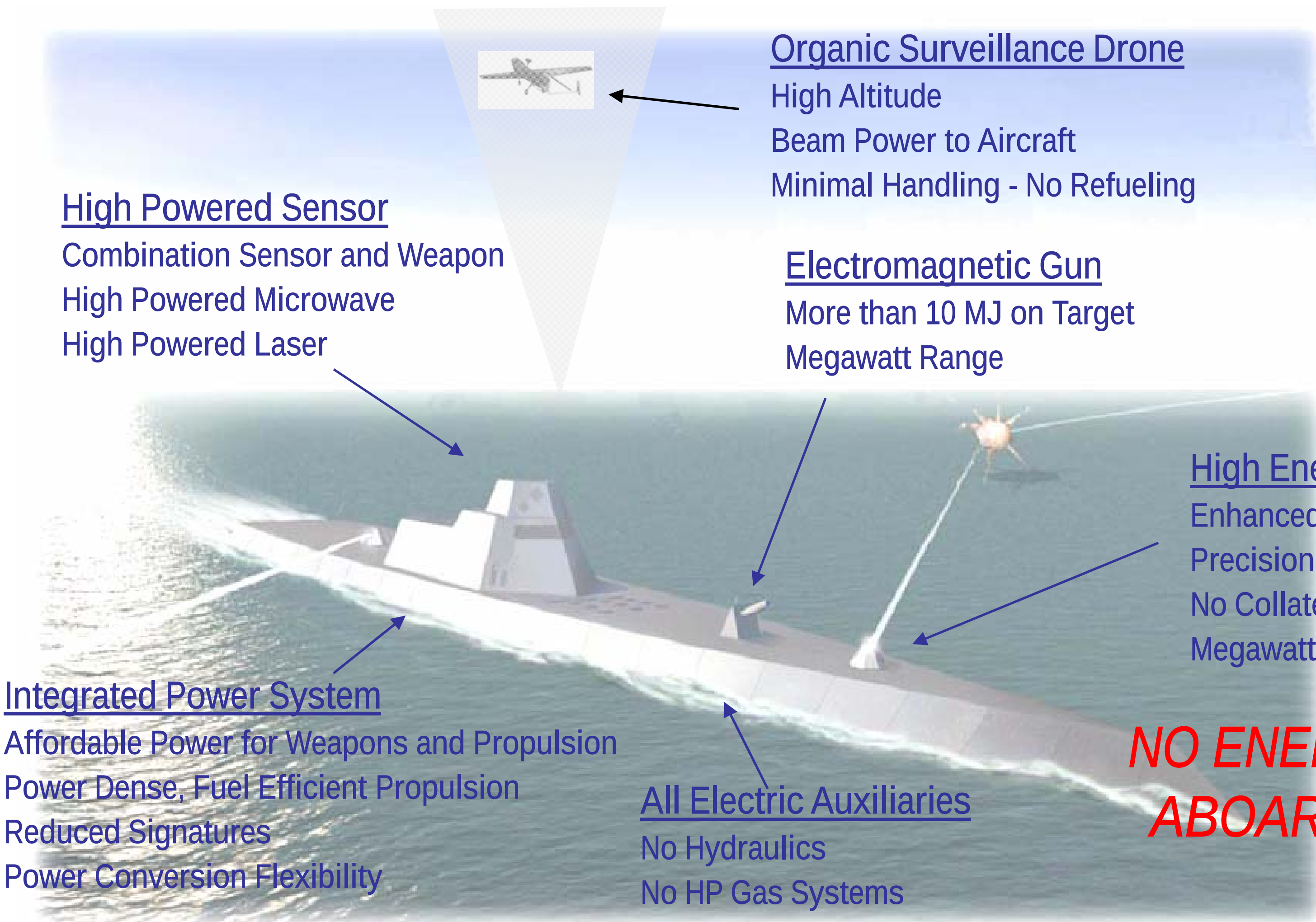
All-Electric Warship Vision



Organic Surveillance Drone
High Altitude
Beam Power to Aircraft
Minimal Handling - No Refueling

High Powered Sensor
Combination Sensor and Weapon
High Powered Microwave
High Powered Laser

Electromagnetic Gun
More than 10 MJ on Target
Megawatt Range

High Energy Laser
Enhanced Self Defense
Precision Engagement
No Collateral Damage
Megawatt Class Laser

Integrated Power System
Affordable Power for Weapons and Propulsion
Power Dense, Fuel Efficient Propulsion
Reduced Signatures
Power Conversion Flexibility

All Electric Auxiliaries
No Hydraulics
No HP Gas Systems
Reduced Sailor Workload

NO ENERGETICS ABOARD SHIP!

