# Systems Engineering and the Navy's Next Generation Integrated Power System

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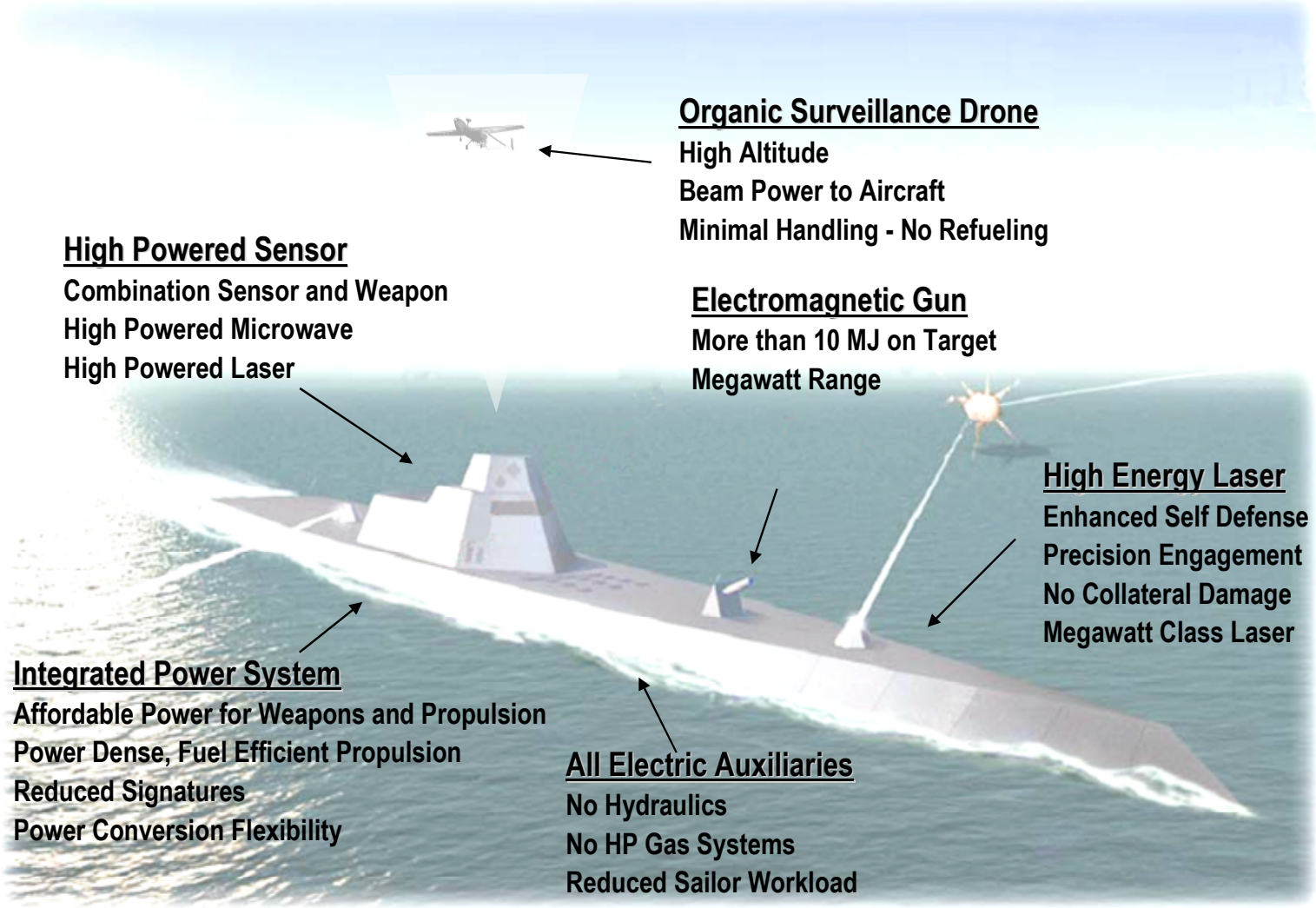
# Naval Electric Power System Design

*The primary aim of the electric power system design will be for survivability and continuity of the electrical power supply.* To insure continuity of service, consideration shall be given to the number, size and location of generators, switchboards, and to the type of electrical distribution systems to be installed and the suitability for segregating or isolating damaged sections of the system.

- *NAVSEA DESIGN PRACTICES and CRITERIA MANUAL, ELECTRICAL SYSTEMS for SURFACE SHIPS*, CHAPTER 300
NAVSEA T9300-AF-PRO-020

# Electric Warship Vision



# The Road to the Electric Warship

**SSN 774**
**Power Electronics**

**DDG 1000**
**Military Integrated Power System**

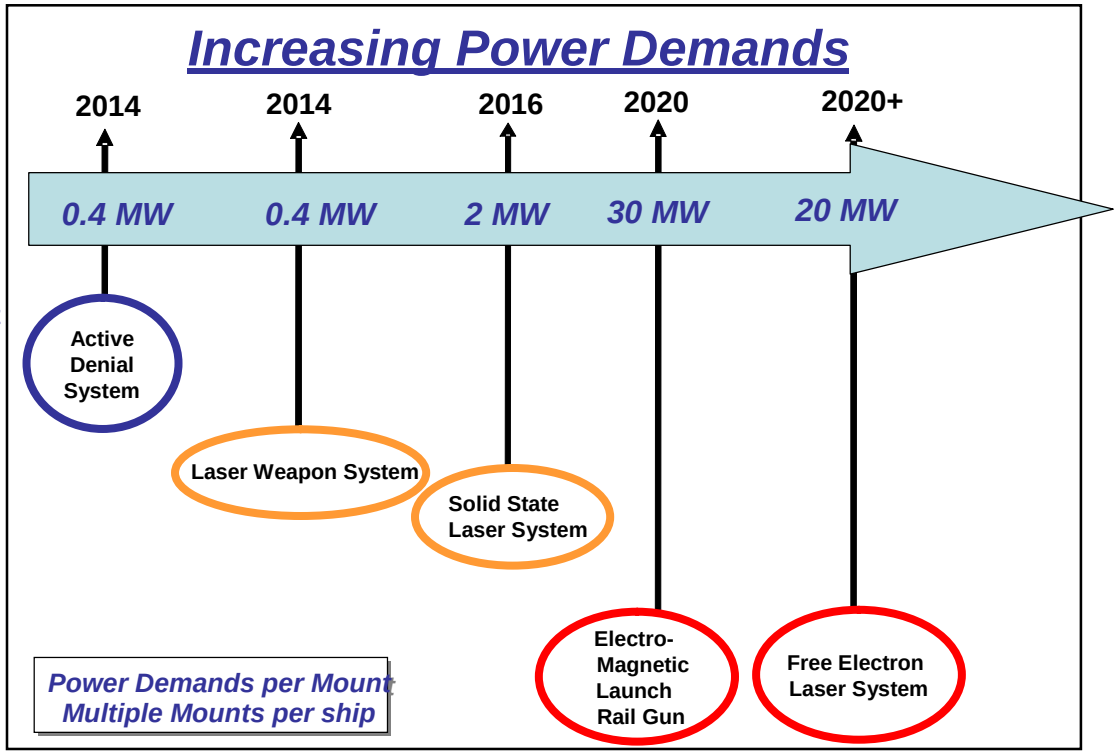
**CVN 78**
**High Voltage, High Power Distribution System**
**Electric Aircraft Launch**

