Institutionalizing the Electric Warship

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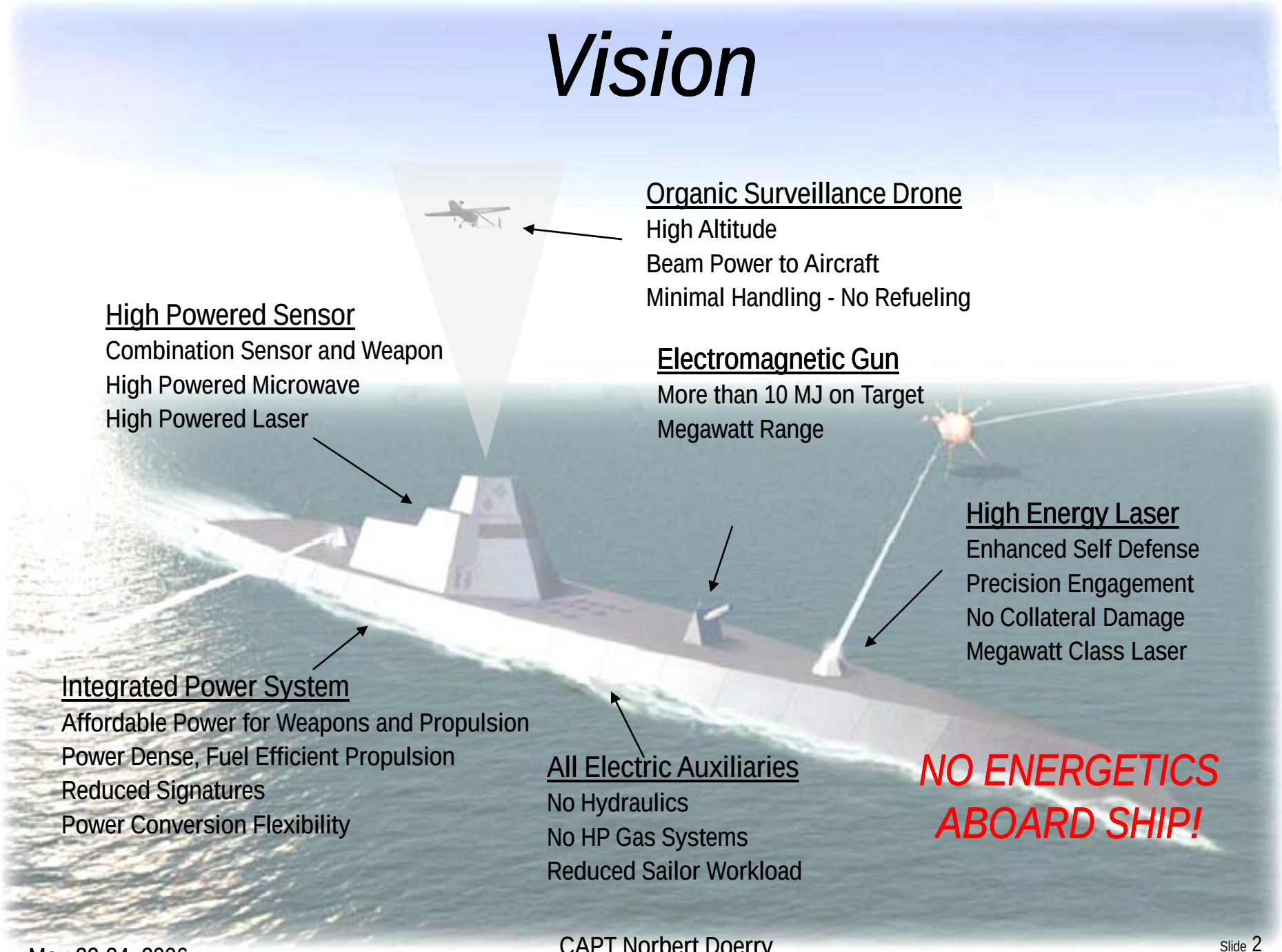
Vision



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!

