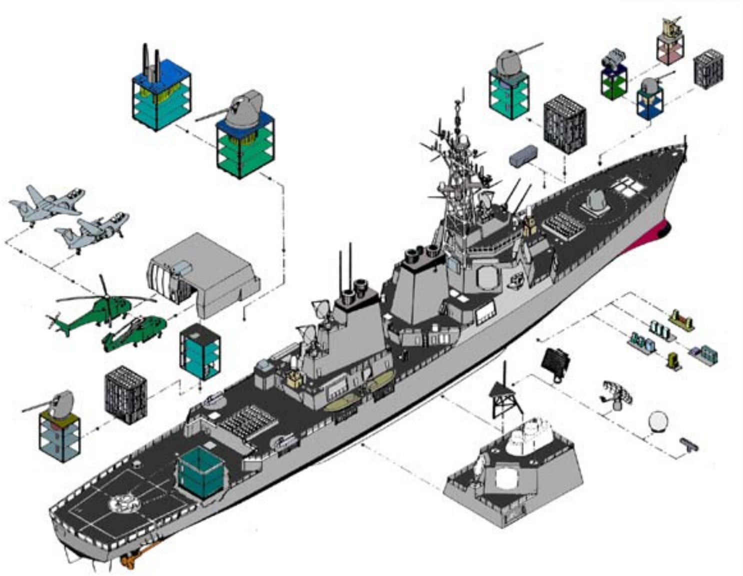


The History of Modular Payload Ships: 1975 - 2005

Jack W. Abbott

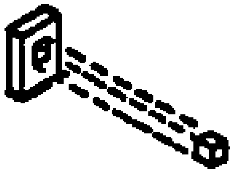
AOC Incorporated

Naval Postgraduate School, April 27, 2006

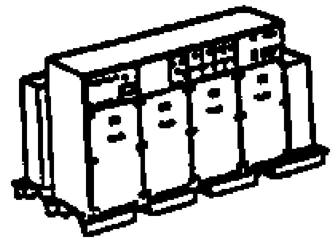
Ship Design Myths of the 1980's

- Computer architecture will never be distributed
- Combat Systems will not need modernization in less than 7 years
- Increase in space and weight will always cause increase in construction costs (a compact ship is cheapest)
- Development of open interface standards are impossible because you cannot predict the future
- The DDG 51 will never need a hanger
- Modular Payload Ships do not require good Systems Engineering
- The enemy will always be the USSR

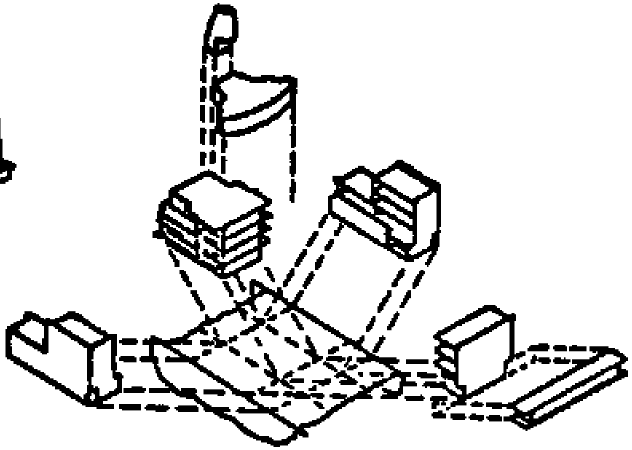
Types of Modularity



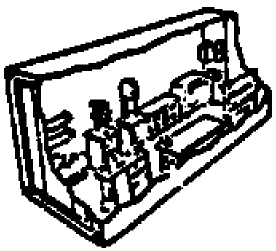
Building Block Modularity



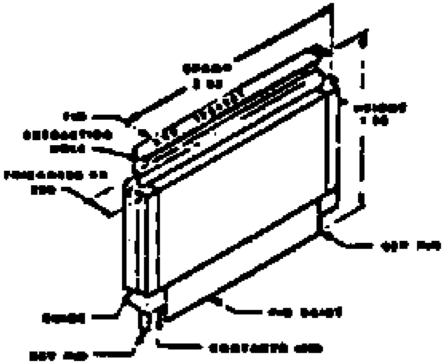
Palletization



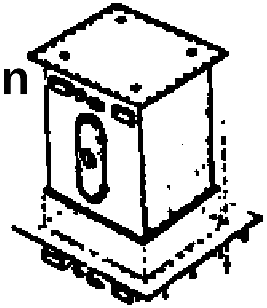
Construction Modularity (Major Subassemblies)



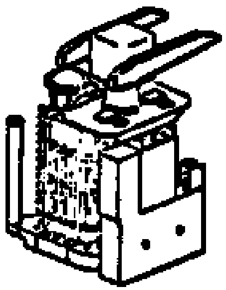
Containerization (Detached)



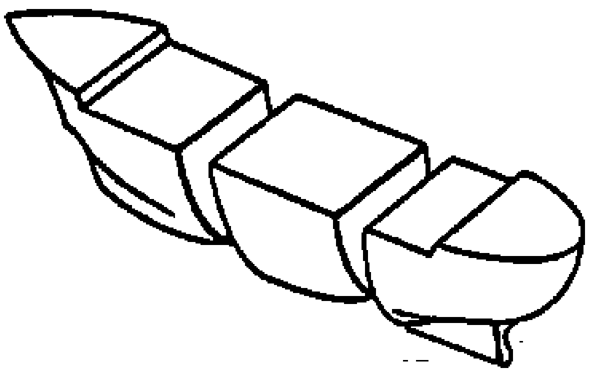
Standard Hardware Circuitboard



Containerization (Integrated)



Weapon Prepackaging



Construction Modularity (Hull Segments)

Modularity Applied to Modular Payload Ships

- Modularity is used for "Capability Swapping"and does not address construction modularity
- Goal is to achieve software/hardware replacement by different/new products/technologies of "like function and capacity" without requiring changes to the overall system
- Equipment modules are built to **standard** interfaces (Open Systems) – not just pre-packaging of components
- Standardization takes place at the interface – NOT INSIDE THE MODULE GUTS – this allows technology insertion and mission reconfiguration
- Ship/equipment interfaces include: physical and functional interfaces (HW), software interfaces (SW) and RF interfaces (links)

Key MPS Programs and Their Characteristics; 1975-1990

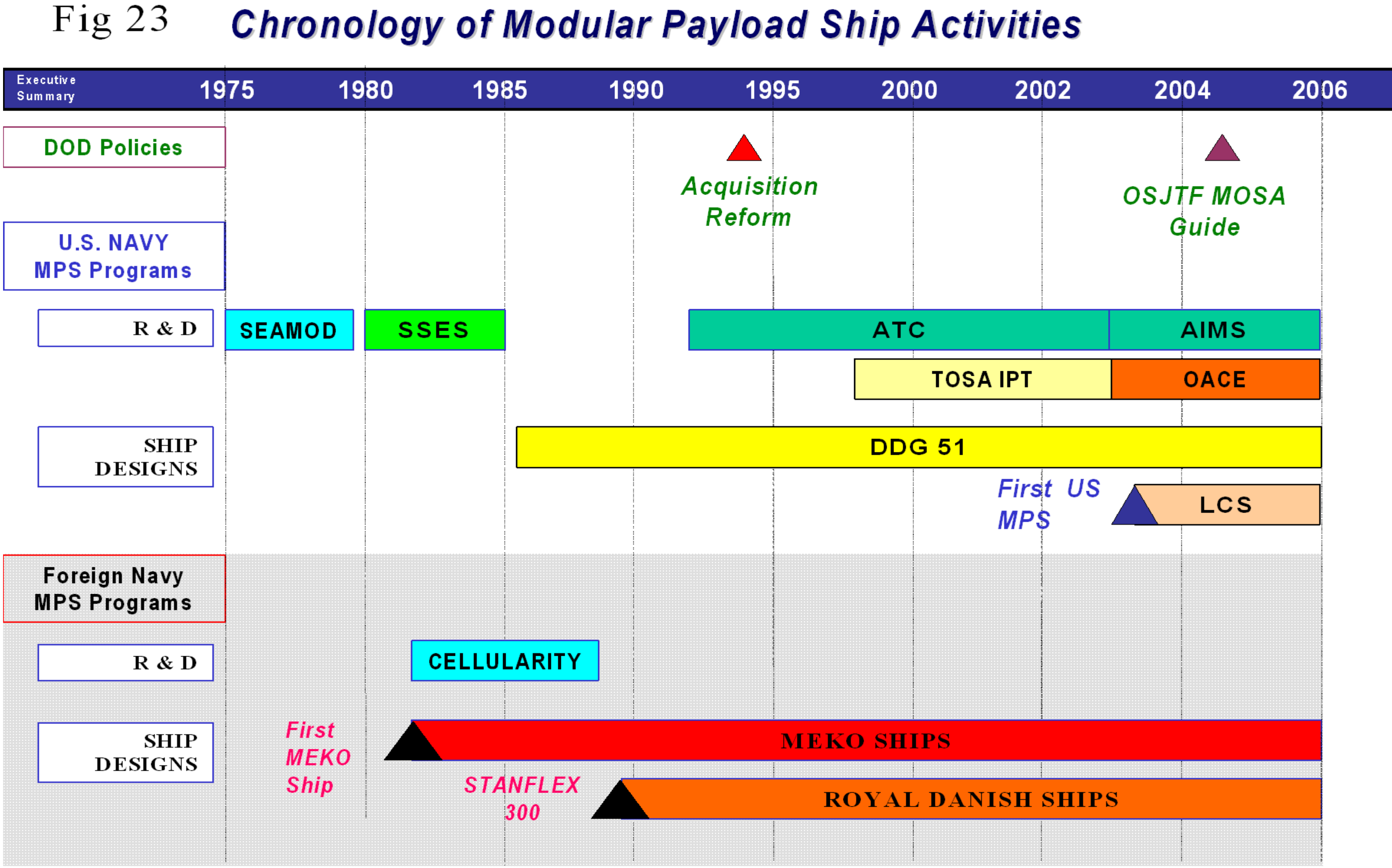
Progam	Scope	Motives	Results
NAVSEA - SEAMOD	HW/SW modularity for ship's Combat System	Reduce Life Cycle Costs (Acq/Modern/Conversion)	Showed cost reductions in modernization/conversion
NAVSEA - SSES /DDG 51	HW modularity for the ship's Combat System	Reduce Life Cycle Costs (Acq/Modern/Conversion)	Developed the VPS concept - Installed A/B modules on DDG 51
Blohm&Voss - MEKO	HW/SW modularity for the entire ship	Reduce Construction Costs (7-15%)	Achieved cost reductions - built over 60 ships
RN - Cellularity	HW modularity for the electonic systems	Reduce electronic change out costs	Part of the RN ship design specifications
RDN - STANFLEX	HW/SW modularity for ship's Combat System	Reduce fleet costs through mission flexibility	New RDN fleet is more flexible to mission change