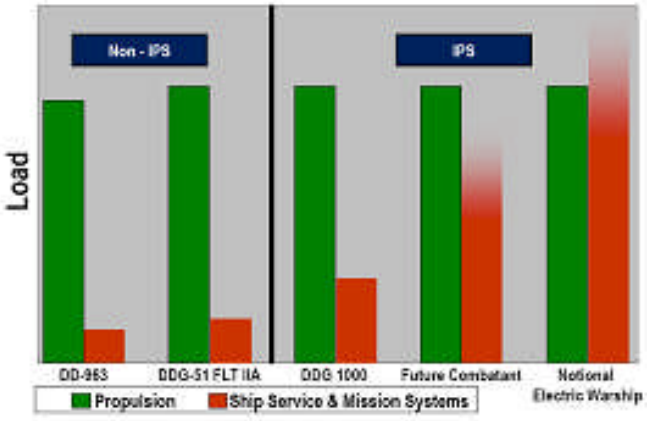
**T-AKE 1**
**Commercial Integrated Power System**

**LHD 8 / LHA 6**
**Hybrid Electric Drive**

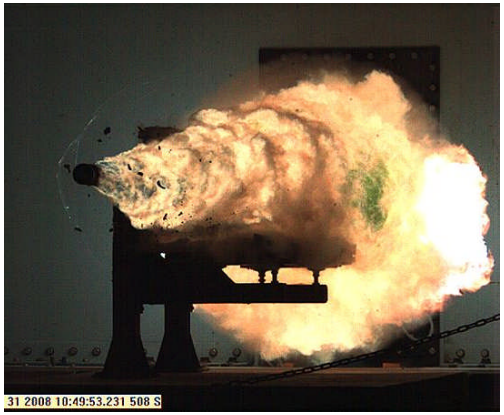
**MLP**
**Commercial Integrated Power System**

# Why IPS?
# Increasing Mission Power Demand



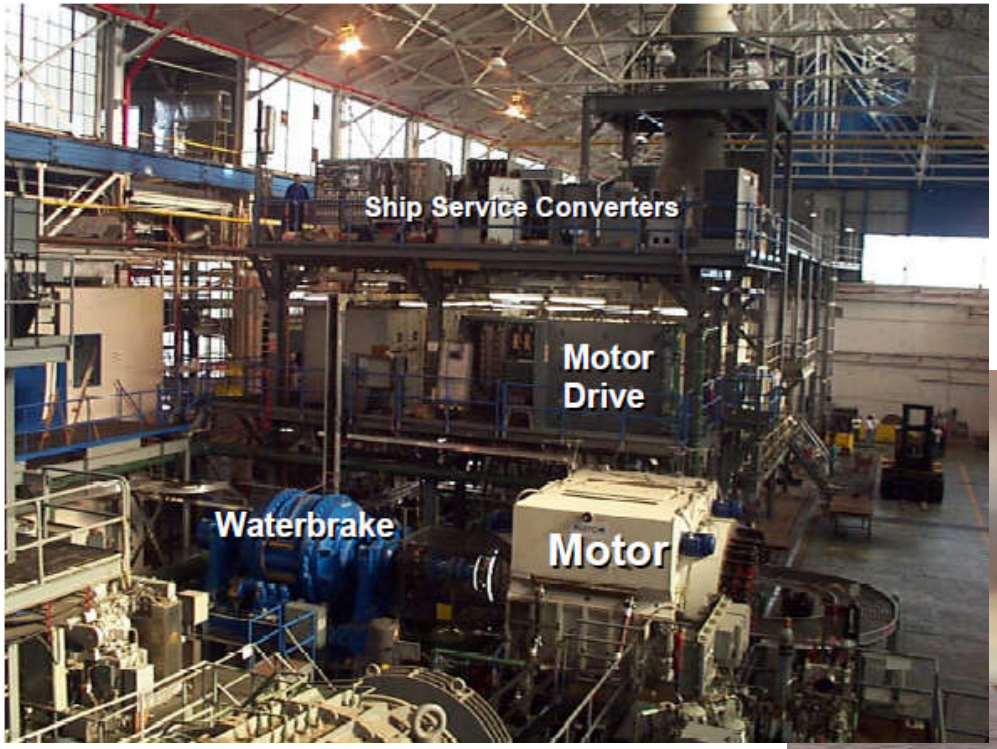

Sensor and Weapons Power Demands will Rival Propulsion Power Demands



# FY 11 Long Range Naval Vessel Construction Plan

| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CVN 21 | | | 1 | | | | | 1 | | | | | 1 | | | | | 1 | | | | | 1 | | | | | 1 | | |
| Large Surface Combatants | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **DDG 51** | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 2 | | | | | | | | | |
| **DDG(X)** | | | | | | | | | | | | | | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Small Surface Combatants | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **LCS** | 2 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | | | | | | | | | |
| **LCS(X)** | | | | | | | | | | | | | | | | | | | | | | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Attack Submarines | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **SSN-774** | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 |
| Ballistic Missile Submarines | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **SSBN(X)** | | | | | | | | | 1 | | | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | |
| Amphibious Warfare Ships | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **LHA 6** | 1 | | | | | 1 | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| **LH (X)** | | | | | | | | | | | | | | | 1 | | | | 1 | | | | 1 | | | | | 1 | | |
| **LPD 17** | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **LSD(X)** | | | | | | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | |
| Combat Logistic Force | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **MLP** | 1 | | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| **T-AO** | | | | | | | 1 | | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | |
| Support Vessels | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **JHSV** | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | | | | | | | | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **T-ATF(X)** | | | | | 1 | | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | |
| **T-ARS(X)** | | | | | | | | | | 1 | | 1 | 1 | 1 | | | | | | | | | | | | | | | | |
| **T-AGOS(X)** | | | | | | | | | | **1** | | 1 | 1 | 1 | | | | 1 | | | | | | | | | | | | |
| **AS(X)** | | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | | | | |
| New Construction | 9 | 8 | 12 | 9 | 12 | 9 | 12 | 9 | 13 | 9 | 11 | 10 | 11 | 8 | 8 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 11 | 8 | 10 | 7 | 10 | 9 | 10 | 7 |

