Electrical Power System Considerations for Modular, Flexible, and Adaptable Ships

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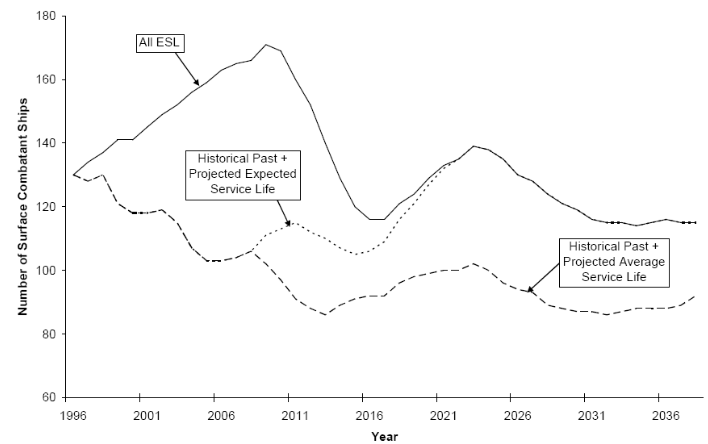
Observations

- Combat System Development vs. Ship Design and Construction

Attribute	Combat Systems	Ship Design & Construction
Timeline	Short	Long
Expertise required	Electronics, software	HM&E, Hardware
Configuration	Volatile	Stable
Effect on *Design* Ship Service Life	Little influence	Strong driver
Effect on *Actual* Ship Service Life	Strong driver – can't cost effectively update	Moderate driver – Ships decommissioned early

- Affordability will become increasingly important.

Modular, Flexible, Adaptable Ship Technologies enable ships to affordably remain Operationally Relevant over their Service Life.



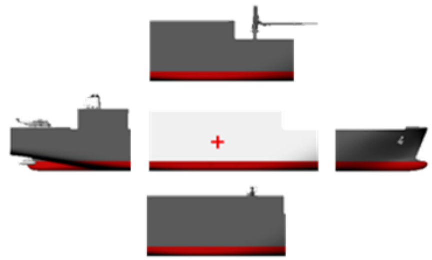
Koenig, Dr. Philip, Don Nalchajian, and John Hootman,"Ship Service Life and Naval Force Structure," ASNE ETS 2008, 23-25 Sept 2008

Modular, Flexible, Adaptable Ship Technologies

Container Stacks

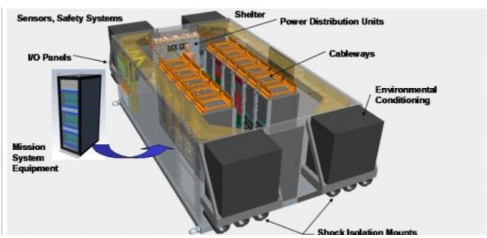
SS *Curtiss* (T-AVB 4)