Key MPS Programs and Their Characteristics; 1990-2005

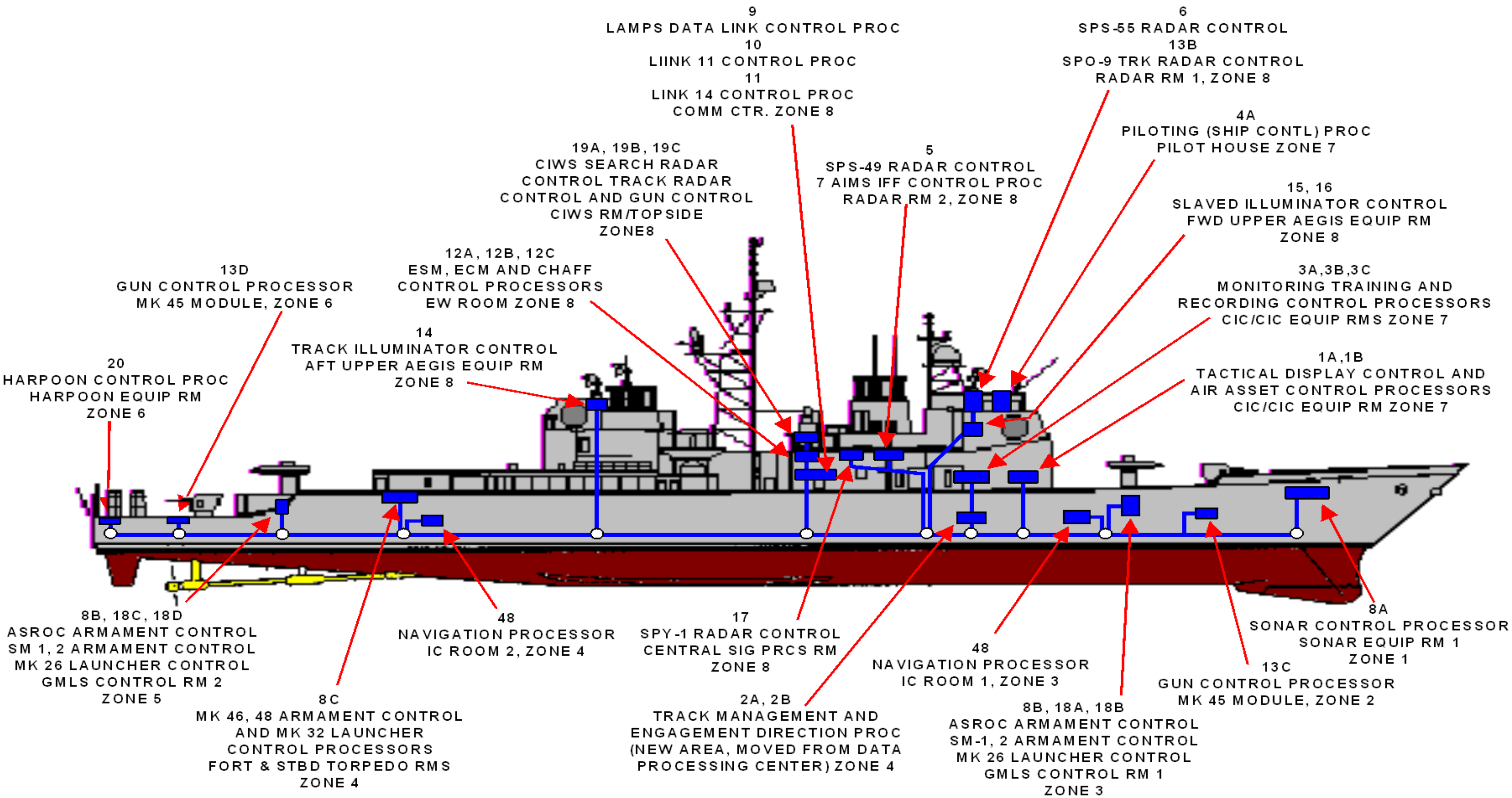
Progam	Scope	Motives	Results
NAVSEA - ATC	HW modularity for the entire ship	Reduce TOC through modularity & standardization	Transitioned Acquisition Reform - Formed the TOSA
DOD - OSJTF	Open Systems Architecture (OSA) for DOD	Develop policy for OSA including the Modular Open Systems Approach (MOSA)	Implemented the MOSA guide for CAT A Program Managers
NAVSEA - TOSA	HW modularity for the entire ship	Apply OSA on Navy ships to reduce TOC	Developed Total Ship Open Systems Architecture concepts
NAVSEA - OACE	SW modularity for the ship's Combat System	Establish OA standards for combat system software	Developing computer OA concepts and categories for implementation
NAVSEA - LCS	HW/SW modularity for the Mission Modules	Mission Reconfigurability - MIW, ASW, SUW Mission Packages	Applying MOSA concepts to the Seaframe and Mission Modules

Chronology Of MPS Activities

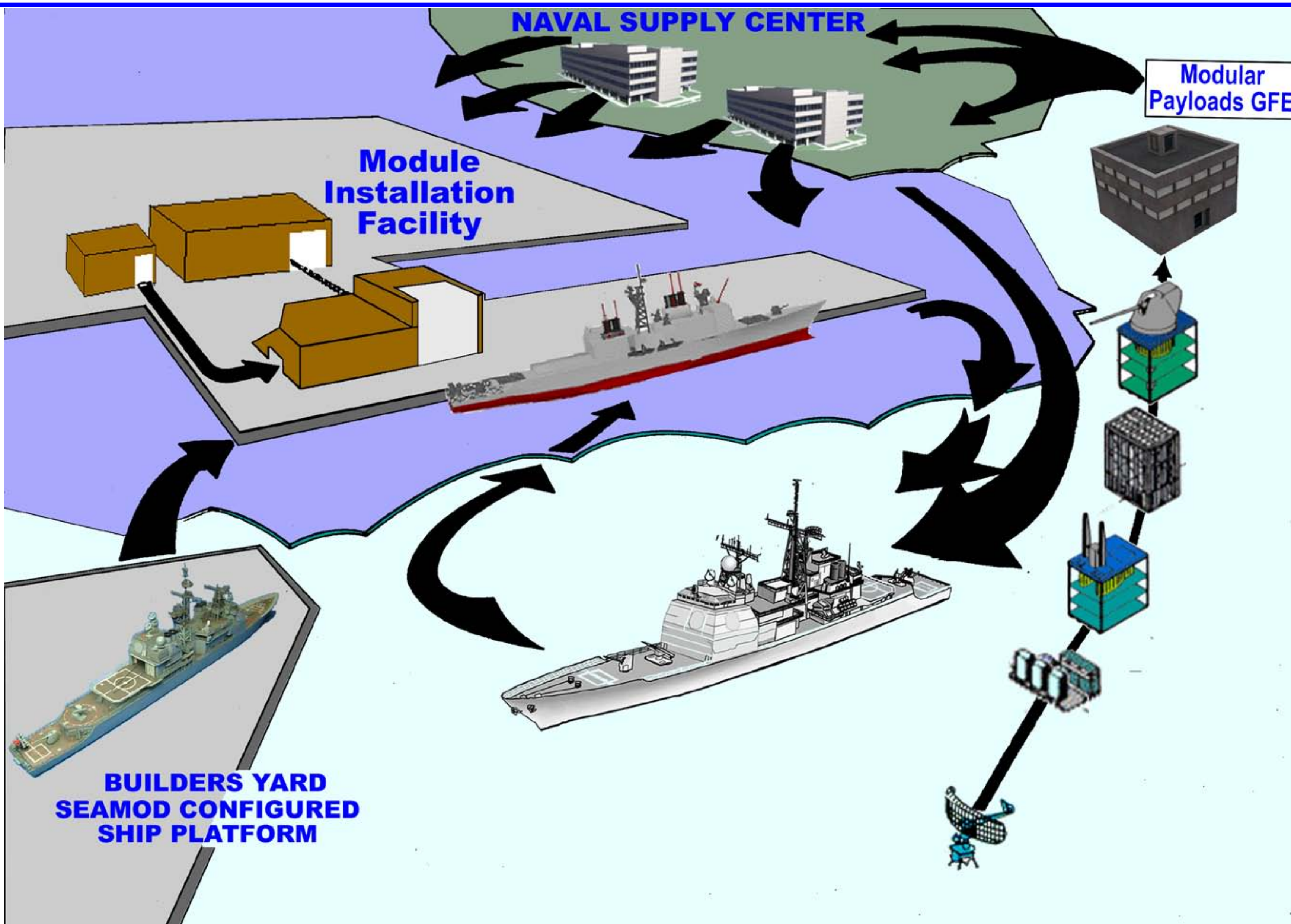
Fig 23



SEAMOD Distributed Combat System



SEAMOD Operational and Support Concept



SSES Program Participants

Shipyards

(AVONDALE)	Avondale Shipyards, Inc.
(BATH)	Bath Iron Works Corporation
(INGALLS)	Ingalls Shipbuilding
(NNSBDD)	Newport News Shipbuilding & Drydock Company
(NNSY)	Norfolk Naval Shipyard
(PNSY)	Philadelphia Naval Shipyard
(TODD)	Todd Pacific Shipyard Corporation