# Integrated Power System on DDG 1000



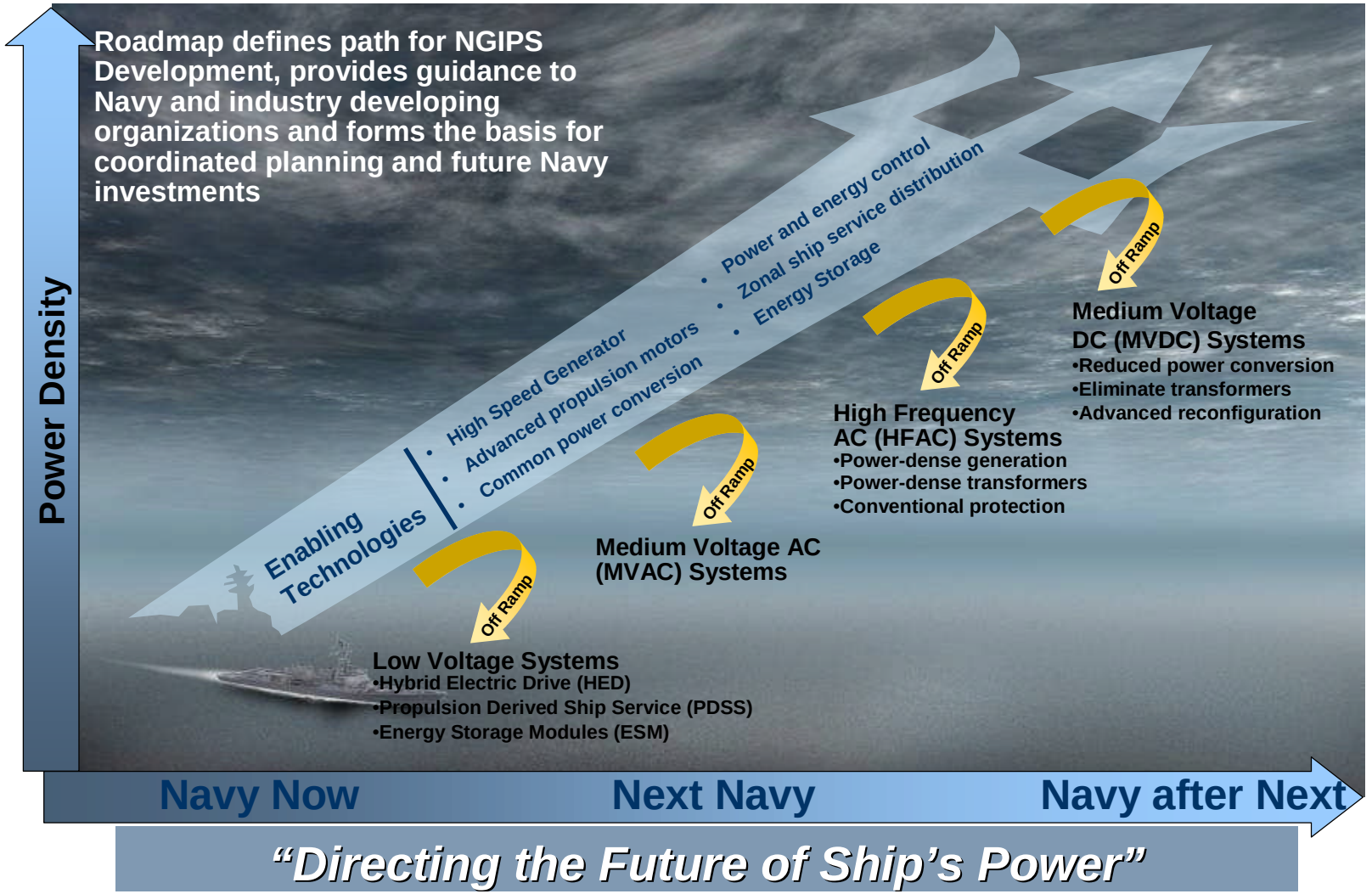

The current generation military IPS

# Next Generation IPS – What's New?

- Implements an Open Architecture Business and Technical Model
- Reflects lessons learned from IPS
- Covers full range of ships in the 30 year shipbuilding plan.
  - 4 Power Generation Technical Architectures
  - Zonal Ship Service Power Architecture

**AFFORDABLY MEET THE POWER NEEDS OF OUR FUTURE FLEET**

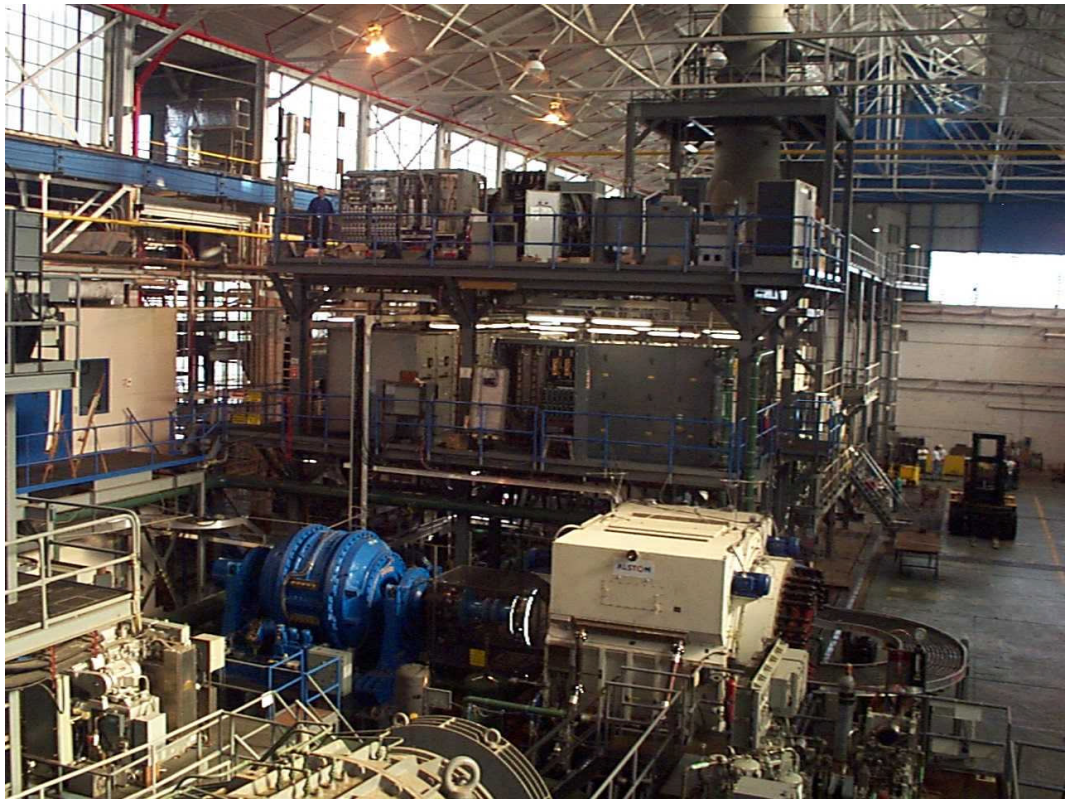
# Next Generation Integrated Power System Technology Development Roadmap




***"Directing the Future of Ship's Power"***

# IPS Architecture

- Integrated Power
  - Propulsion and Ship Service Loads provided power from same prime movers
- Zonal Distribution
  - Longitudinal Distribution buses connect prime movers to loads via zonal distribution nodes (switchboards or load centers).