Modular Hull Ship

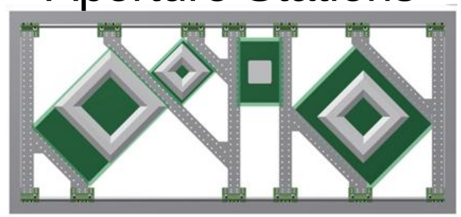


Off-Board Vehicles

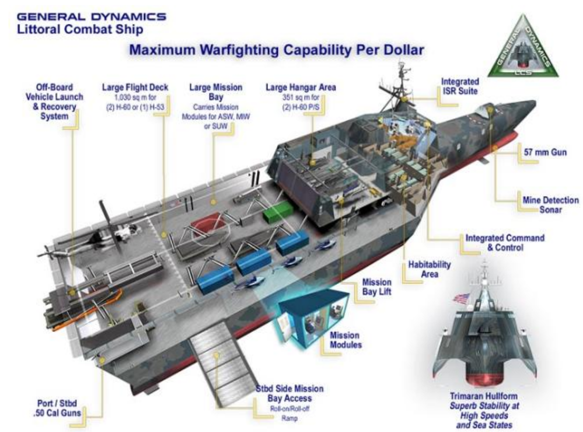
Electronic Modular Enclosures



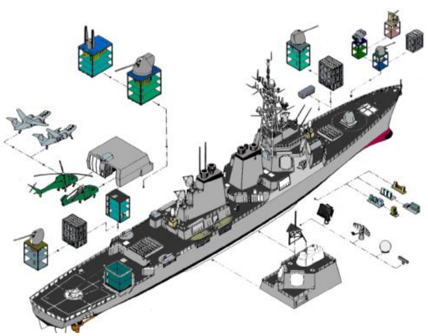
Aperture Stations



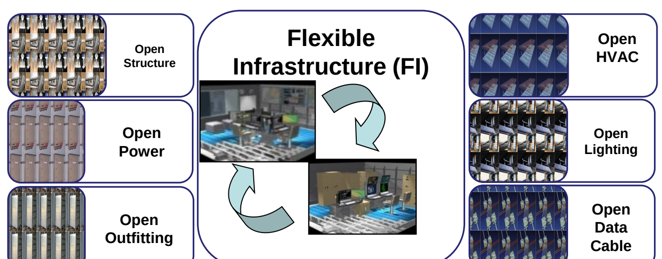
Mission Bay



Weapons Modules



Flexible Infrastructure



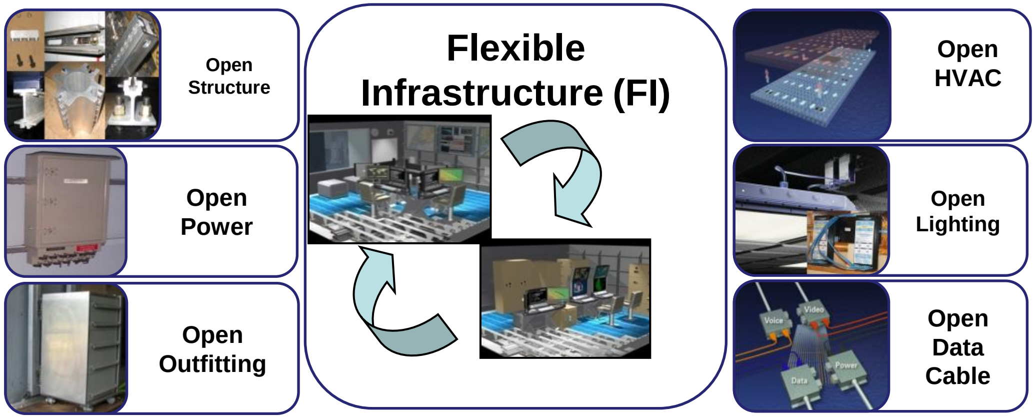
Flexible Infrastructure

What:

Infrastructure for an interior space to enable rapid reconfiguration without welding or other labor intensive activities.

Includes Integrated Power Node Center (IPNC)

- Defined in MIL-PRF-32272
- Integrates Input and Output Multifunction Power Modules (MFPMs)



Why:

Facilitate rapid adaptation of spaces likely to change often during the service life of a ship.

Impact on Electrical Power Systems:

Understand potential variability of electrical load for different operating conditions over the life of the ship.

Consider sizing feeder cable to IPNC to serve largest available input module.

Modular Hull Ship

What:

Pre-engineered bow and stern section to accommodate variable length Parallel Midbody (PMB).

Why:

Eliminate rework in bow and stern design to accommodate need for additional displacement or volume for new combat systems. Facilitates rapid insertion of new disruptive technologies (Rail gun, FEL)

Enable prefabrication and testing of parallel midbody sections for relatively rapid insertion during ship modernization availabilities.

Facilitate preservation of industrial base by allowing different shipyards to construct and test bow, stern, and parallel midbody.

Impact on Electrical Power Systems:

Consider Electric Drive to locate all propulsion in the aftbody; avoid shaft lines crossing PMB and use forward retractable propulsor for longitudinal separation to improve mobility survivability.

Align PMB boundaries with electrical zones

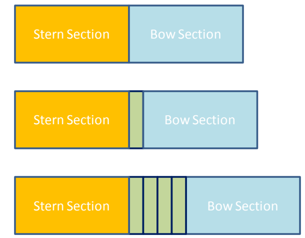
Allow only longitudinal busses to cross PMB boundaries.

Current Rating of longitudinal bus must consider load flow for different PMB options.

Since cost of the bus is dominated by labor, consider installing the highest ampacity cable/duct that is practical.

Use DDS 310-1 Rev 1 to estimate electrical loading for different PMB options

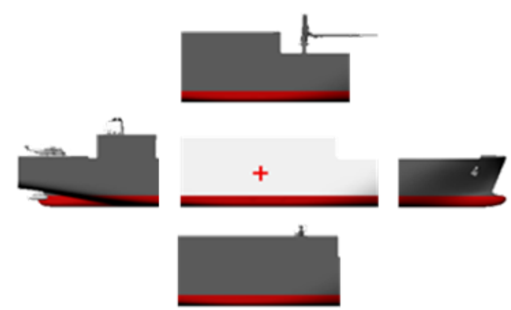
Use DDS 200-1 Rev 1 and DDS 200-2 to estimate impact of different PMB options on ship's endurance and on annual fuel usage.