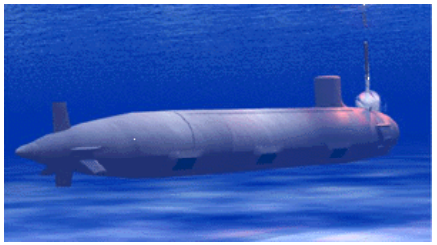
Baseline - Programmed Today

LHD 8
Hybrid Electric Drive

T-AKE
Commercial Integrated
Power System

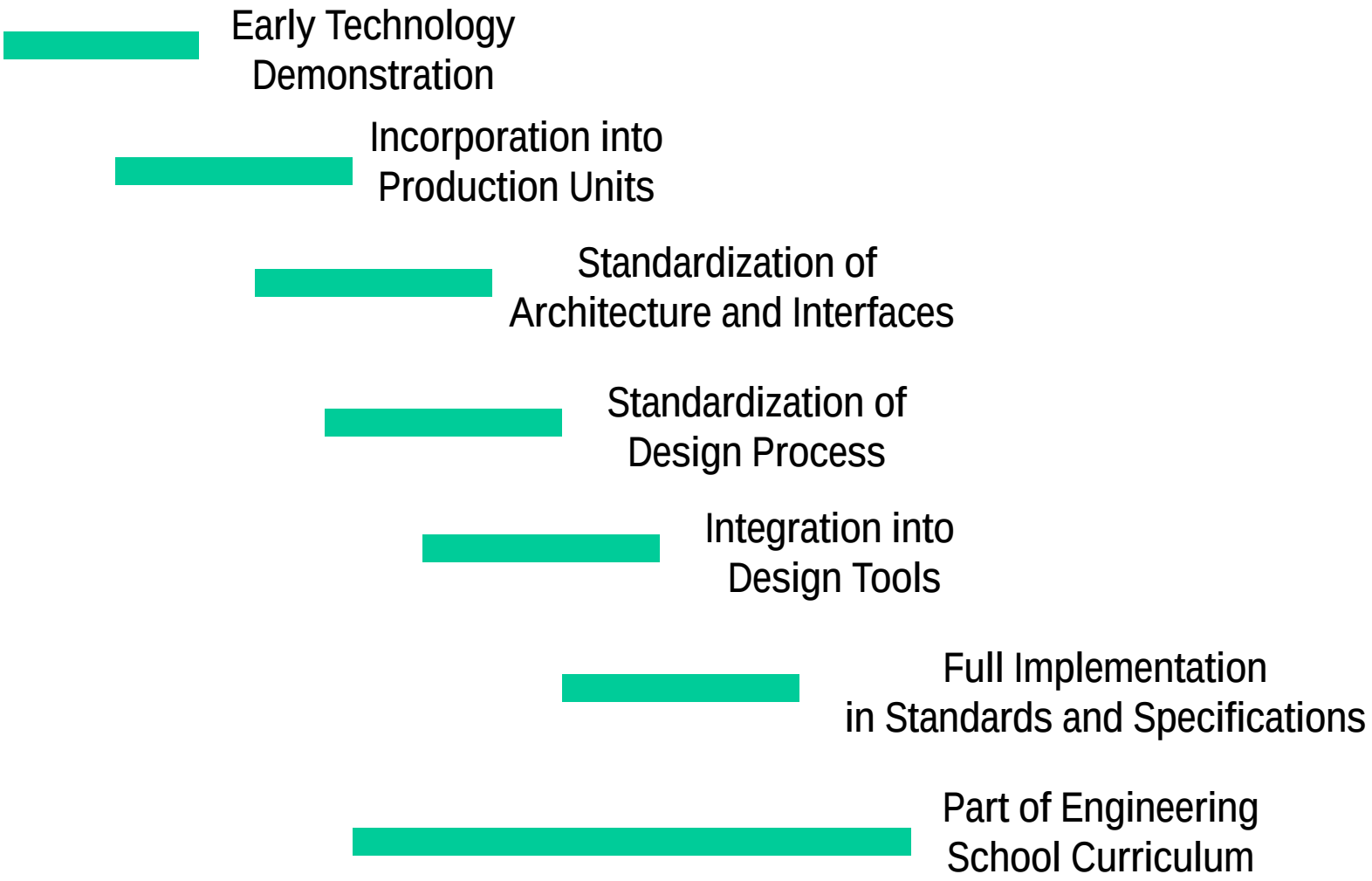
DD(X)
Military Integrated Power System

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

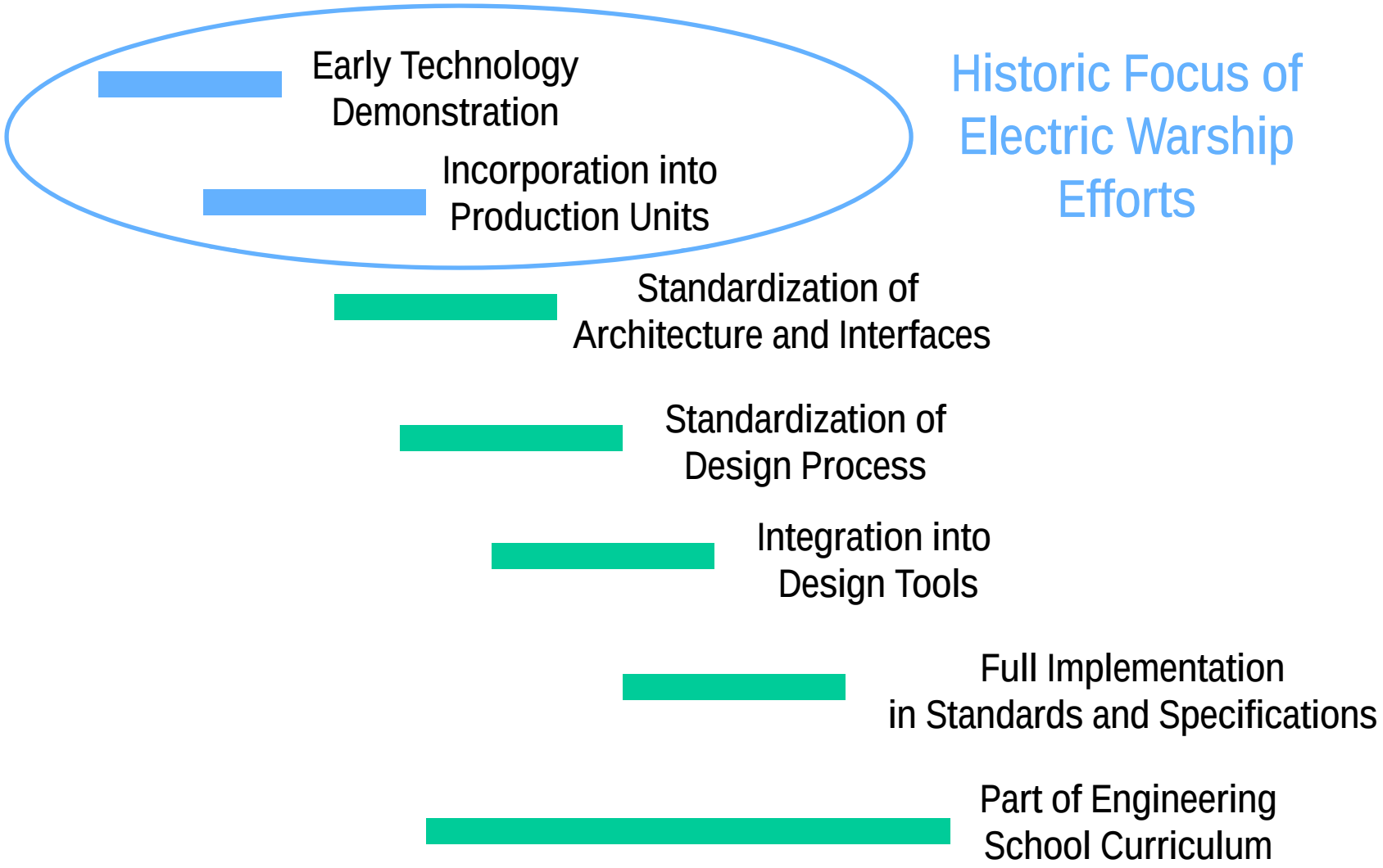


VIRGINIA
Power Electronics

Institutionalizing Technology



Institutionalizing The Electric Warship



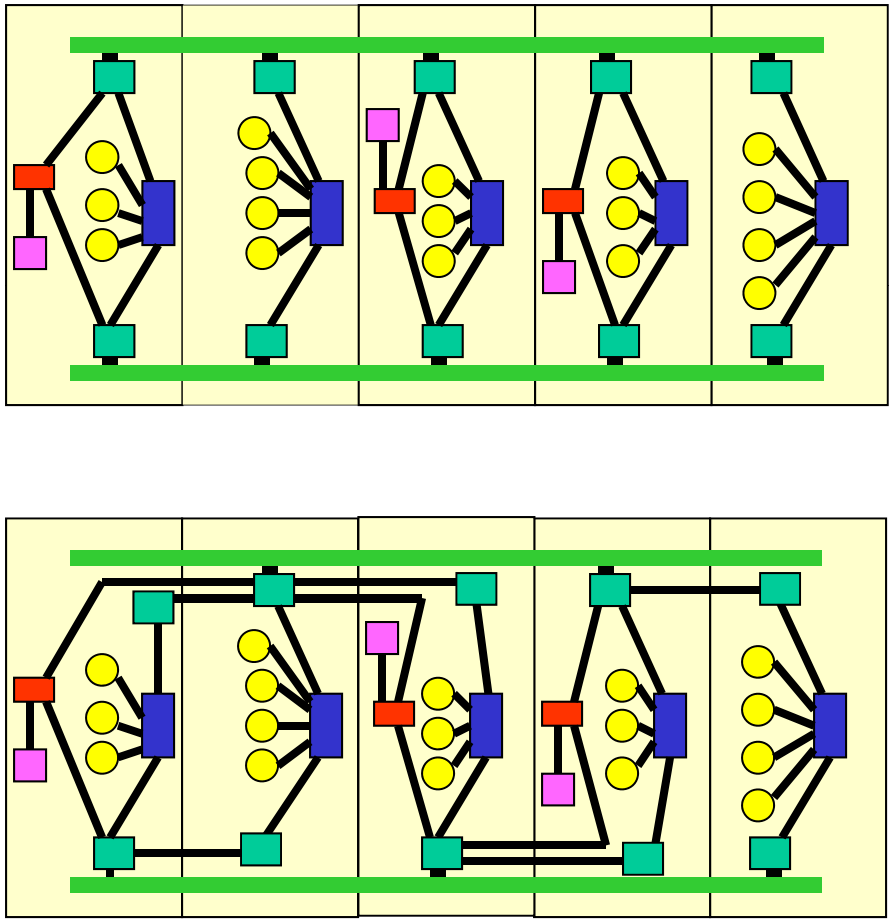
IPS Architectural Components

- Power Generation Module (PGM)
- Power Conversion Module (PCM)
- Power Distribution Module (PDM)
- Propulsion Motor Module (PMM)
- Power Load Module (PLM)
- Energy Storage Module (ESM)
- Power Control Module (PCM)

Zonal Distribution

Based on Zonal Survivability

- Zonal Survivability assumes:
  - Damage will impact only one or possibly two adjacent zones
    - ★ Zones must be large enough to preclude damaging more zones
  - For systems with unsegmented “mains”, damage will not impact at least one longitudinal “main”
    - ★ Requires separation and possibly protection of “mains”
- Zonal Survivability requires:
  - All loads (or Vital loads) in undamaged zones do not experience a “service interruption”
- Additional Design Goals include
  - Minimize “service interruption” to non-vital loads in undamaged zones
  - Minimize “service interruption” to vital loads in damaged zones



So What's the Problem?