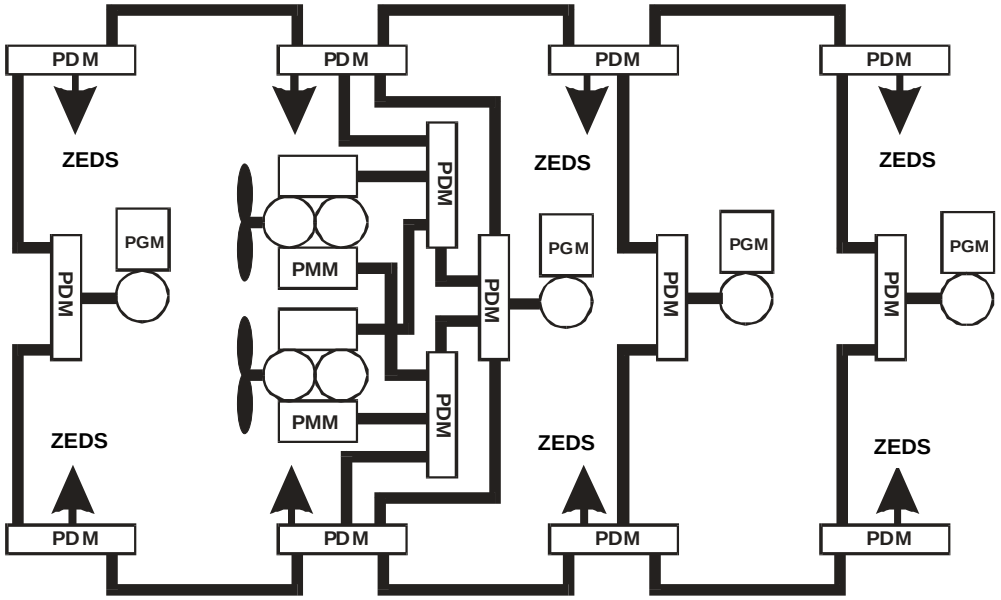


**IPS Test Site: NAVSSES Philadelphia**

# Integrated Power System Functional Architecture

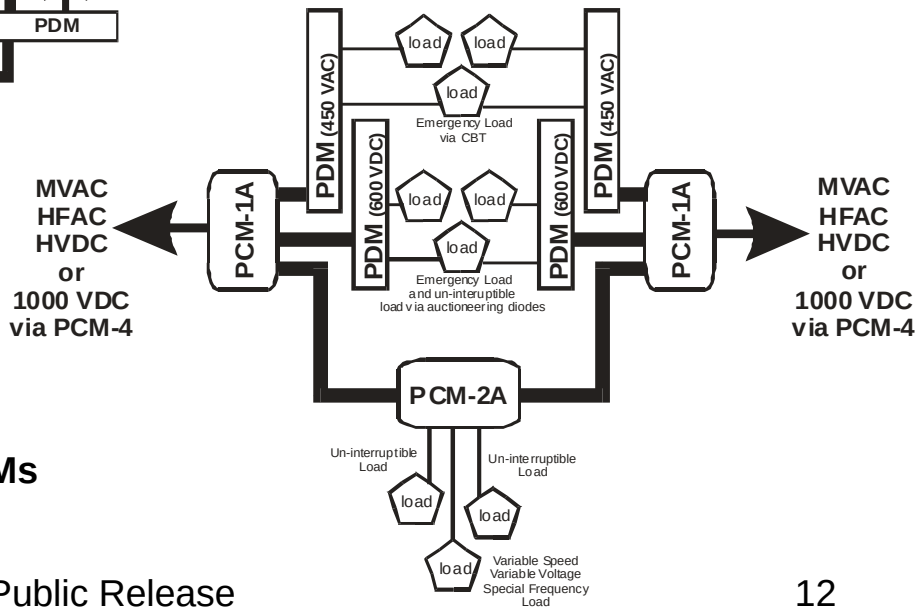
- IPS consists of an architecture and a set of modules which together provide the basis for designing, procuring, and supporting marine power systems applicable over a broad range of ship types.
  - Power Generation Module (PGM)
  - Power Distribution Module (PDM)
  - Power Conversion Module (PCM)
  - Power Control (PCON)
  - Energy Storage Module (ESM)
  - Load (PLM)
  - Propulsion Motor Module (PMM)

# Power System Architectures




**Notional**
**Power Generation Bus**
**(MVAC, HFAC, MVDC)**

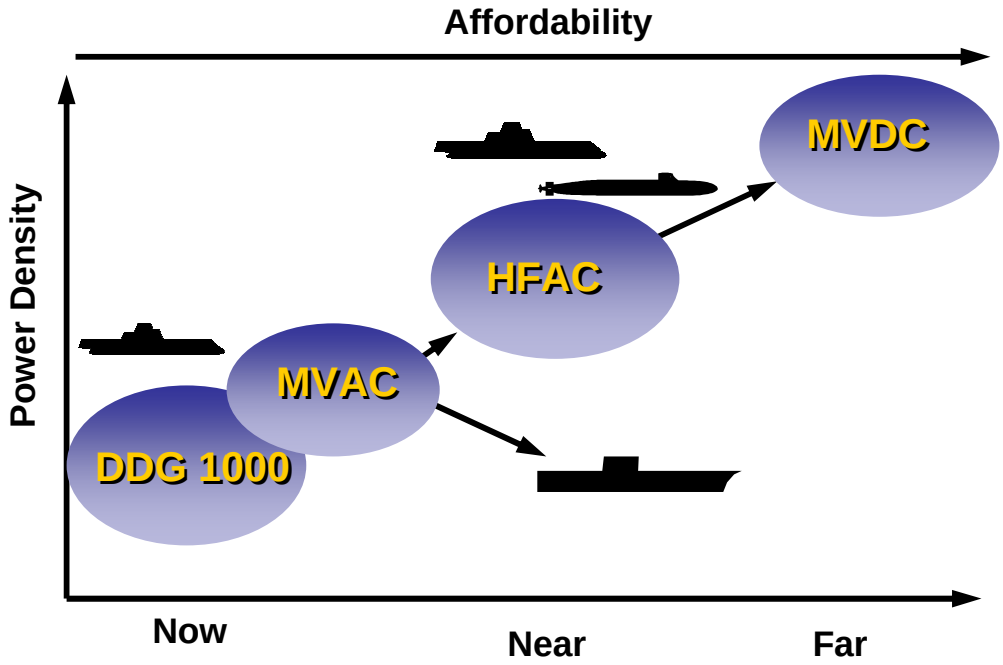
**Notional**
**Zonal Electrical Distribution**




**Power Generation Bus configurations (including number of zones and number and location of PGMs / PMMs) will vary based on ship requirements**

# NGIPS Technical Architectures

- **Power Generation**
  - Low Voltage AC
    - Upgrade legacy applications
  - Medium Voltage AC (MVAC)
    - Today's Technology
    - Appropriate for ships without power density requirements
  - High Frequency AC (HFAC)
    - Intermediate Step towards MVDC for ships with high power density requirements
  - Medium Voltage DC (MVDC)
    - Target Architecture for ships with high power density requirements
- **Zonal Ship Service Distribution**
  - Common to all Power Generation Systems
  - Affordably provide requisite level of Survivability and Quality of Service
    - Zonal Survivability – limit impact of damage to affected zones
    - Quality of Service – Ensure reliable power under normal operating conditions