Bow = 4 x Beam
Stern = 4 x Beam
PMB = 0 to 2 x Beam

"Van Ameijden says Schelde is "very much aware" of the "90:10 rule" of shipbuilding: Changing 10% of the ship requires changes to 90% of the drawings. This, he adds, is not necessary with the Sigma concept because of the high degree of standardization."

Schelde Naval Shipbuilding: Sigma Design Concept



Mission Bay

What:

Large open interior area in ship to accommodate multiple elements of a mission module. Generally has access to the exterior for vehicle launch and recovery and for loading/unloading mission modules.

Can be combined with the Helicopter Hangar.

Why:

Enable customization of the ship's combat systems for each deployment

Enables development and testing of a mission module independent of the ship.

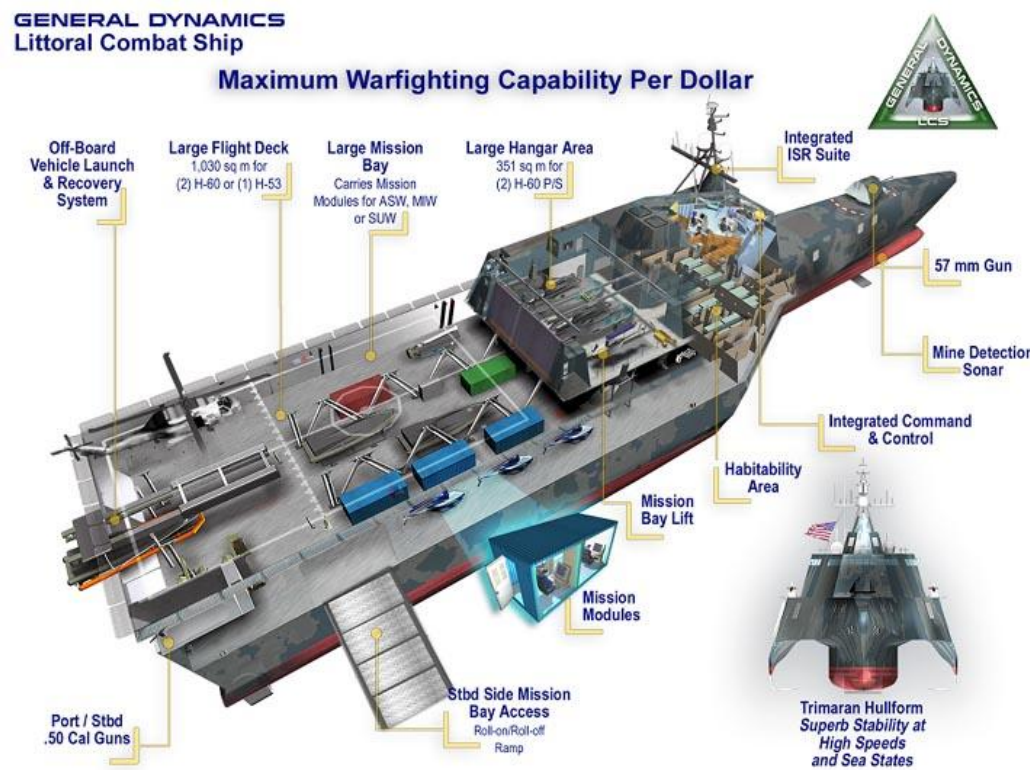
Impact on Electrical Power Systems:

Electrical Power Interface

- 440 VAC 60 Hz 3 Phase up to 30 kW
- 115 VAC 60 Hz 1 Phase up to 3 kW
- 115 VAC 400 Hz 3 Phase up to 15 kW
- 28 VDC, up to 0.84 kW

Consider using Integrated Power Node Center (IPNC) for 400 Hz and 28 VDC to provide common solution for point-of-use power conversion. Avoid special distribution systems.

Consider using IPNC for 60 Hz. power if non-interruptible power is required.



Container Stacks

What:

Develop a shipboard interface for standard ISO containers that enable COTS equipment within the container to survive in a naval environment.

Entire mission functionality contained in the containers

Differs from a Mission Bay in the environmental protection (shock, vibration) and the closer packing of modules

Why:

Enable complete combat systems to be tested independent of the ship.