Agenda

- Challenges with current methods for sizing power generation and fuel tank capacity
- Proposed Solution
  - Sizing Power Generation
  - Sizing Fuel Tank Capacity
- Future Work

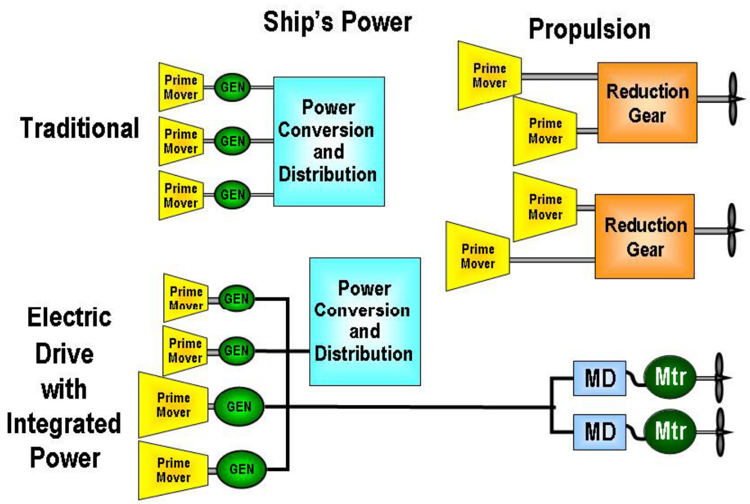
Current Methods

Sizing Power Generation

- Propulsion Power
  - Achieve Sustained Speed at 80% of installed Shaft HP with clean bottom and calm seas to account for
    - Weather
    - Sea state
    - Heading Relative to wind and sea direction
    - Fouling
- Ship Service Power
  - Serve the Maximum margined electrical load with service life allowance without the generator of highest rating and paralleled generators loaded no more than 95%.

Sizing Fuel Tank Capacity

- Fuel Tanks must be large enough to achieve a given endurance range at a given endurance speed
  - 24 hour average electric load assumed.



So What's the Problem?

<u>**Sizing Power Generation**</u>

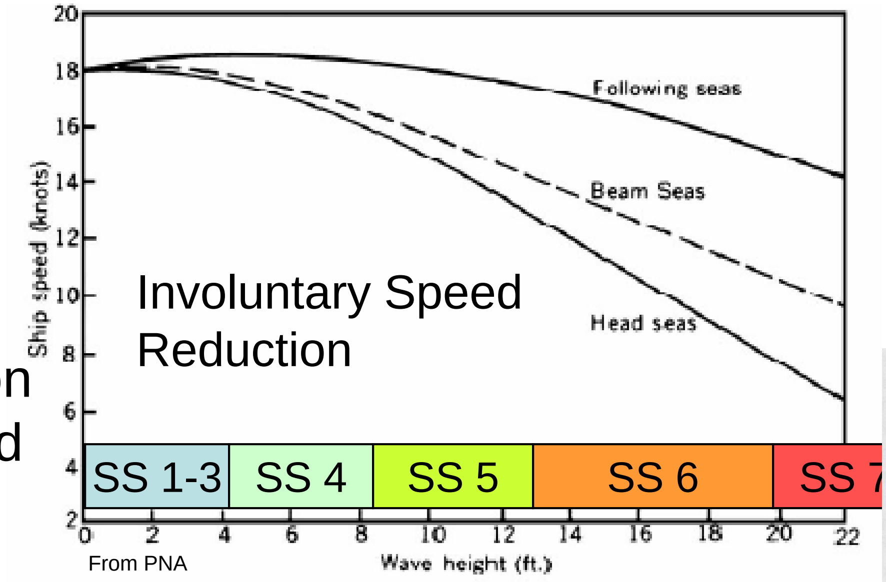
- Maximum margined electrical load may not occur when ship is at maximum speed.
- No incentive to reduce drag at other than calm water conditions
  - No credit for anti-fouling efforts
  - No credit for hull forms that reduce drag in higher sea-states.