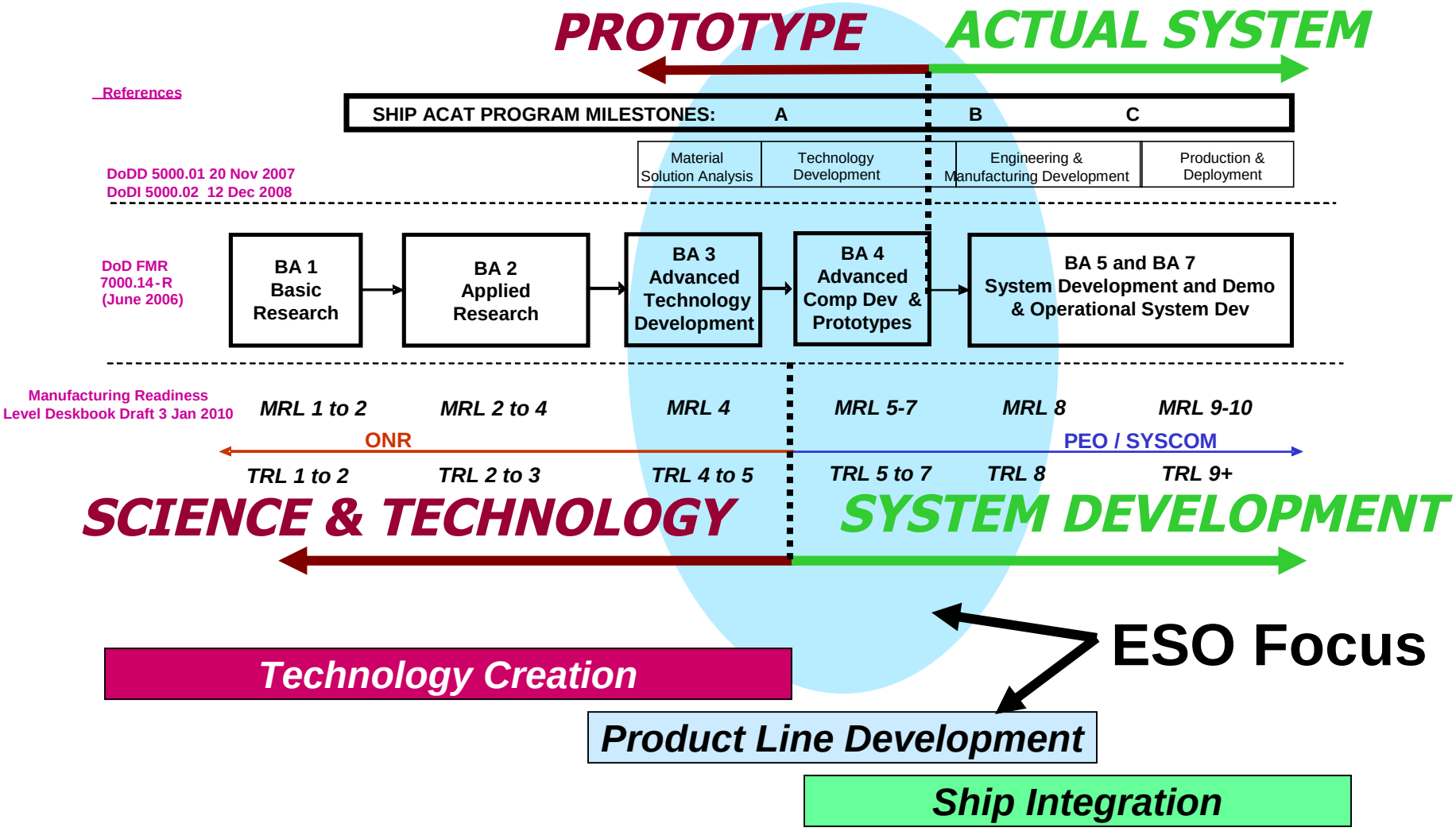


# Electric Ships Office Charter

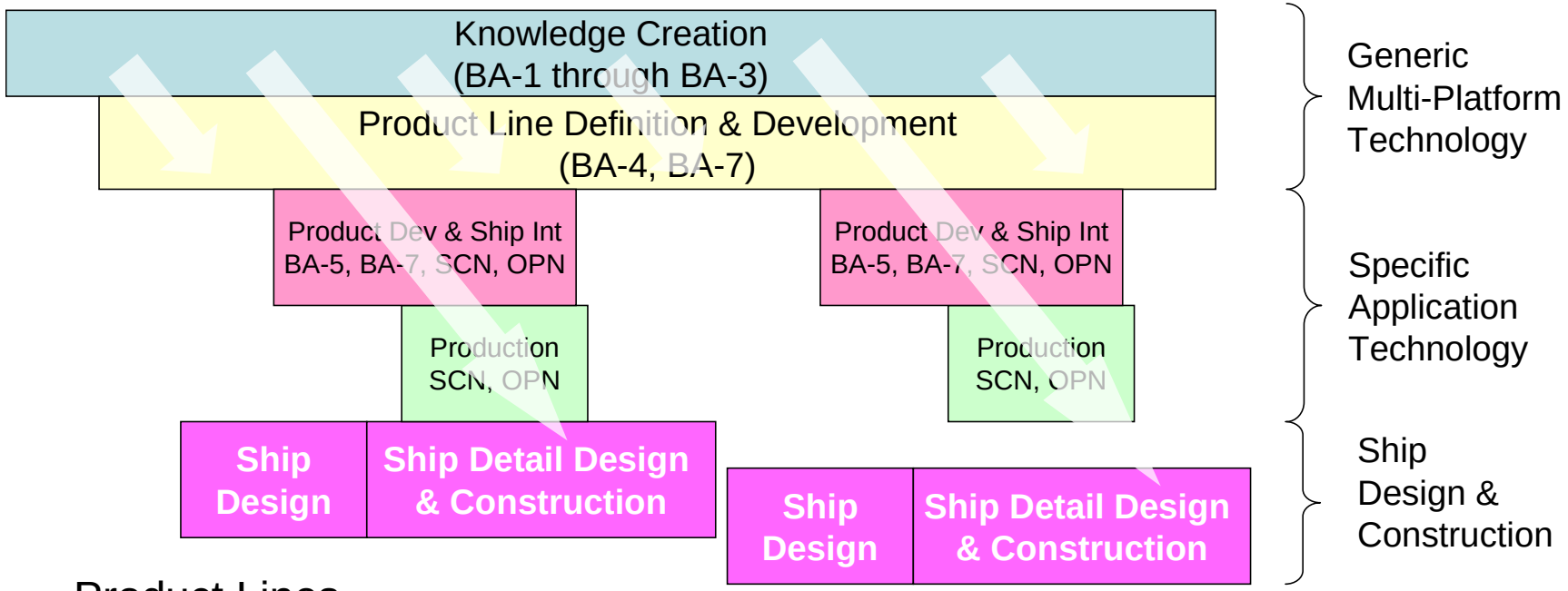
- Mission: Provide smaller, simpler, more affordable, and more capable ship's power systems for Navy platforms by defining common open architectures, developing common components, and focusing Navy and industry investments.
- The Electric Ships Office
  - Provides affordable tailored IPS products through application of system architecture, systems engineering, systems integration, modularity and commonality principles to reduce acquisition and life cycle costs.
  - Provides IPS vision …
  - Supports the development and platform integration of future weapons systems with high electric power demands.
  - Enhances the transition of IPS related Science and Technology
  - Improves Naval Platform Mission Capability through selection and enhancement of IPS components and architecture.