Could manage combat systems suites independent of the hull – integrate combat systems into the hull shortly before a deployment. (Treat Combat Systems like an Air Wing)

Hull replacement and Combat Systems replacement do not have to be aligned in time.

Impact on Electrical Power Systems:

Consider using LCS ICD as basis for electrical power system interface; may have to extend for higher power levels.

Ensure ICD includes Quality of Service requirements

Consider using an IPNC for providing power; isolate power system impact if interface requirements change.

Consider sizing feeder cable to IPNC to serve largest available input module.

SS *Curtiss* (T-AVB 4)

RFA Reliant with ARAPAHO
(RFA Nostalgia)

Electronic Modular Enclosures (EME)

What:

Encapsulation of Commercial Off the Shelf (COTS) electronics in a modular enclosure to enable equipment survival in a naval combatant environment.

Why:

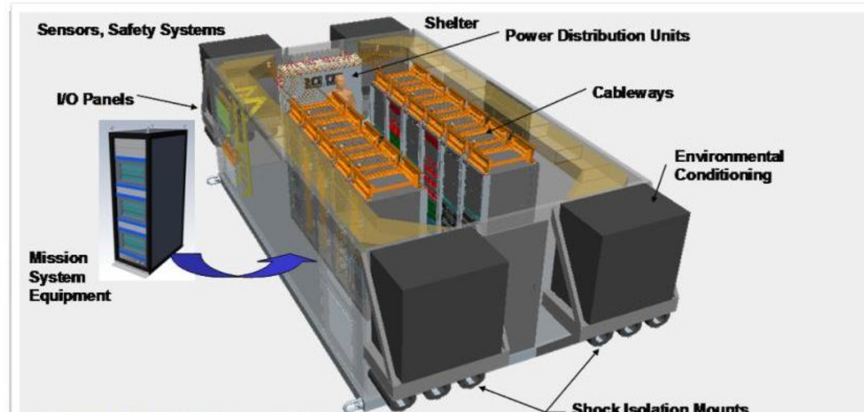
Allow COTS equipment to be used on a naval combatant.

Provide standardized equipment racks to enable rapid reconfiguration of the electronics.

Impact on Electrical Power Systems:

Ensure ICD includes Quality of Service requirements as well as anticipated range of electrical loads for different operating conditions.

Consider using an IPNC for providing power (serve as Power Conditioning Unit); isolate power system impact if interface requirements change.



4 sizes of EME, 16 per Ship

	Length	Width	Height
Mini	18 ft	7 ft	7.45 ft
Small	25 ft	11.8 ft	7.45 ft
Medium	30 ft	11.8 ft	7.45 ft
Large	35 ft	11.8 ft	7.45 ft

- Specialized shelter provides environment for Commercial Off The Shelf (COTS) Hardware
- 16 shelters house 236 cabinets
- Shock, Thermal, EMI, Security, & Noise Reduction
- Power Distribution and Control
- Enables Integration of electronics in factory

Weapons Modules

What:

Predefined and standardized physical, structural, and distributed system interfaces for weapons modules.

Why:

Facilitate upgrading of combat systems elements

Facilitate reuse of combat system elements across ship classes.

Works well for elements that require both internal to the ship and external access.

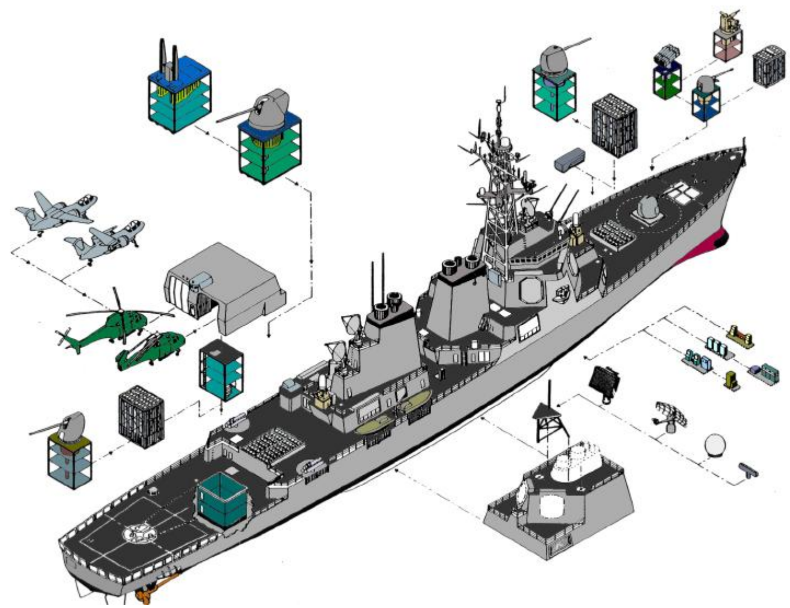
Impact on Electrical Power Systems:

Develop interfaces to anticipate electric weapons

Specify pulse power requirements

Specify reserve power requirements

Anticipate future weapons



Aperture Stations

What:

Standardized ship-aperture interfaces in the topside design of the ship to enable upgrading of transmit and receive modules

Integrated into the ship in a manner to minimize co-site / EMI issues.