- Zonal Survivability isn't defined in any authoritative document
- A "service interruption" isn't defined anywhere either
  - Is it 30 minutes? (Local Control response)
  - Is it 2 minutes? (MIL-STD-1399 hints at this)
  - Is it 2 seconds? (switchgear clearing time)
  - Is it 100 milliseconds? (studies on hold up time)
  - Is it anything greater than 0?
- Don't have a good way of verifying that the detail design of Cable Routing results in a survivable design.

Other Electric Warship Architectural Issues

- Machinery Control System Standards
  - An open software architecture does not exist
- Power Quality Standards Incomplete
  - DC standards aren't codified
  - "Dirty" bus
- Quality of Service
  - Is the Electric Plant reliable as seen from the loads?
- System Stability
  - Issue largely due to constant power loads
  - No codified system for allocating "stability" for power system elements
- Grounding
  - Historic ungrounded systems on naval ships not aligned with industry practice and less appropriate for growing power systems.

Design Process Issues

- Definition of “Requirements” Terms outdated
  - Sustained Speed
  - Endurance Speed
- Load analysis more critical, but not standardized
  - Power quality (dirty / clean bus)
  - Zonal balancing of loads
  - Margin policy
- Power Distribution Equipment Sizing
  - Load Factors vs Zonal Load Factors vs Demand Factors
  - Inrush currents
- Power Generation Planning
  - Dark Ship Start
  - Preventing cascading failures
  - Transient stability of paralleled large and small PGMs
  - Margin policy
  - Impact of harmonic currents
- System Protection
  - Coordination of breakers
  - Allocation of system protection functions to PGM, PCON, PDM, PMM, PLM, etc.
  - Energy Storage Module requirements derivation

Design Process and associated Design Certification Process not Institutionalized

Design Tools

- Total Ship Integration (Concepts)
  - ASSET
  - LEAPS
- Power System Simulations
  - Currently every program does their own thing
  - Navy (including ONR) has invested in basic technology
    - ★ Virtual Testbed
    - ★ Stability Toolbox
    - ★ Distributed Heterogeneous Simulation
    - ★ Commercial Packages: Saber, ACSL, ...
  - Analytical requirements not established