Create and Implement the Next Generation IPS

# Transitioning Technology



# Product Line Based Technology Transition Model




- Product Lines
  - Provide capability to create and produce specific applications when needed.
  - Promote Commonality across Ship classes.
  - Decouple S&T from specific ship applications
    - Eliminate churn in aligning S&T and ship acquisition programs.
  - Capture knowledge in Specifications, Standards, Handbooks, Design Data Sheets, Rules, etc.
- Technology Development Roadmaps facilitate communication

# Naval Open Architecture

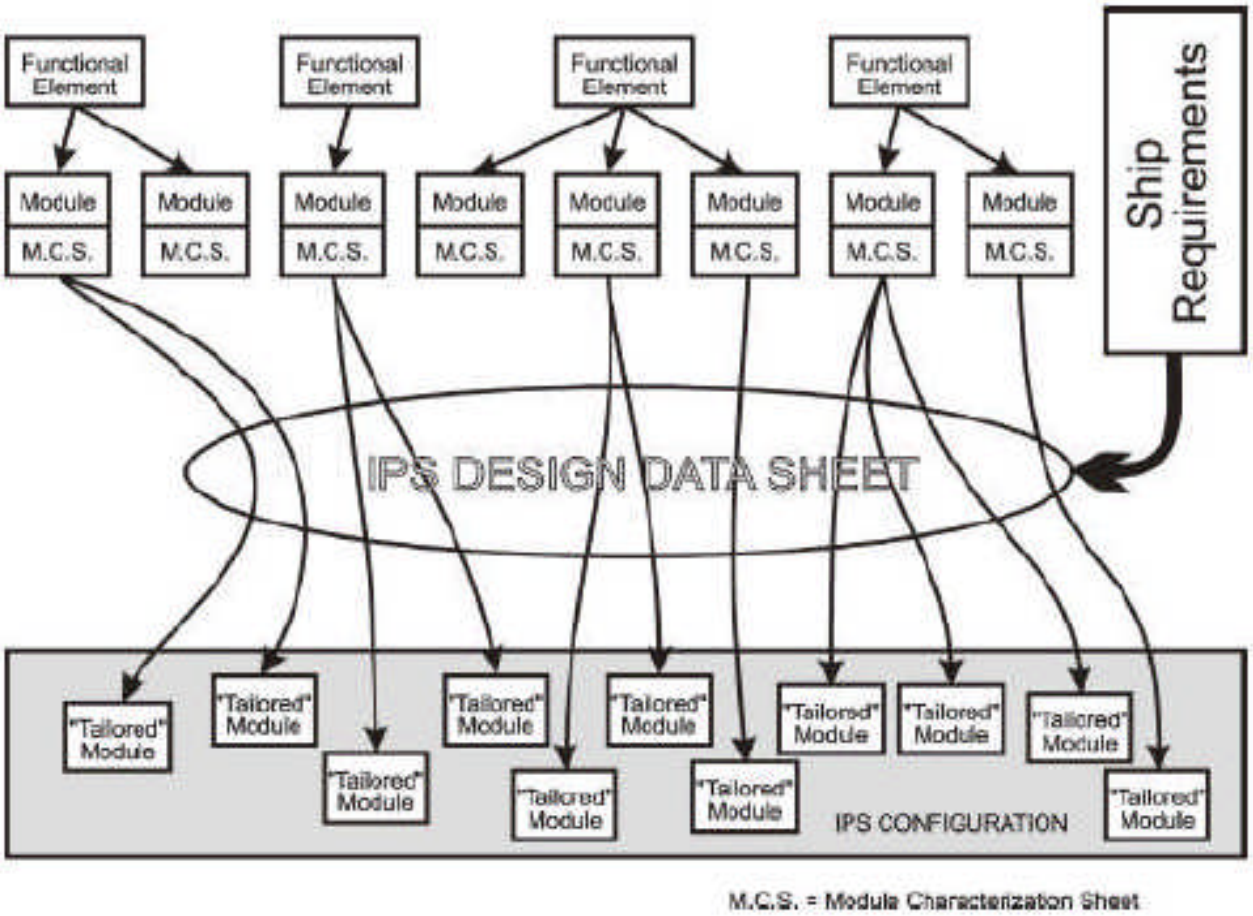
- ***"Naval OA is a combination of collaborative-competition business and technical practices; including Peer Reviews for cost-effective innovation, with rapid Technology Insertion processes fostering third-party developed modules (hardware and/or software), for continuous, incremental increases in warfighting capability, while reducing cost."***

  Open Architecture Task Force (OATF)
  December 2006

# Open Architecture (OA) Business Model

- Using Performance Specifications that define "what" is needed not "how" it is designed
  - Includes extensive use of well-defined and detailed interface specifications (Technical Architecture)
  - Includes well defined validation methods
- Subdividing labor and specialization at the module or component level
- Defining and segregating roles and responsibilities for component delivery, system integration and life cycle support
- Including a "spiral" process to provide feedback from the evaluation of fielded systems to update architecture documentation and module designs

# Systems Engineering Model



# Architect

- What (Technical Architecture – Not Ship Specific)
  - Develop and Maintain standards and specifications such as NVR , MIL-SPECs as well as participation in industry standards bodies such as IEEE.
  - Develop and Maintain interface specifications and validation / testing standards for NGIPS modules.
  - Develop and Maintain standard Performance Specifications for NGIPS modules
  - Develop and Maintain design data sheets and associated design and analysis tools.
  - Develop and Maintain Module Characterization Sheets for capturing data on qualified and developmental modules for use with design and analysis tools.
  - In collaboration with a Peer Review process and ship concept analysis, develop and maintain a technology roadmap / priority list for desired technology improvements.
  - Incorporates lessons learned from fielded systems into the Technical Architecture
- Who
  - Led by a Government Technical Warrant Holder
  - Assisted by a Government / Industry Peer Review

Works Cross-Platform – Not Ship Specific

# Systems Engineer

- What (Systems Architecture – Ship Specific)
  - Works with Ship Design Manager (SDM) and Design Integration Manager (DIM) in early stages of design to conduct trade studies and develop alternative power systems solutions adhering to the NGIPS technical architecture
    - One Line Diagrams
    - Electric Load Analysis
    - Technical Risk Assessments
    - Configuration Details
  - Develops derived requirements for the power and propulsion system during Preliminary Design
  - Manages power and propulsion system risk mitigation activities
  - During Contract Design, transitions knowledge and configuration management of the systems architecture to the Systems Integrator
  - Assists the Program Manager in selecting power systems solutions as well as modules and module vendors
- Who
  - Led by a Government Lead Engineer
  - Assisted by a Government / Government Support / Industry