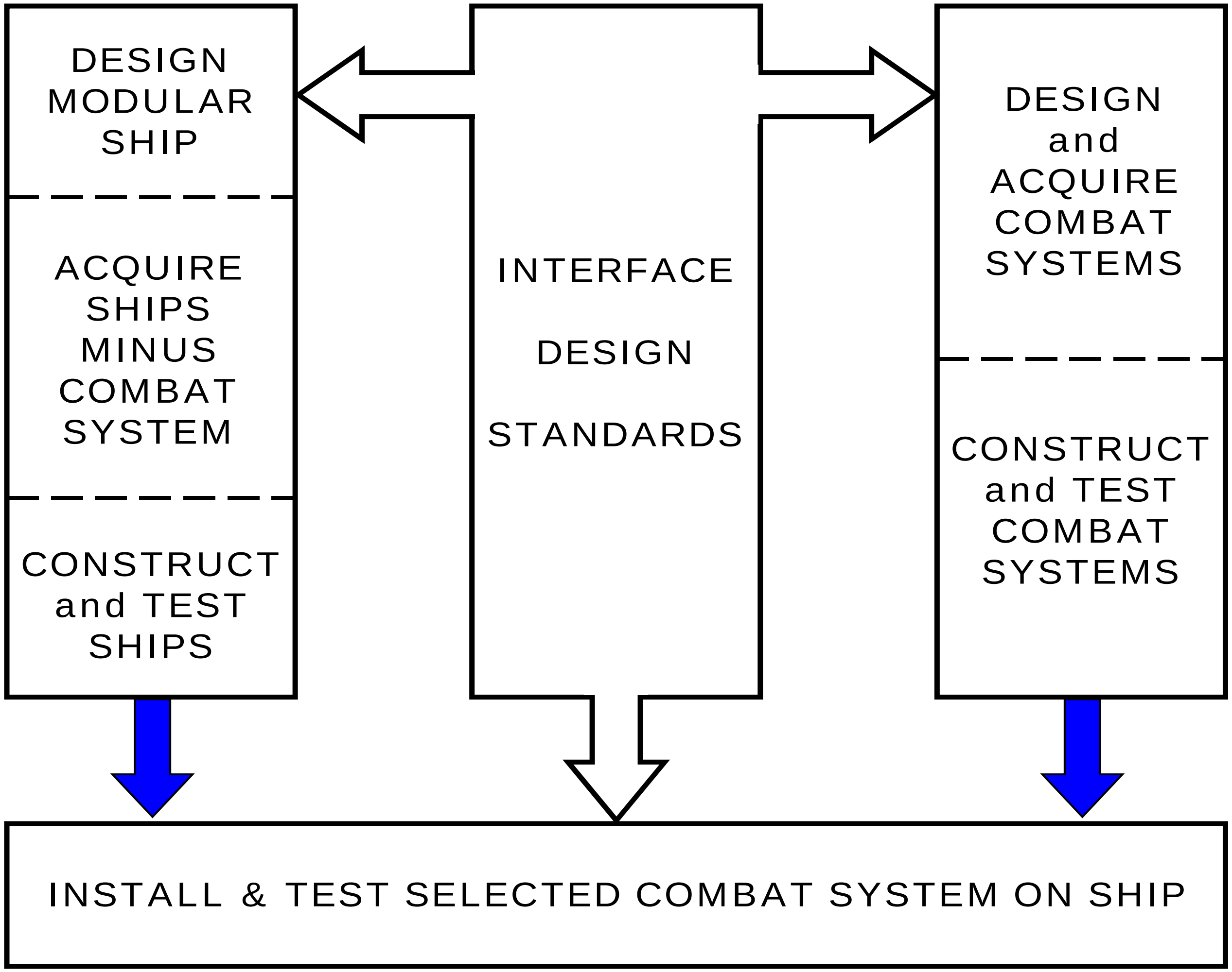
Navy Labs, etc.

(JCMP)	Joint Cruise Missile Program
(NAEC)	Naval Air Engineering Center
(NESEA)	Naval Electronic Systems Engineering Activity
(NMMAC)	Naval Manpower & Material Analysis Center
(NOSC)	Naval Ocean Systems Center
(NRL)	Naval Research Lab
(NSMSES)	Naval Ship Missile Systems Engineering Station
(NSRDC)	Naval Ship Research & Development Center
(NSWC)	Naval Surface Weapons Center
(NSWSES)	Naval Ship Weapons Systems Engineering Station
(NTEC)	Naval Training Engineering Center
(NUSC)	Naval Undersea Systems Center
(ONR)	Office of Naval Research

Contractors

(APL/JHU)	Applied Physics Laboratory/John Hopkins University
(ARC)	Atlantic Research Corporation
(BOGGS)	G. E. Boggs, Inc.
(CER)	Cost Engineering Research, Inc.
(CHU)	CHU Associates, Inc.
(CRC)	Columbia Research Corporation
(D&P)	Designers & Planners, Inc.
(EPOCH)	Epoch Engineering
(ERC)	Evaluation Research Corporation
(FMC)	FMC Corporation, Northern Ordnance Division
(FI)	Forecasting International, Ltd.
(GD)	General Dynamics
(HNYWL)	Honeywell
(HUGHES)	Hughes Aircraft Company
(IBM)	International Business Machines
(LOCKHEED)	Lockheed Shipbuilding & Construction Company
(MCMULLEN)	J. J. McMullen Associates, Inc.
(MMC)	Martin Marietta Corporation
(MRC)	Meta Research Corporation

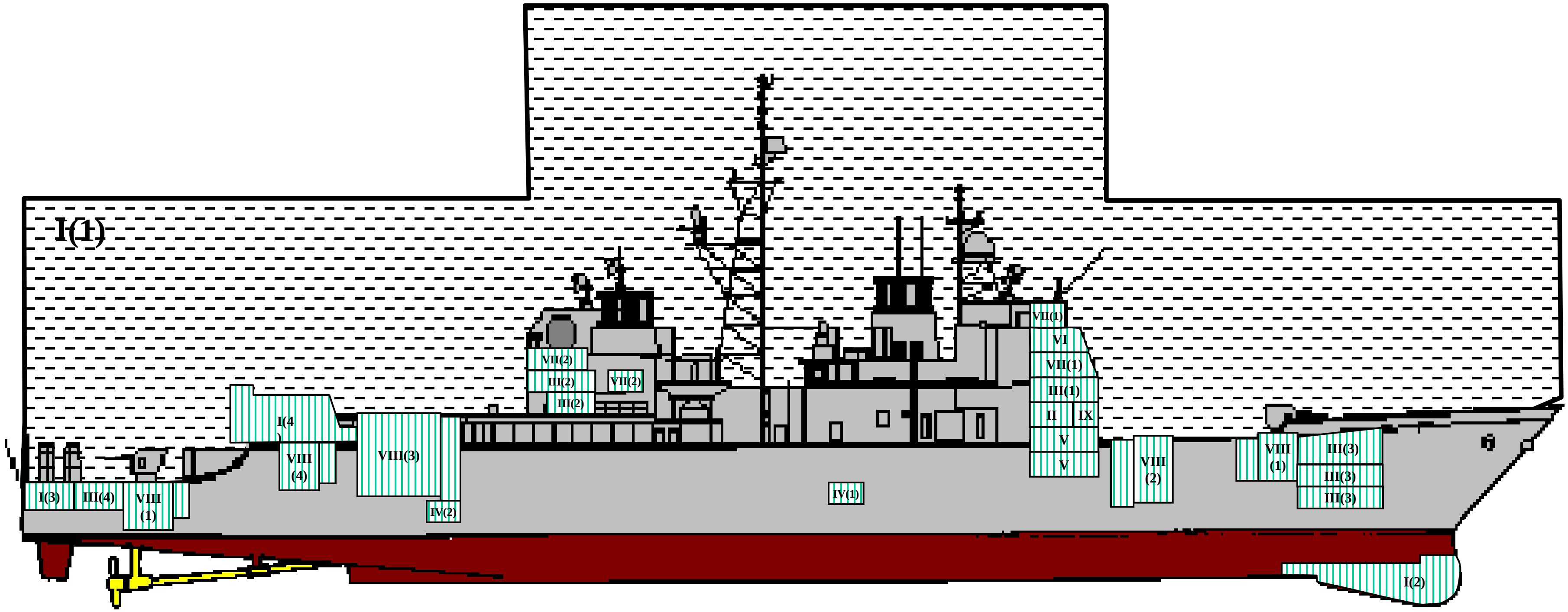
Payload and Platform Decoupling



Combat System Functional Elements

• **RADAR SYSTEMS** – Navigation – Surface Search Radar – 2-D Air Search Radar – 3-D Air Search Radar	• **COMMAND SYSTEMS** – TFCC – HF/DF – Outboard – Combat DF • **IFF SYSTEMS**
• **ELECTRO-OPTICAL SYSTEMS**	• **ACOUSTIC COUNTERMEASURES SYSTEMS**
• **SONAR SYSTEMS** – Bow Mounted – Towed Array	• **ELECTRONIC WARFARE SYSTEMS**
• **NAVIGATION SYSTEMS**	• **FIRE CONTROL SYSTEMS** – Gun Fire Control – Missile Fire Control – ASW Fire Control – Weapon Direction
• **EXTERIOR COMMUNICATIONS** • **UNDERWATER COMMUNICATIONS** • **INTERIOR COMMUNICATIONS**	• **GUN SYSTEMS**
• **DATA TRANSFER**	• **LAUNCHER SYSEMS** – Missiles – Torpedo Tubes – Point Defense – Chaff, Decoy
• **INFORMATION PROCESSING** – Data Processing – Signal Processing • **INFORMATION DISPLAY** – Command Display	• **AVIATION SYSTEMS** – Shipboard Electronics – Facilities – Aircraft • **TEST AND MAINTENANCE SYSTEMS**

SSES Zone Designations and Names



Zone I(1) – RF Sensing
Zone I(2) – Forward Acoustic Sensing
Zone I(3) – After Acoustic Sensing
Zone I(4) – Aviation Support

Zone II – Exterior Communications

Zone III(1) – Forward RF Processing
Zone III(2) – After RF Processing
Zone III(3) – Forward Acoustic Processing
Zone III(4) – After Acoustic Processing