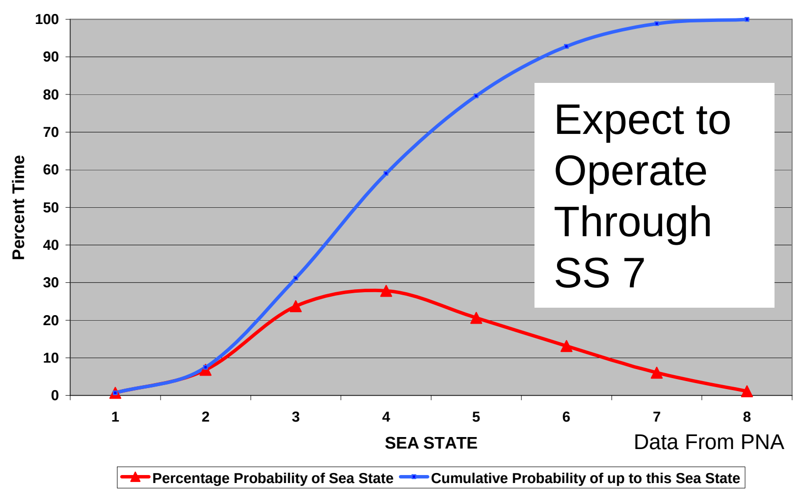
<u>**Sizing Fuel Tank Capacity**</u>

- High power mission system loads can be a significant fraction of power
  - On station time can become more important operationally than range at endurance speed.
- No incentive to reduce fuel consumption at high speeds
  - High Speed surge to theater may become operationally significant with a small fleet size.

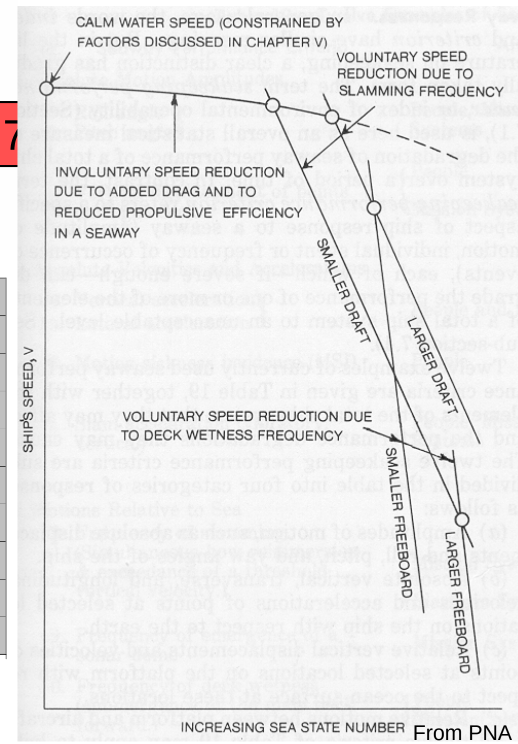
Sizing Power Generation: Impact of Sea-State

- Involuntary speed reduction
  - Depends on Direction of seas and wind
- Voluntary speed reduction
  - Slamming
  - Deck wetness





Voluntary Speed Reduction



Sizing Power Generation – Proposal

- Define Mobility as a Mission System
  - For each operational condition based on a Concept of Operations, specify …
    - Mission System states
    - Speed time profile
    - Required maximum speed and minimum tactical speed
    - Percentage of time at 10°F, 59°F, and 100°F
  - Specify a realistic sea-state to use (Upper end of SS 4?)
  - In calculations, include impact of hull fouling and reduced propulsion efficiency due to unsteady loading. Use the worst case heading for determining impact of Sea state
- Include margins appropriate for stage of design and degree of uncertainty.
- Include a Service Life allowance for Ship Service electrical loads.
- Power Generation must be capable of providing requisite Quality of Service for all operational conditions
  - Power Generation must be sufficient to serve all propulsion and ship service loads for all operational conditions
  - Power Generation must be capable of serving ship service loads in all operational conditions with sufficient propulsion power to achieve the minimum tactical speed without the largest Generator Set.