Ship Specific Application of Technical Architecture before MS B

# Module Development

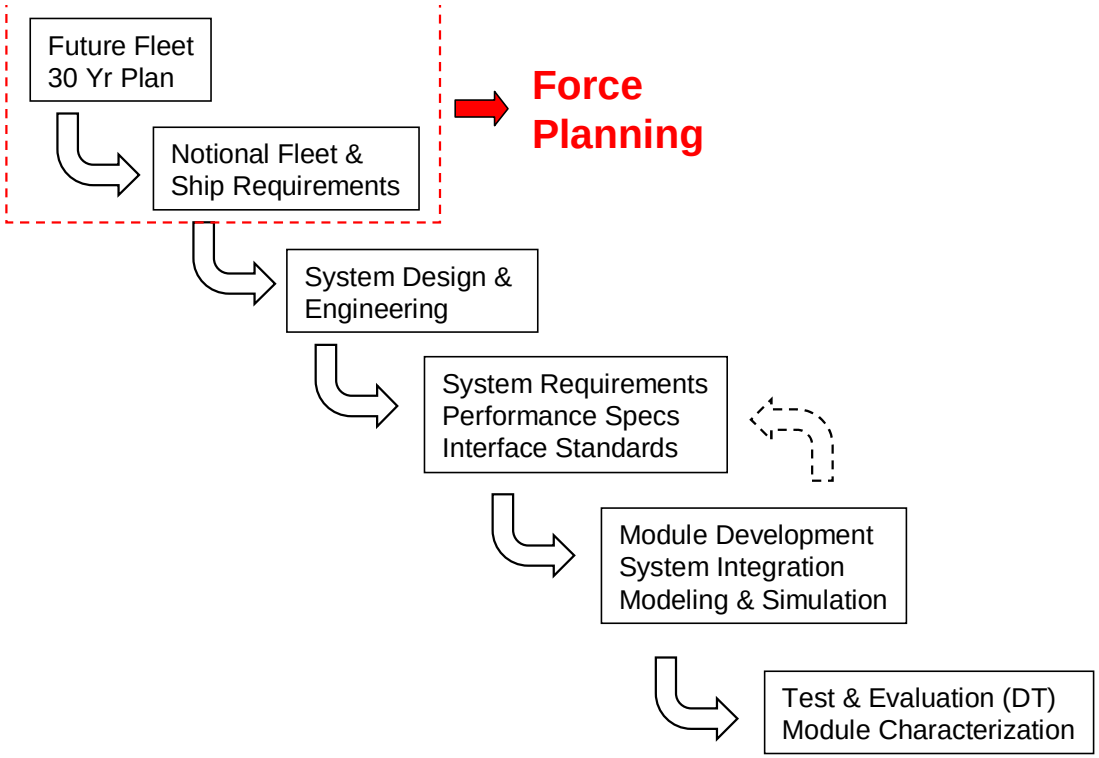
- What
  - Mature technology to produce a “qualified” module ready for integration with other modules and insertion into a ship acquisition program.
- Who
  - ONR and / or Industry matures technology to TRL 5 or 6
  - For Government matured technologies, a Government program office prepares specifications / SOWs for Development contracts in conformance with the NGIPS Technical Architecture to mature technology to TRL 7 or 8
  - Industry, as the module developer, is responsible for maturing the technology and “qualifying” the module through the module validation and testing standards.

# NGIPS Systems Integration

- What
  - Use the derived requirements from the systems engineering process, the technical architecture, and results from analysis, modeling and simulation to produce the ship specific Systems Architecture and associated module procurement specifications.
  - Once the module procurement is made
    - Assist the government / ship integrator in ensuring the vendor is meeting the procurement specifications
    - Continue to validate that the Power and Propulsion system will work (and if not, what ECPs are needed to make it work)
    - Participate in component and system testing.
  - Is not a decision authority for module procurement.
- Who (options)
  - Industry partner chosen by ship integrator for a specific ship acquisition
  - Industry partner chosen by Government for a specific ship acquisition
  - Industry partner(s) chosen by Government for a given period of time to serve multiple ship acquisitions.

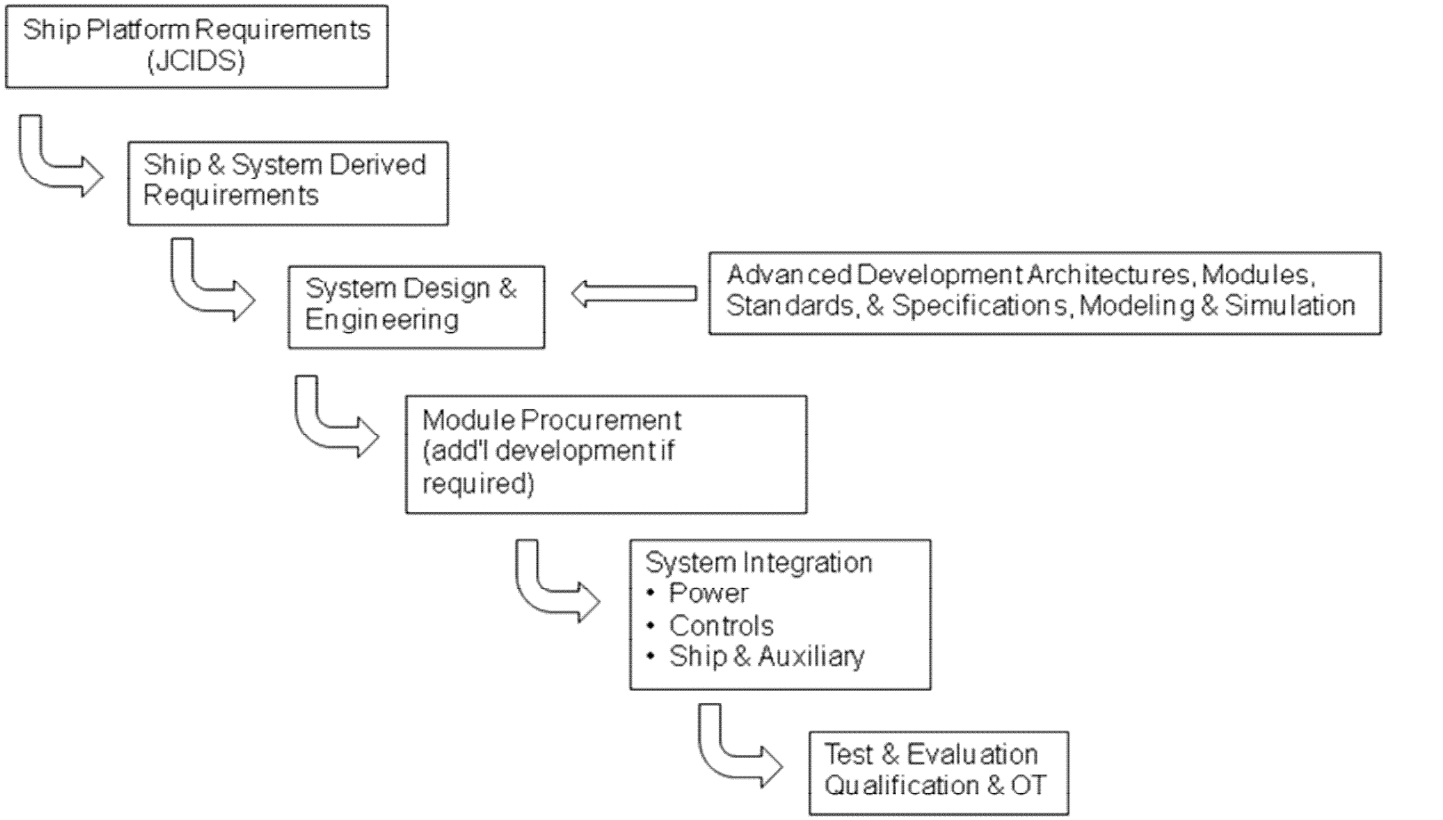
Ship Specific Application of Technical Architecture starting in Contract Design (Prior to MS B)