Zone IV(1) – Forward IC and Gyro
Zone IV(2) – After IC And Gyro

Zone V – Command and Control

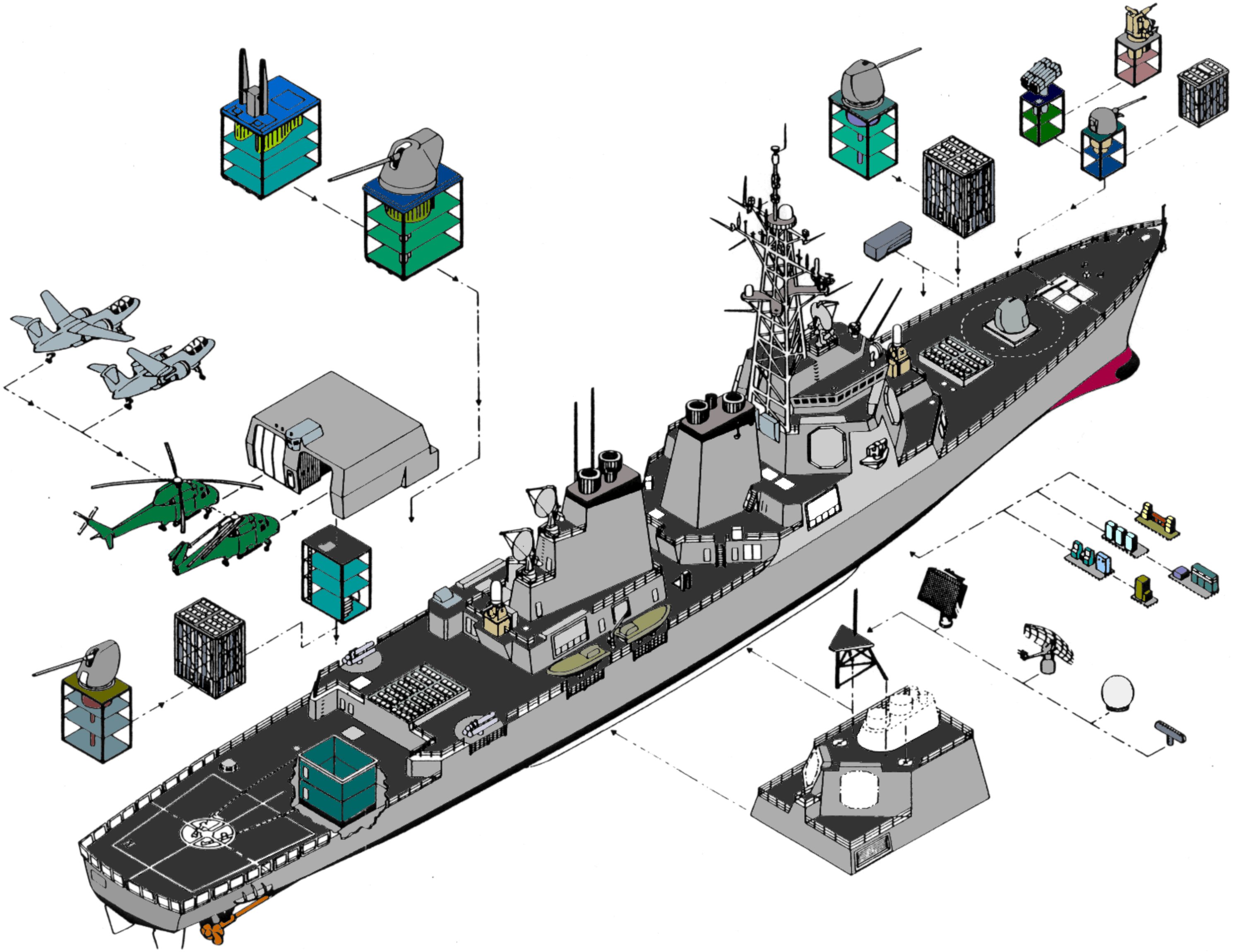
Zone VI – Ship Control

Zone VII(1) – Forward Weapons Control
Zone VII(2) – After Weapons Control

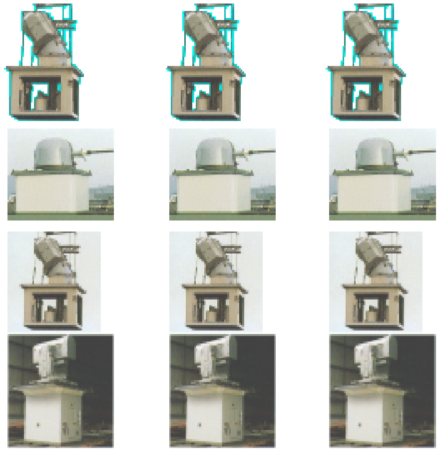
Zone VIII(1) – AA-size Weapons
Zone VIII(2) – A-size Weapons
Zone VIII(3) – B-size Weapons
Zone VIII(4) – A(2)-size Weapons

Zone IX – Special Purpose Electronics

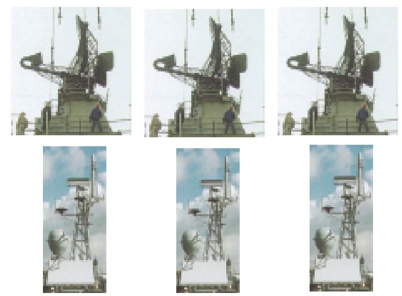
Modular Payload DDG 51



The MEKO Concept



SET OF WEAPONS FUNCTIONAL UNITS

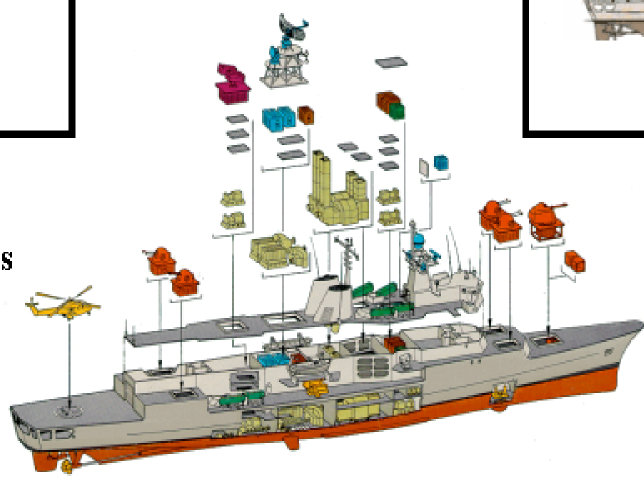


SET OF ELECTRONIC FUNCTONAL UNITS

SET OF STANDARD SHIP PLATFORMS

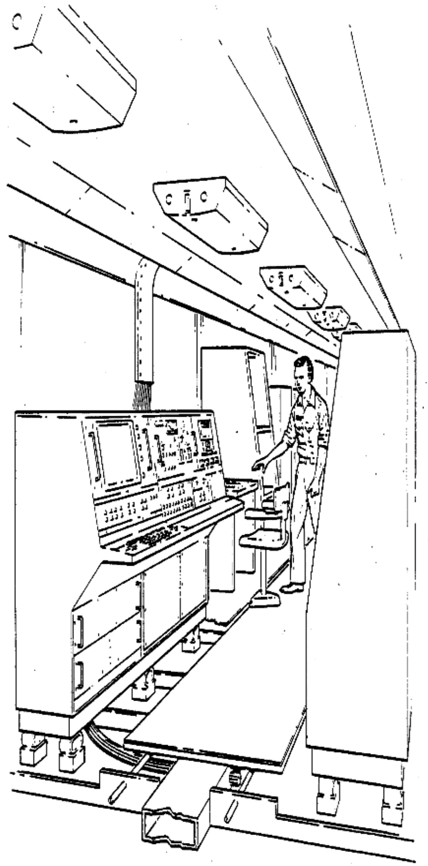
Determine Mission requirements

- SELECT STANDARD PLATFORM
- SELECT WEAPONS
- SELECT ELECTRONICS



The Cellularity Concept

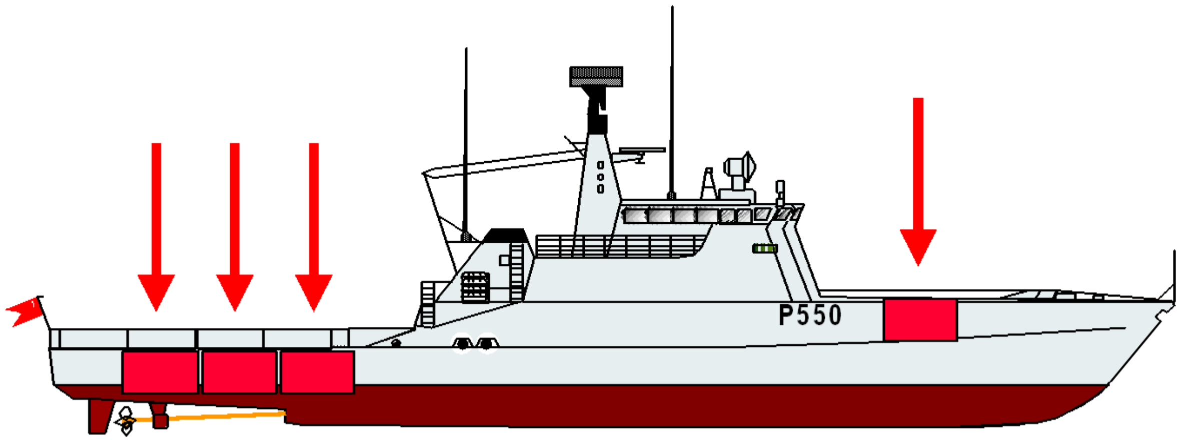
Fig 8



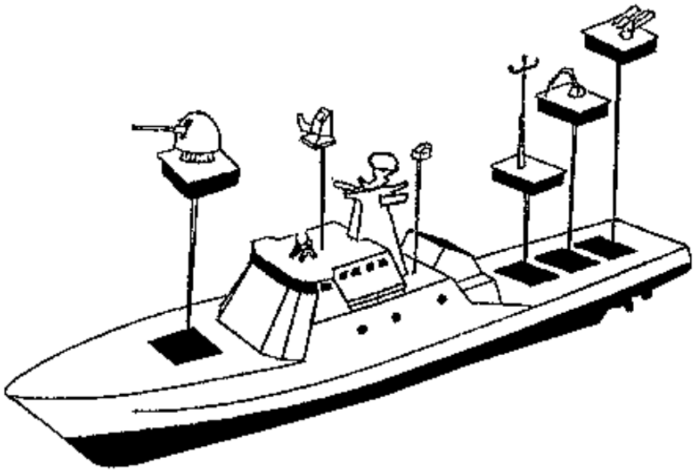
StanFlex 300

Fig 9

Standard Flex 300



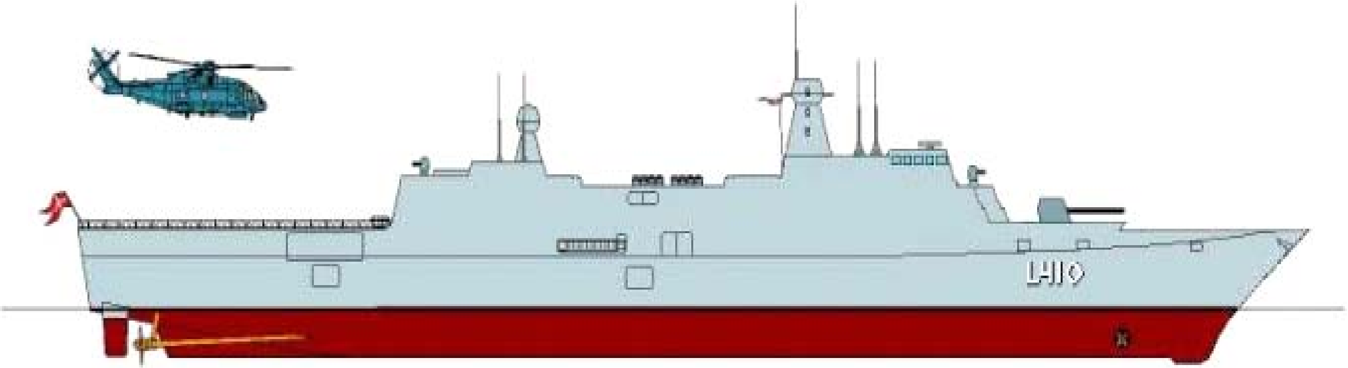
Standard displacement	=	320 tonnes
Length	=	54 m
Beam	=	9 m
Container positions	=	4
Hull material	=	GRP