Why:

Decouple transmit / receive module design from the ship design

Enable combat systems design to be concurrent with detail design and construction of the ship.

Enable upgrading of apertures during the ship's lifecycle

Impact on Electrical Power Systems:

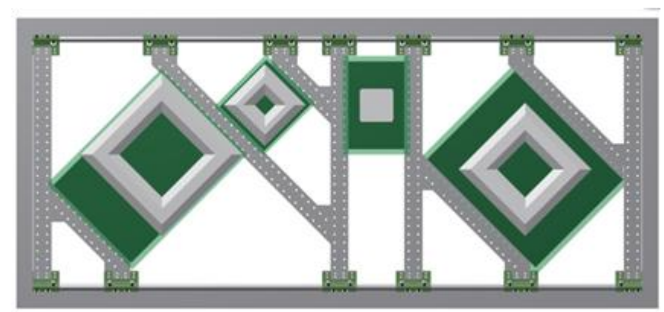
Develop interfaces to anticipate high power sensors

Specify pulse power requirements

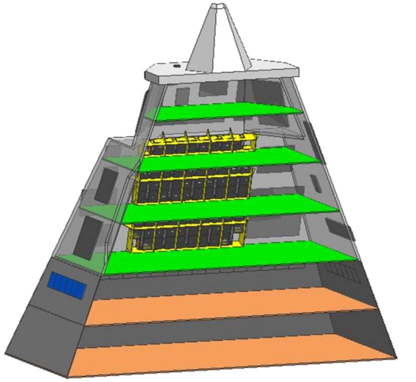
Specify special power requirements

Specify reserve power requirements

Anticipate future sensors



Modular Mechanical Architecture concept for INTOP antenna subsystem (Courtesy ONR)



Aperstructures

Off-Board Vehicles

What:

Support for multiple types of aircraft, boats, unmanned underwater vehicles, unmanned air vehicles, and unmanned surface vehicles.

- Vehicle Handling
  - Boat Davits and Helo Deck
  - UUV / USV handling gear
  - UAV launch and recovery
- Vehicle Stowage, Communications, Command and Control, Maintenance

Why:

Extend the offboard reach of sensors and weapons.

Enable independent development of the ship and the embarked vehicles.

Impact on Electrical Power Systems:

Ensure ICD specifies whether starting an engine from shipboard power system required: short-duration large peak load.

Consider using IPNC to reduce impact to power system if vehicle requirements change.

Other Power System Considerations

- The intent of a Service Life Allowance should be captured in the ICDs for the modular, flexible, and adaptable technologies;
  - ICDs become a constraint for future growth
- ICDs must go beyond defining a nominal voltage type and current/power rating, must include:
  - Power Quality
  - Quality of Service
  - Load Shed Priority

Future Work

- Modify MIL-PRF-32272 to include 28 Volt output MFPMs in the IPNC. Also modify to include 115 VAC 400 Hz 3 Phase output MFPMs of higher power ratings.
- Revise MIL-STD-1399 sections 300 and 680 to add a power management / power control interface that addresses real-time allowable power levels and ramp rates.
- Create a Design Data Sheet, Design Criteria and Practices Manual or other document detailing the electrical (and other) parameters that must be defined for a modular interface.
- Create standards and specifications for the implementation of Open Power and Open Lighting for Flexible Infrastructure spaces.
- Create a document describing required survivability features to enable short shaft lines that do not penetrate the parallel mid-body.
- Create an ICD for Weapons Modules and Aperture Stations that anticipate electric weapons and high power sensors.
- Create a specification for a forward, retractable propulsor.

Conclusion

- Modular, Flexible, Adaptable Ships require new approaches to defining power system requirements
- The IPNC can serve a valuable role in providing a modular, flexible, and adaptable power system interface to systems and loads that:
  - are expected to undergo significant change over the ship's service life,
  - require special power interfaces.