# Open Architecture Advanced Development



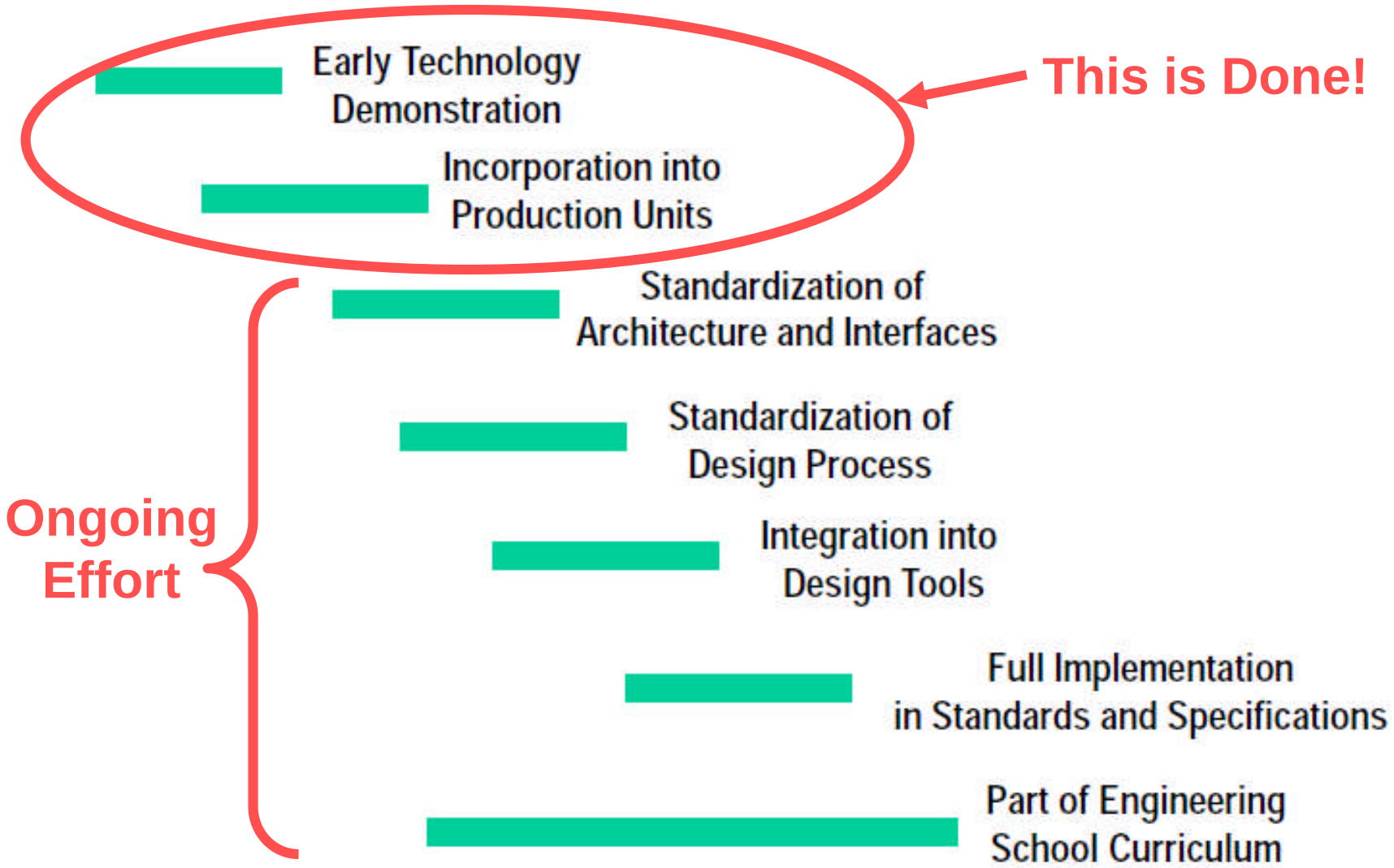

Products: System Architectures
Risk Reduction
Standards & Specifications
Module Characterization

# Open Architecture Engineering Development & Qualification



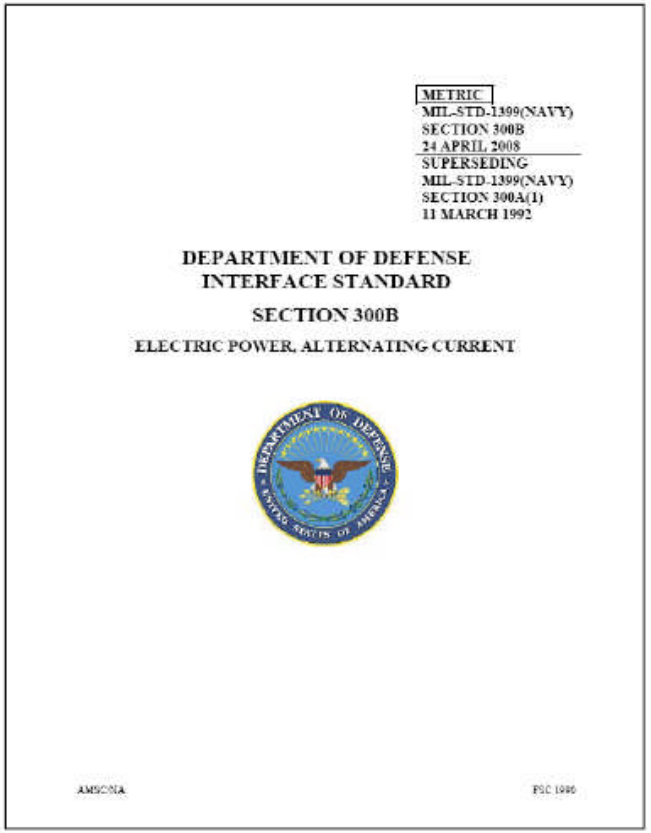

Products: Fleet Introduction of Open Architecture Qualified Modules, Life Cycle Support Data Package and Approach for Tech Refresh

# Institutionalizing Technology



# Technical Architecture Efforts

- Military Standards
  - MIL-STD-1399-300B
  - MIL-PRF-32272
- IEEE Standards
  - Letter of Adoption
    - IEEE 1662-2008
    - IEEE 1709-2010
  - Standards Development
    - P45
    - P1826
- Design Data Sheets
  - DDS 200-1
  - DDS 310-1
- Naval Vessel Rules updates (annual)
- NGIPS Conceptual Design Application Handbook


METRIC
MIL-STD-1399(NAVY)
SECTION 300B
24 APRIL 2008
SUPERSEDING
MIL-STD-1399(NAVY)
SECTION 300A(1)
11 MARCH 1992

DEPARTMENT OF DEFENSE
INTERFACE STANDARD

SECTION 300B

ELECTRIC POWER, ALTERNATING CURRENT

AMSC/NA

FSC 1990

# NGIPS Take - Aways

- Affordability
  - Commonality where it makes sense
  - Each ship must affordably satisfy its requirements
  - NGIPS Open Architecture Business Model
- Technical Architectures
  - 4 Power Generation Architectures
    - LVAC – today
    - MVAC – today and for ships without power density requirements
    - HFAC – Interim Step to MVDC for ships with power density requirements
    - MVDC – Goal for ships with power density requirements
  - Zonal Ship Service Distribution Architecture