RDN Fleet

STANFLEX 300

STANFLEX 3000



Larger STANFLEX – Flexible Support Ship

STANFLEX 100

info sources: Naval Team Denmark web site / briefings from RDN – Sept. 2002

Benefits of ATC

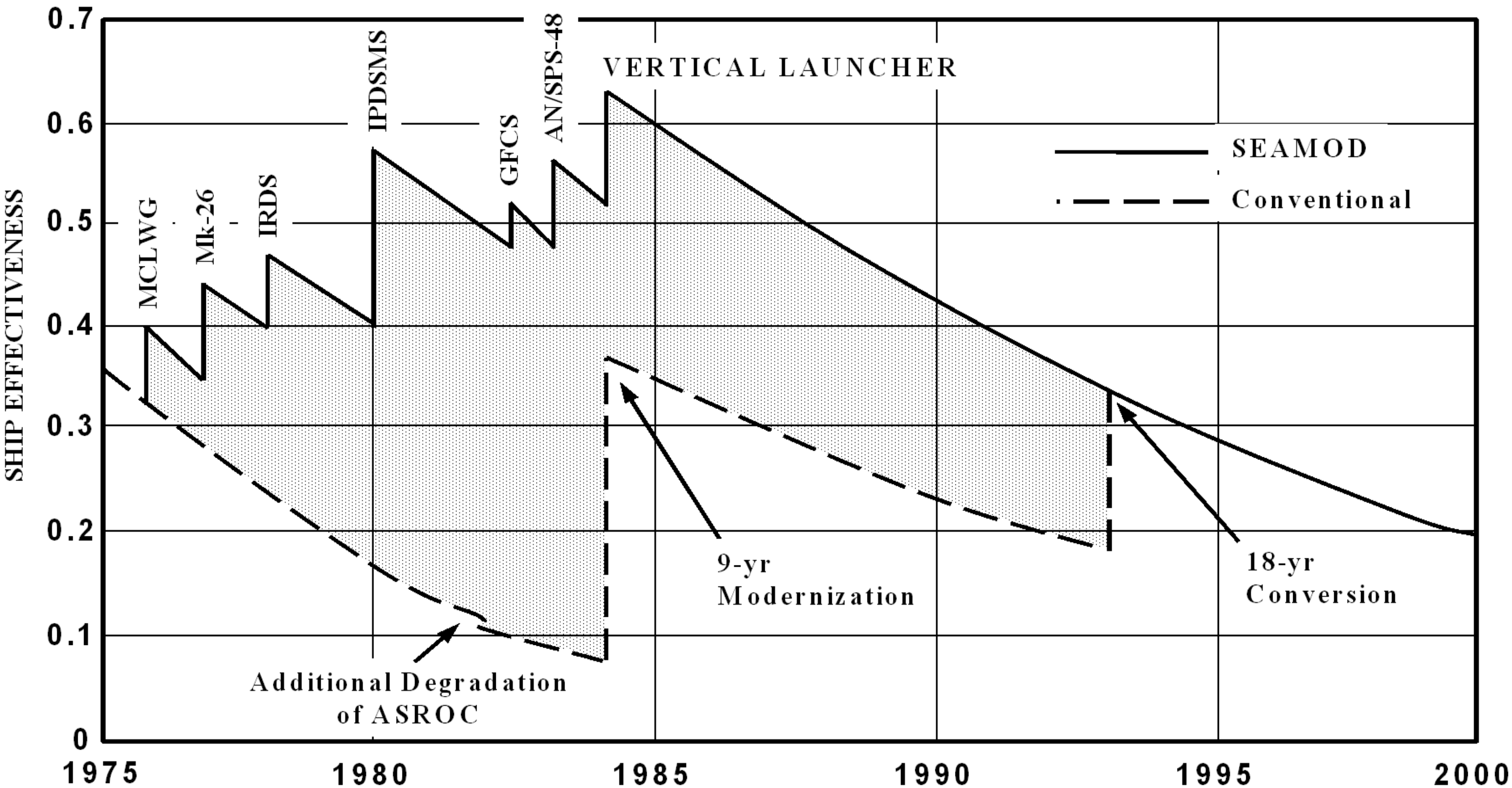
ACQUISITION	MODULARITY	EQUIPMENT STANDARDIZATION	PROCESS SIMPLIFICATION
Design	1. Flexibility in using basic design building blocks 2. Ease of design integration 3. Ease of upgrade	1. Wide application of fewer standard designs 2. Accurate performance prediction 3. Known physical characteristics	1. Fleet-oriented architecture 2. Standard equipment modules 3. Standard components
Procurement	1. Better contractual control 2. Broadens competition	1. Fleetwide procurements at the subsystem level 2. Use of commercial components	1. Simplified contract specs and standards 2. Procurement strategies/procedures 3. Generic assembly/test procedures for products (modules)
Production	1. Increased efficiency 2. Reduced construction time 3. Greater throughput	1. Fewer customized parts 2. More accurate pricing 3. Better quality products	1. Generic build strategies 2. Parallel assembly/test of major ship systems 3. Simplified quality control procedures

OPERATIONS AND SUPPORT	MODULARITY	EQUIPMENT STANDARDIZATION	PROCESS SIMPLIFICATION
Spares	Better contractual boundaries	Smaller spares population	Improved configuration management methods
Training	Common configurations/layouts	Fewer schools/courses	Module simulators
Maintenance	Ease of removal	Simplified maintenance universe	Module support procedures
Modernization	Flexibility to introduce new technology	Interface control	Combat system module interface standards

Ship Effectivenes:
SEAMOD vs. Conventional

FIG 12

AVERAGE SHIP EFFECTIVENESS FOR SEAMOD AND CONVENTIONAL UNITS



The TOSA Process

REQUIRMENTS

ORD, MNS, Regulations

REFERENCE MODELS

Functional Analysis And Partitioning

Key: Continuous Market Surveillance Technology Projection

ARCHITECTURES

Select Major System Architectures & Innovative Concepts:

- Adaptable Ship, FE Zones
- Zonal Distribution
- Modular Approach

OSA INTERFACES

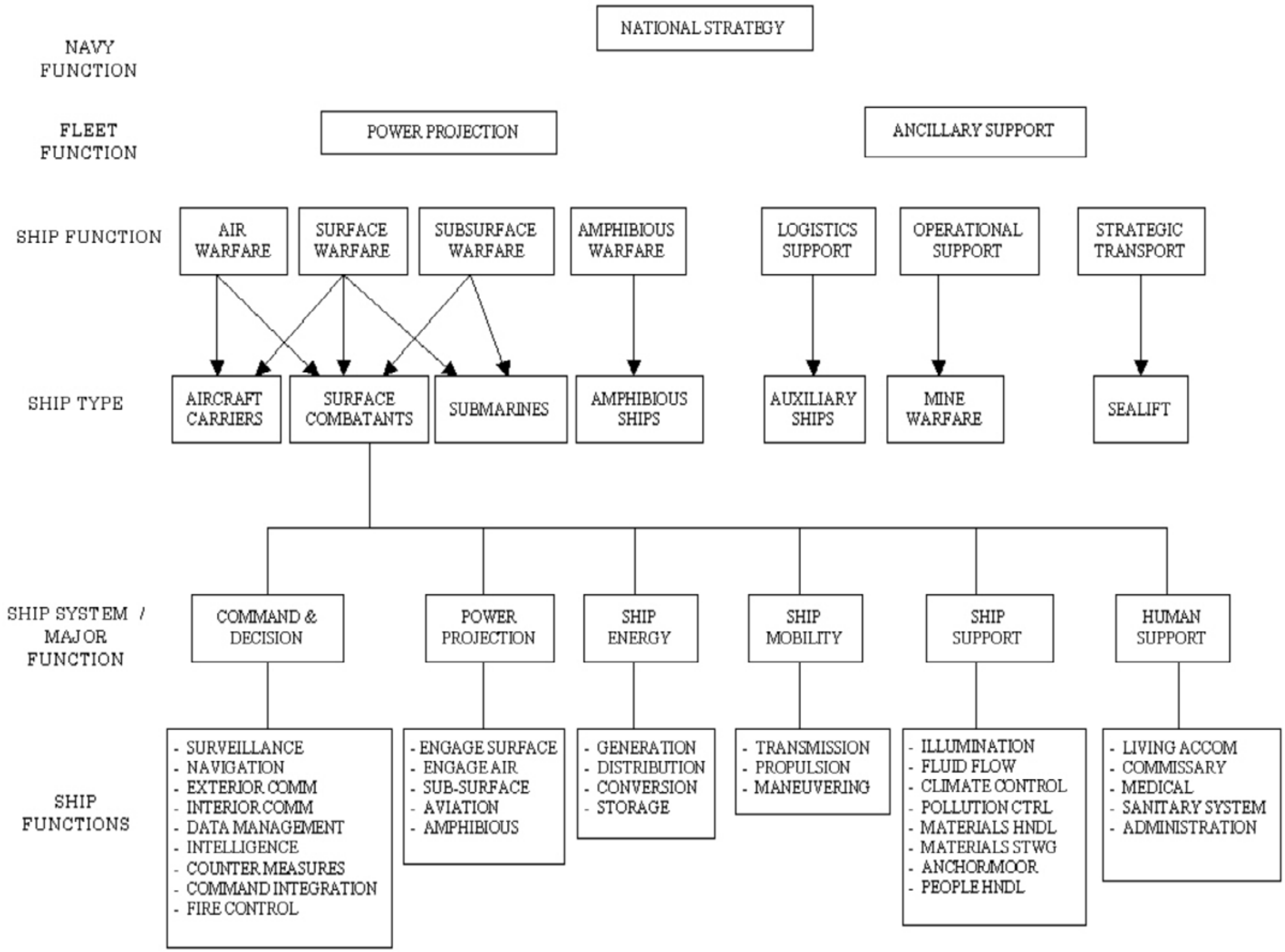
ID OSA Options & Functional Interfaces

Products

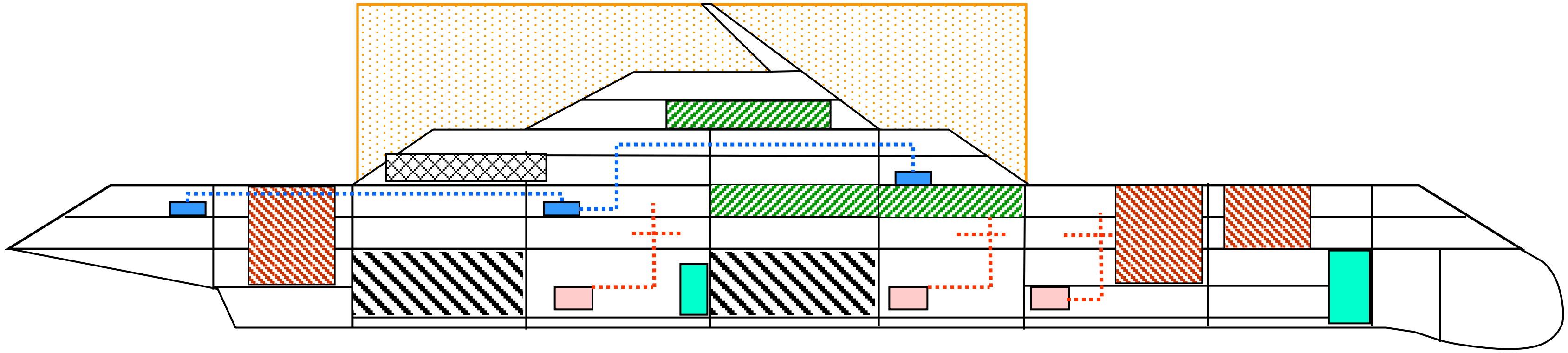
Systems Selected for OSA based on:

- Anticipated Life Cycle Cost
- Rate of Change due to Technology, Mission Needs, Regulations or Maintenance
- Availability of Commercial Technology

Functional Partitioning of Ship Systems



TOSA Vision: The Adaptable Ship



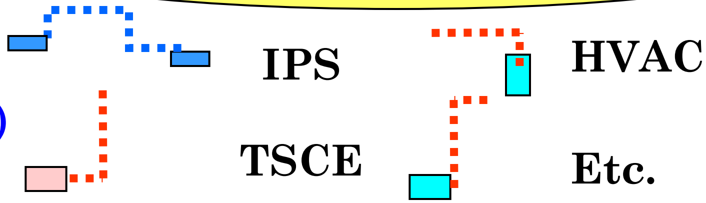
Open Zones

- Ordnance
- Machinery Equipment
- **C4I**
- Organic Off board Vehicles (OOV)
- Topside
- Other

Open Modules

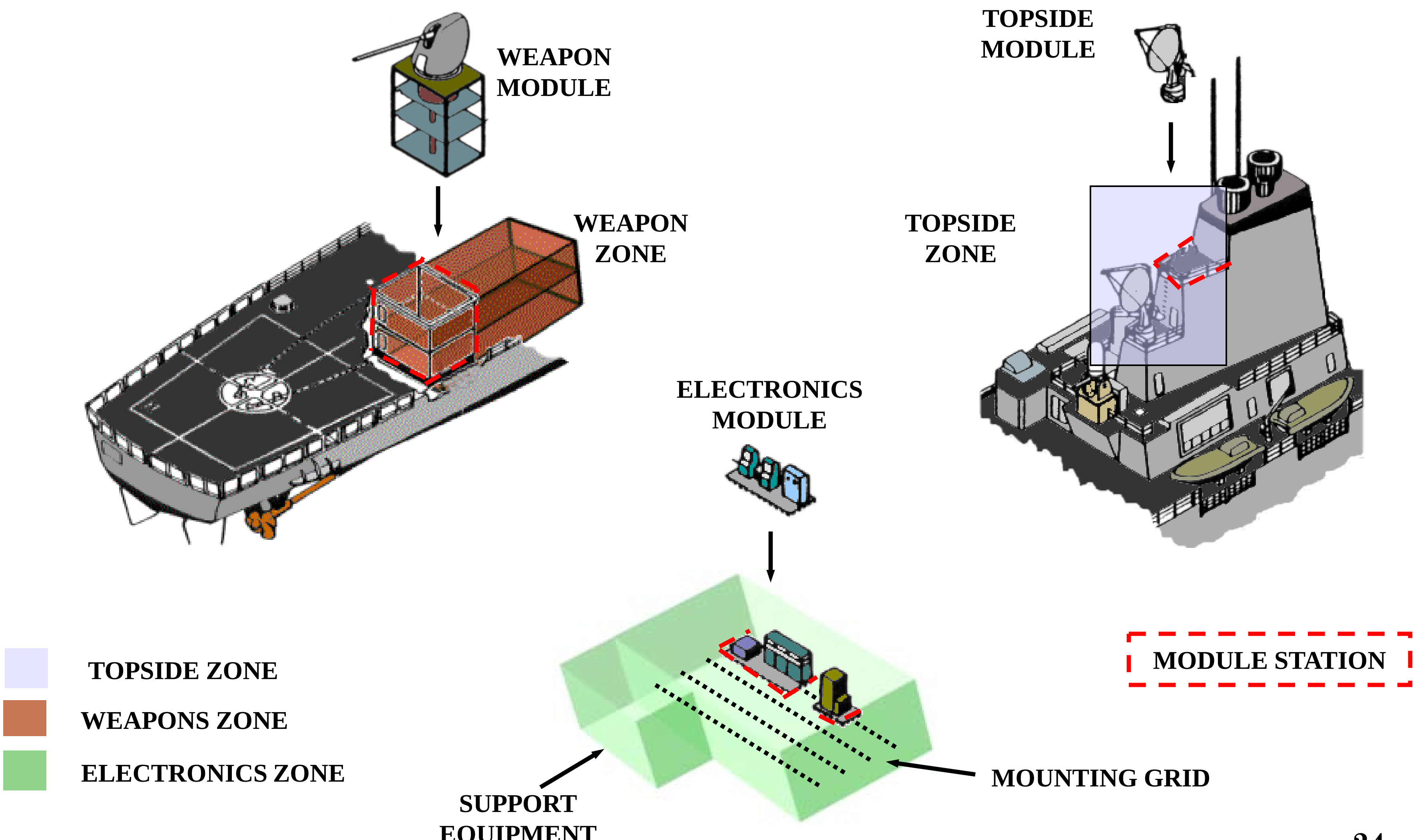
Various

Open Distributed Systems



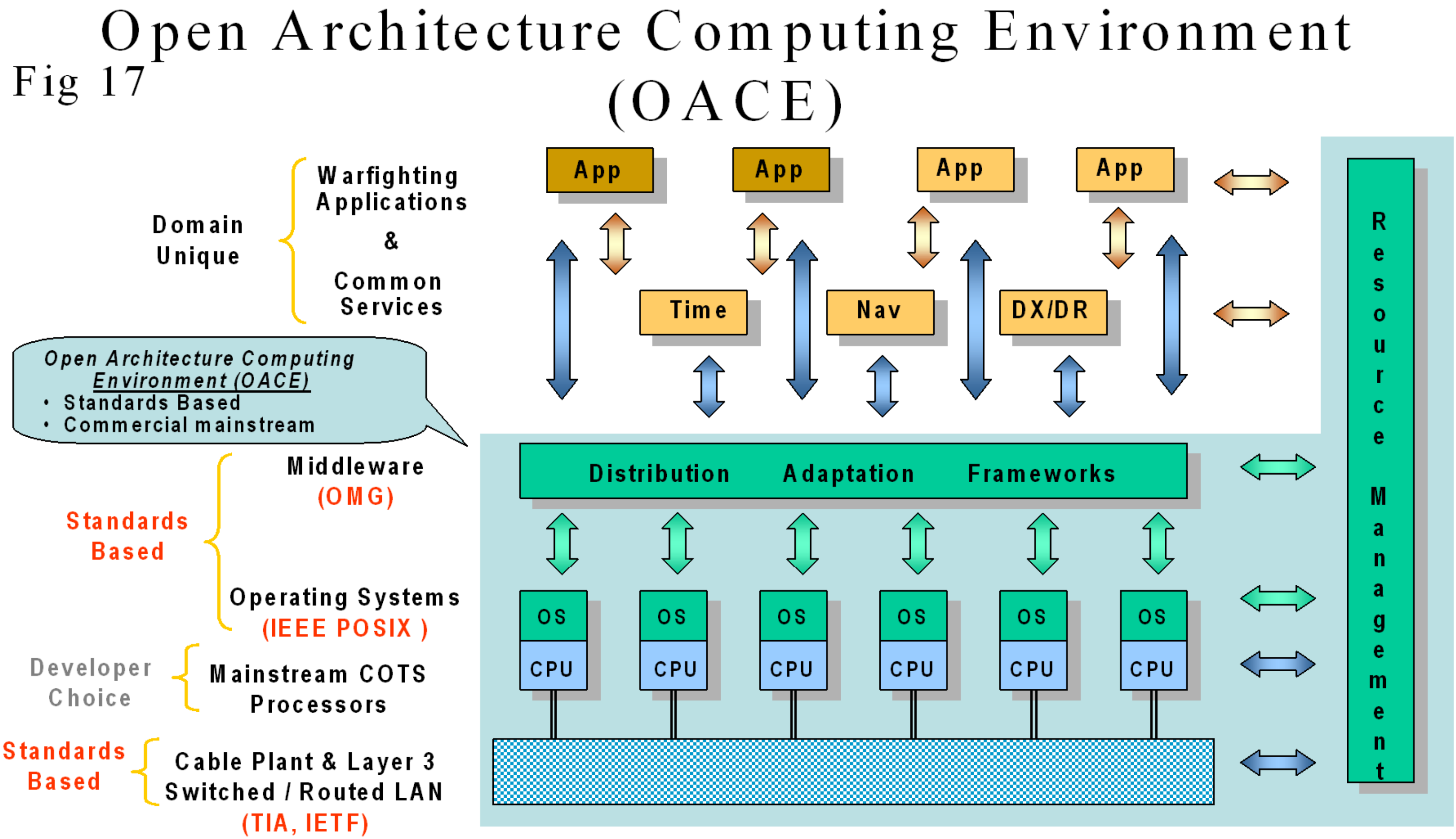
+Monitoring **+Maintenance** **+Supply**

Open Zones and Modules



Open Architecture Computing Environment

Fig 17

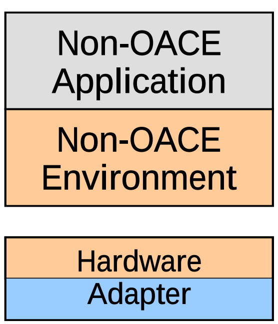


Standards and Middleware Isolate Applications From Technology Change

OA Compliance Categories

Category 1
Hardware Adapter

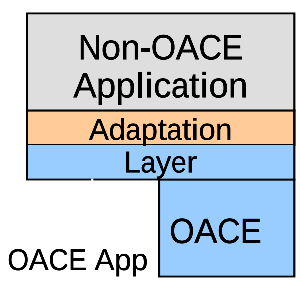
- Legacy Application
- Legacy Hardware
- Legacy OS, Middleware, etc.
- Physical I/F Adapter
- Little reuse



OACE Applications

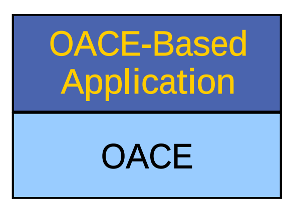
Category 2
OACE Interface

- Legacy Applications or Requirements -Based Innovative Application
- Legacy Middleware &OS APIs
- "Wrapper" Layer Makes Application Code Portable
- OACE Middleware for External Interfaces
- Subsystem-Level Reuse



Category 3
OACE Standards

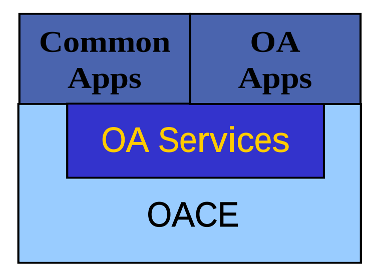
- Applications Running on OACE OS & Middleware Standards
- OACE Standards Used Internally
- OACE Physical Infrastructure
- Minimal Change to Application Software Design
- Supports Common Function Reuse
- Integrated or Federated Architecture
- Distributed Computing Resource Management†
  - Location Transparency
  - Shared Resources



† As standards become available.