Electric Warship Design Tools are not Institutionalized

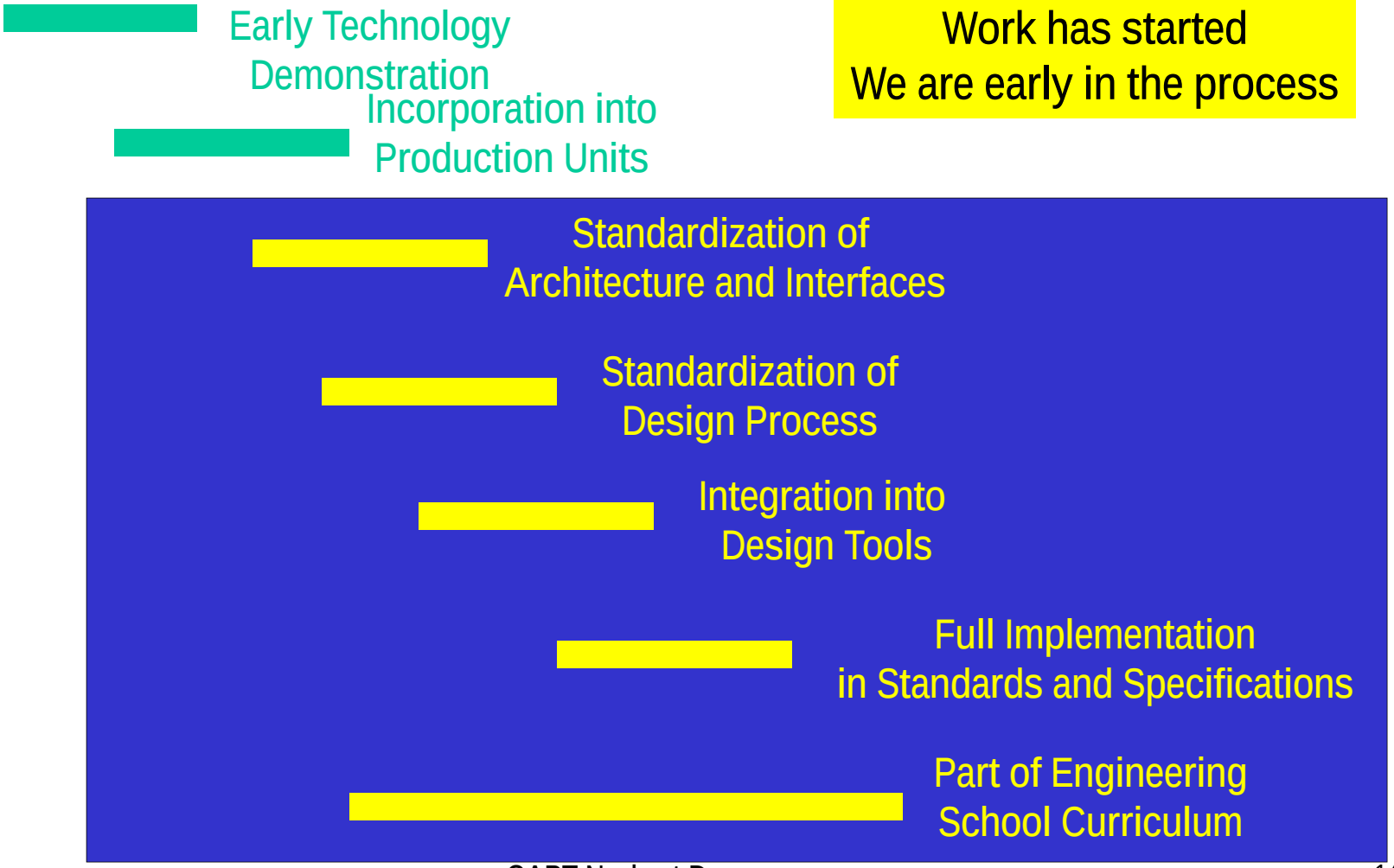
Standards & Specifications

- Naval Vessel Rules
  - Includes provisions for IPS
    - ★ Part 3 Chapter 5 Section 4
  - Doesn't currently address all issues
- DOD-STD-1399
  - Being updated to address interface issues
  - Update is in progress
- NAVSEA Design Practices and Criteria Manual for Ship Service Electrical Systems
  - Under development to be consistent with NVR
  - Update is in progress

Engineering School Curriculum

- Designing IPS ships is part of the concept level design of several Post Graduate programs
  - Treats IPS components at the module level
  - Does not address all aspects of IPS integration
- The development of IPS component technology is an integral part of University research programs
- The design of IPS systems is not addressed in depth.
  - Reflects lack of maturity of IPS design processes
  - Systems Engineering typically taught at a higher conceptual level
- Basics of IPS system design taught as part of the Summer Naval Surface Ship Design Program
  - Summer Professional Development Program taught at the University of Michigan
  - Partnership of University of Michigan, NAVSEA, Virginia Tech, and Naval Postgraduate School
  - Ship Mobility and Support Systems (May 30 – June 2, 2006)

Summary


Early Technology Demonstration
Incorporation into Production Units
Work has started
We are early in the process
Standardization of Architecture and Interfaces
Standardization of Design Process
Integration into Design Tools
Full Implementation in Standards and Specifications
Part of Engineering School Curriculum

Conclusions

- Electric Warship is here
  - Technology Demonstrations complete or underway
  - “Early Adopter” ships complete or in design
- Institutionalizing the Electric Warship has just begun
  - Many issues require resolution
  - NVR and other documents under development should help resolve the issues
  - Need investment in tools and education
- Stay Tuned
  - A lot is happening