Tie Power Generation Requirements to Operational Conditions

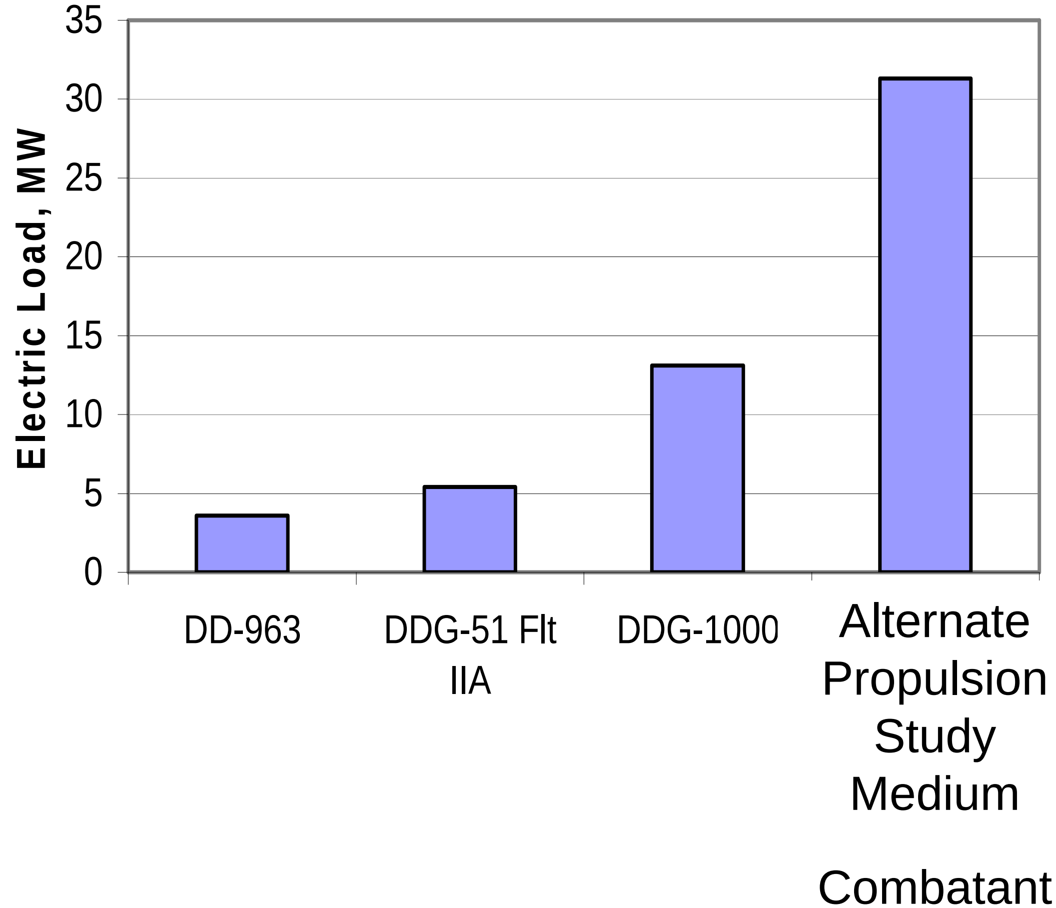
Sizing Power Generation – Challenges

- Design Tools for accurately predicting ship resistance at different sea states.
- Method for translating ship trial data to mobility requirements
- Improved electrical load amalgamation methods needed
  - Accuracy of existing load factors questionable.

http://www.nauticalweb.com/superyacht/530/tecnica/optimisation.htm

Sizing Fuel Tank Capacity: Growth of Mission System Loads

- Future non-mobility Mission Systems will likely drive fuel requirements more than propulsion
- Endurance Range and Speed may no longer be appropriate for sizing fuel tanks



Sizing Fuel Tank Capacity: High Speed Efficiency

- Getting to Theater fast can be important
  - Reduced Fleet Size – can't be everywhere all the time
  - Need for Maritime Power will not be predictable.
- Efficiency at high speed currently not a design factor for sizing fuel tanks
  - Ships are designed for efficiency at endurance speed, little incentive to improve efficiency at high speed
  - Ship speed can be operationally limited by availability of replenishment ships

http://www.navatekltd.com/hyswac.html

Sizing Fuel Tanks – Proposal

- Fuel Tanks should be large enough to satisfy three conditions …
  - Surge to Theater
    - Distance at maximum design speed using only 50% of fuel
    - Goal is to minimize dependence on replenishment ships to arrive at a theater of operations as fast as possible
    - Must define capability of other mission systems (self defense)
  - Economical Transit
    - Similar to traditional Endurance speed and range
    - Only difference is that capability of other mission systems are defined, rather than using 24 hour average load
  - Operational Presence
    - Minimum time that a ship should be capable of conducting one or more missions (such as theater ballistic missile defense) using a given speed-time profile and mission system capability
    - Use only 1/3 of fuel capacity

Future Work

- Produce and implement a guidance document for specifying ship requirements.
- Formalize the methodology in standards such as the Naval Vessel Rules and Design Data Sheets.
- Develop and validate improved ship resistance tools for predicting powering requirements in various sea-states.
- Develop and validate improved tools for predicting the efficiency of propulsors in various sea-states.
- Develop and validate improved electric load forecasting models.
- Develop and formalize methods to correlate trials data in observed sea-states to ship mobility requirements under other sea-states.
- Develop and validate tools for predicting the rate of fouling and its impact on ship's resistance for a given operational profile, antifouling features and hull cleaning strategy.
- Institutionalize the use of operational profiles and operational conditions as a basis for calculating life cycle cost.

Summary

- Current sizing methods for Power Generation and Fuel Capacity no longer appropriate for modern warships
- Proposed new methods
  - Based on operationally significant requirements
  - Take advantage of modern analysis tools
- Much work remains to develop methodology and supporting tools and data.