Category 4
OA Common Functions

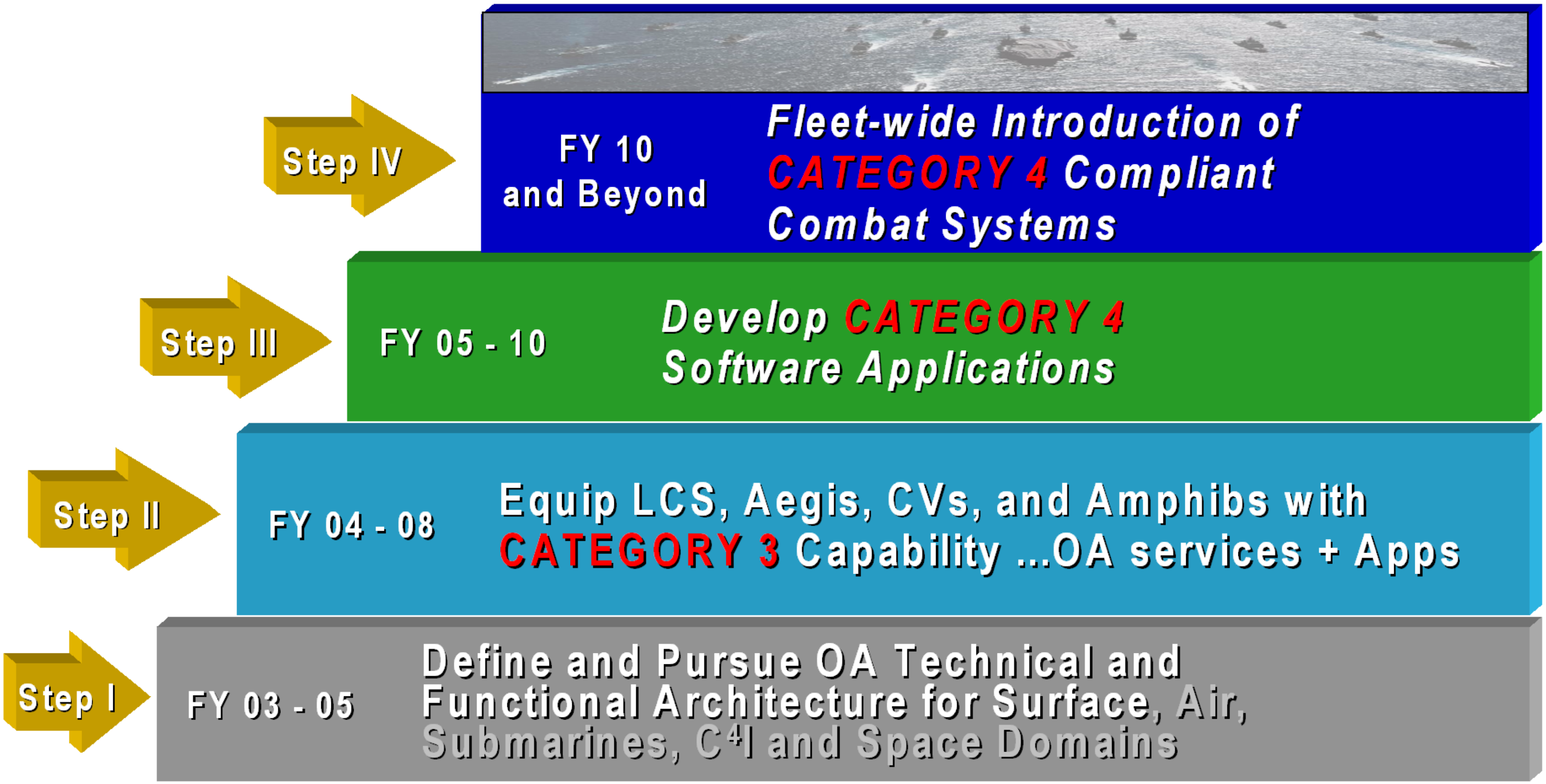
- Common Applications Built on OACE OS and Middleware Standards
- Application Uses OA Common Services and or Functions
- Applications use OA Frameworks Where Applicable, e.g. Fault Tolerance
- Integrated or Federated Architecture



OA Fielding Strategy

Fig 20

Surface Domain OA Fielding Strategy*



*Consistent with strategy reported at EXCOMM I & II

Obstacles to Implementation in the 80's

- Vested interest in the Status Quo
- No compelling reason to change the Status Quo
- Viewed as a threat to key acquisition programs
- Unwillingness to believe positive impacts on time and costs
- Concern over the impact on the procurement process
- Unwillingness to assume responsibility for promulgation of interface standards
- Failure to grasp the importance of flexibility and upgradeability
- Not organized for successful implementation

General Observations

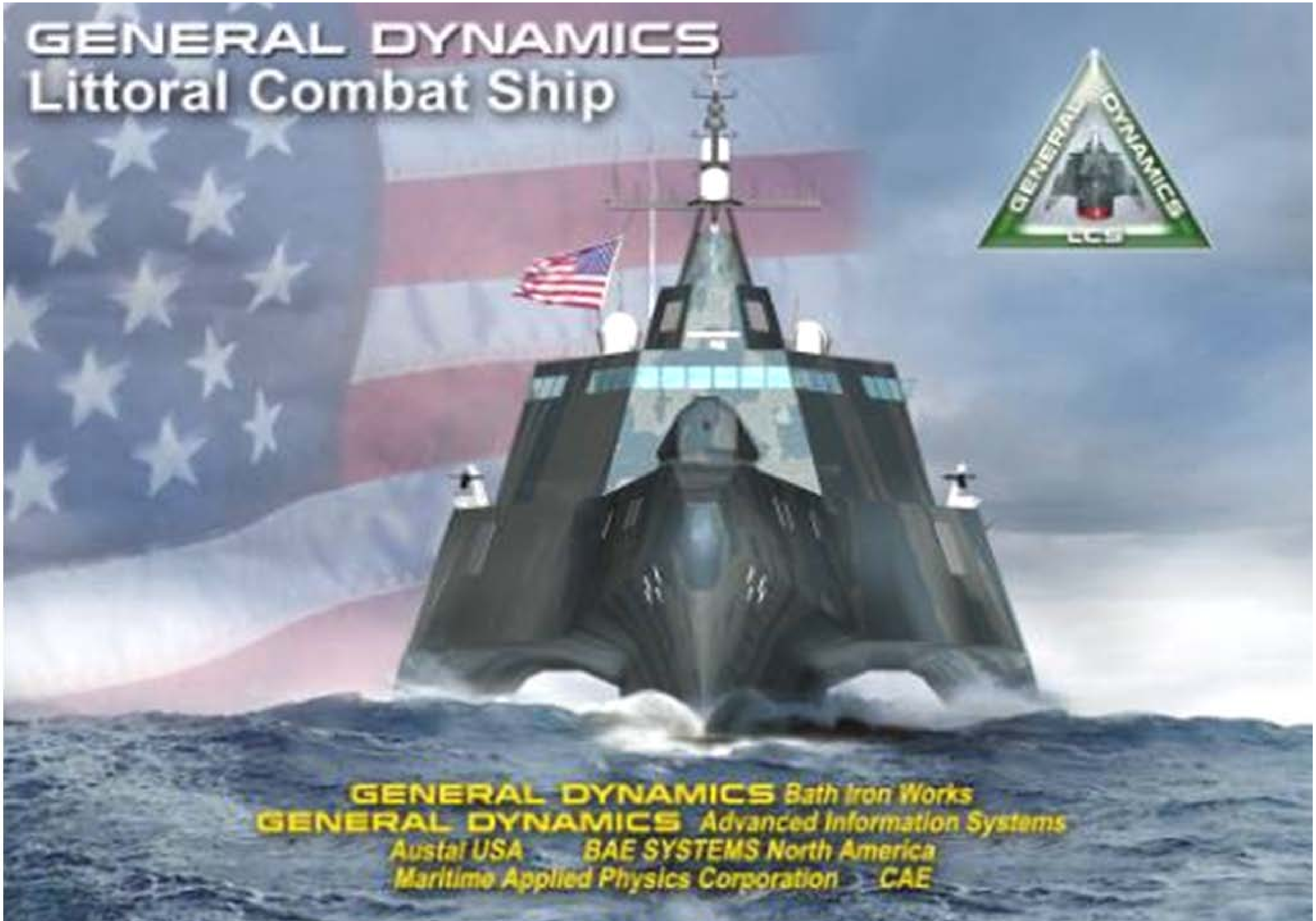
- US Navy viewed MPS benefits as only applicable to modernization/conversion whereas foreign activities were driven by potential for lower construction costs
- US Navy MPS efforts were led by the government whereas foreign MPS efforts were led by private industry
- Foreign activities achieved both cost and mission reconfiguration objectives
- US Requirements to build Modular Payload Ships began with the Open Systems Joint Task Force (OSJTF)
- Although DOD Acquisition Reform changed ship design from “in house” to industry, requirements for OSA demands government maintain control of key interfaces

Why Now?

- Economics of a smaller fleet – need for more flexible ships that can be configured to the mission vice multi-mission ships
- Faster rate of technology change – software can change every 18 months
- Computer industry proved interfaces for plug and play can work – even among competitors
- Increased number of open standards now available – ISO, IEEE, NIST, MIMOSA, etc.

Lockheed Martin LCS Seaframe

General Dynamics LCS Seaframe



Lessons Learned

- The Technical Architecture should be based upon logical functional boundaries – not procurement boundaries

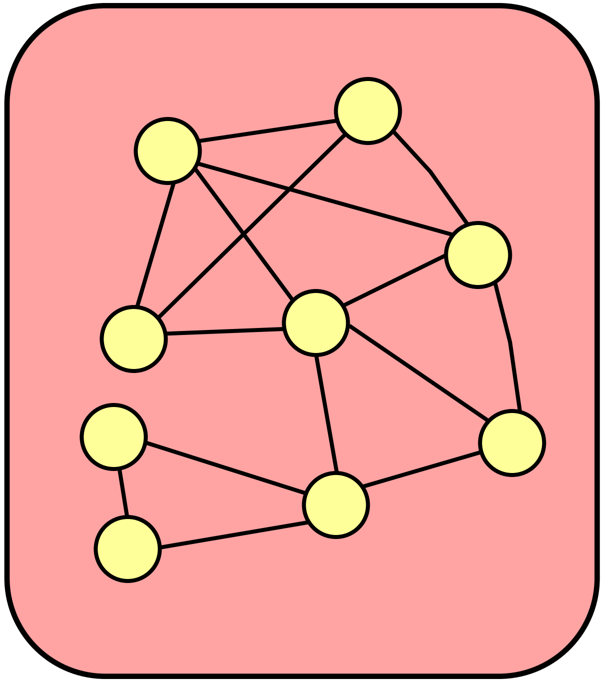
- Technical Architecture development should begin with ship functional partitioning and allocation of Functional Element zones – development of module/module station interfaces are then detailed to check zone sizing and shape

- Interfaces for ship services should be done AFTER alternate user requirements have been determined and the system design is completed

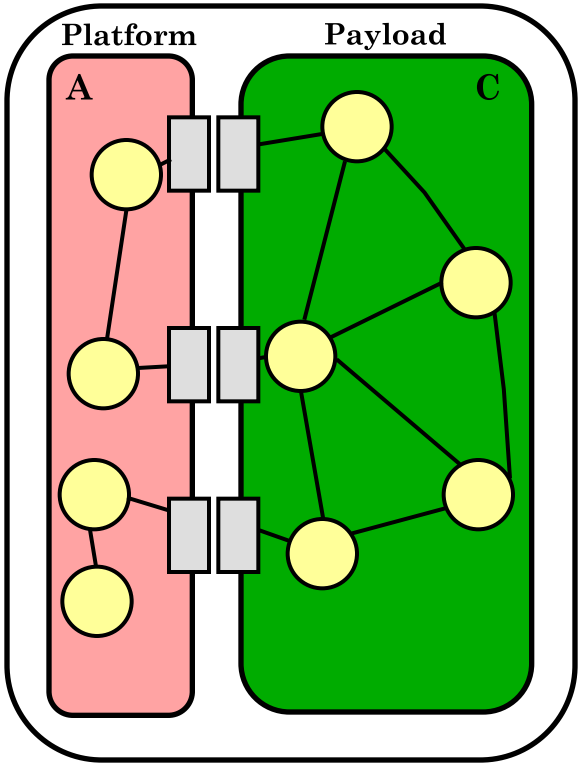
- Owners of modular systems must learn to accept the interface standards as "design to" requirements

- Ability to use interface standards cross fleet depends on the level of modularity/standardization attempted

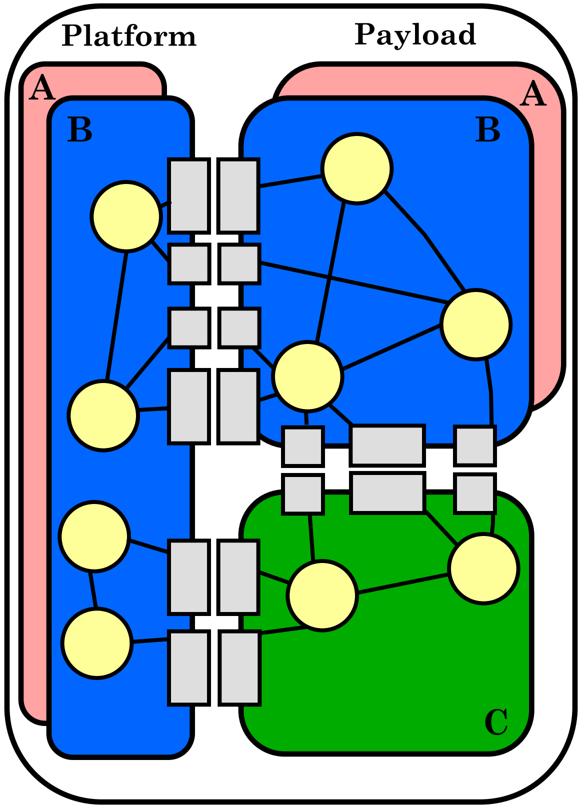
Acquisition Structures vs. Technical Architecture



Closed Embedded System
(Platform + Payload)

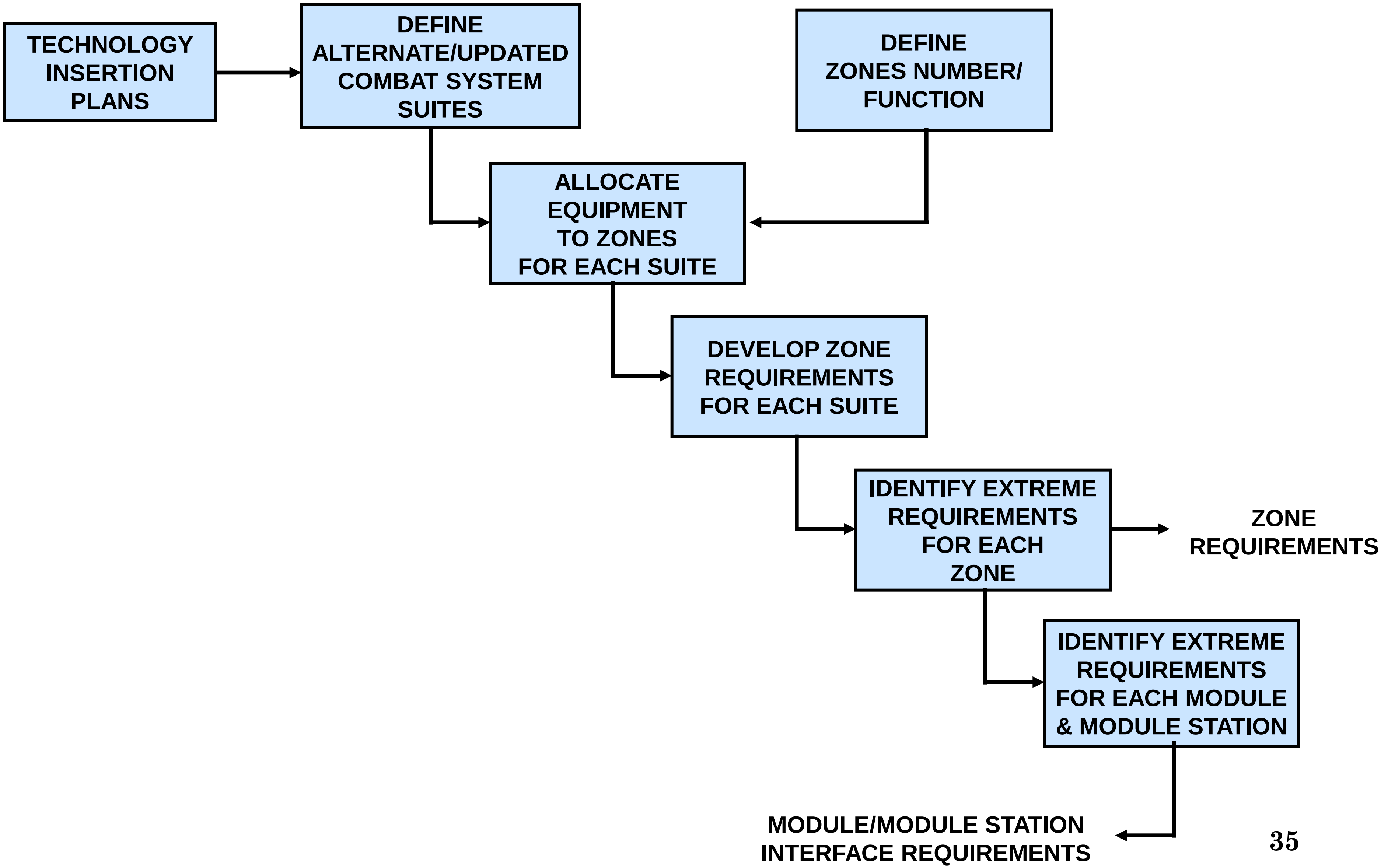


Open System – Aligned with Organizational Implementation



Open System - not Aligned with Organizational Implementation

Technical Architecture Development



Levels of Modularity / Standardization

Level		Parameters		Applicable to
SHIP ARCHTECTURE (ZONES) LEVEL		SPACE AND WEIGHT		SHIP CLASS (DESTROYER)
EQUIPMENT AND MODULE STATION LEVEL		SIZE, STRUCTURE, SERVICES		SHIP TYPE (COMBATANTS)
COMPONENT LEVEL ---				
Physical Connections (Electrical, Fluids)		CONNECTOR PINS, FLANGES		FLEET
Digital Connections		API'S, MESSAGES		FLEET
Communications		LINKS		FLEET

Recommendations

- Stay the course and apply good Systems Engineering – MPS is the only known concept that can reduce costs without reducing performance
- Establish a NAVSEA warrant holder – maintain the technical baselines used for ship design
- Carry out adequate configuration management of all MPS interface standards – without it there will be chaos
- Insist that system level developers accomplish the paradigm shift of "designing to interfaces" up front to fully realize the potential of MPS
- Realize that not all systems should be open – it depends on the business case
- Apply modularity and open systems concepts to the NAVSEA Affordable Future Fleet (AFF) effort now underway

Conclusions

- Modular Payload Ships using a modular open systems approach will:
  - "Simplify the acquisition, construction and modernization of ship platforms and payloads"
  - "Hasten the introduction of new technology/weapon systems (payloads) into the fleet"
  - "Quickly convert the type and mix of combat system elements to counter new and changing threats"

Jack W. Abbott
SNAME Annual Meeting
November 1977