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Shock Assessment of Interchangeable Systems Modules

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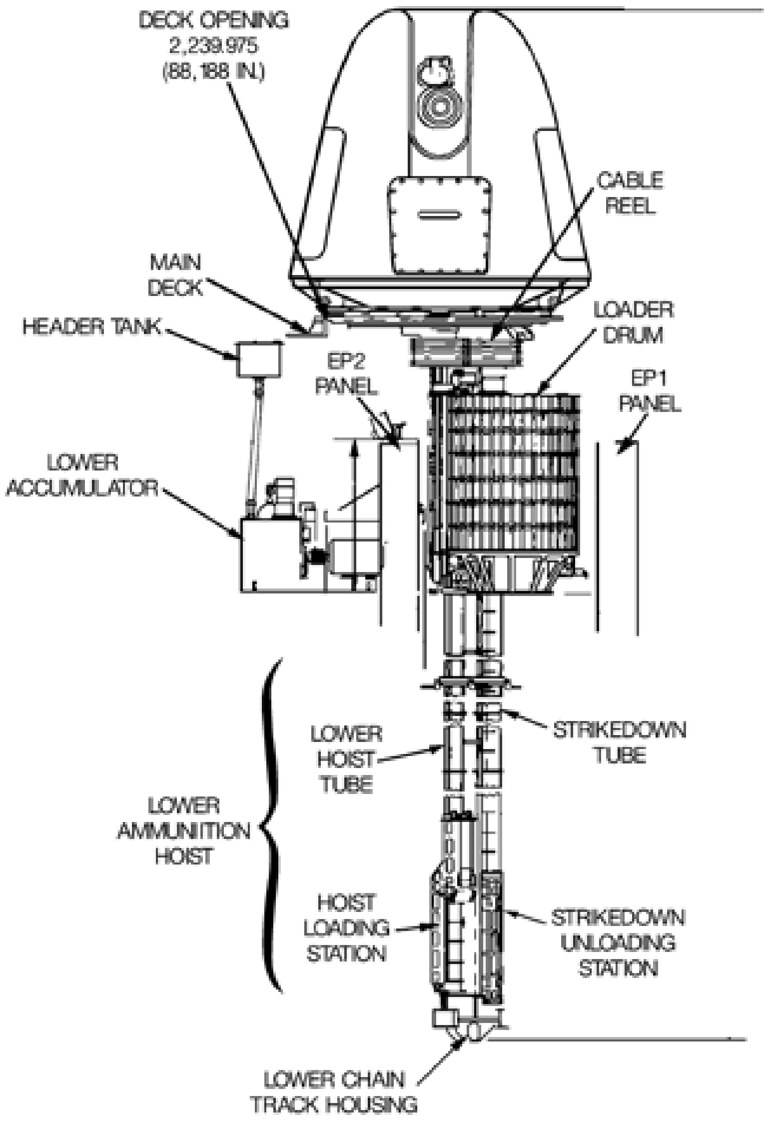

Shock Assessment of Interchangeable Systems Modules

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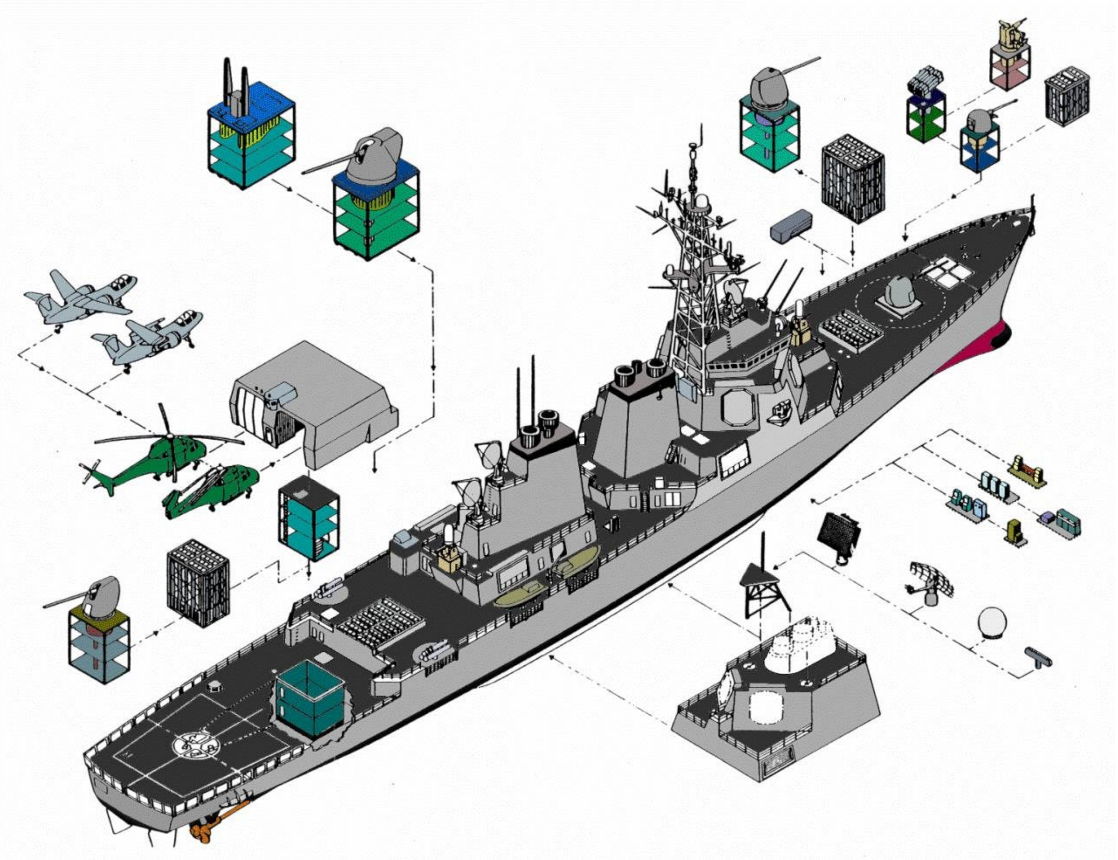
11 May 22

Research Statement

Shock Hardness of Interchangeable Payload Modules is Required

Examine Survivability of these Systems

Inform Future Combatant Ship Design

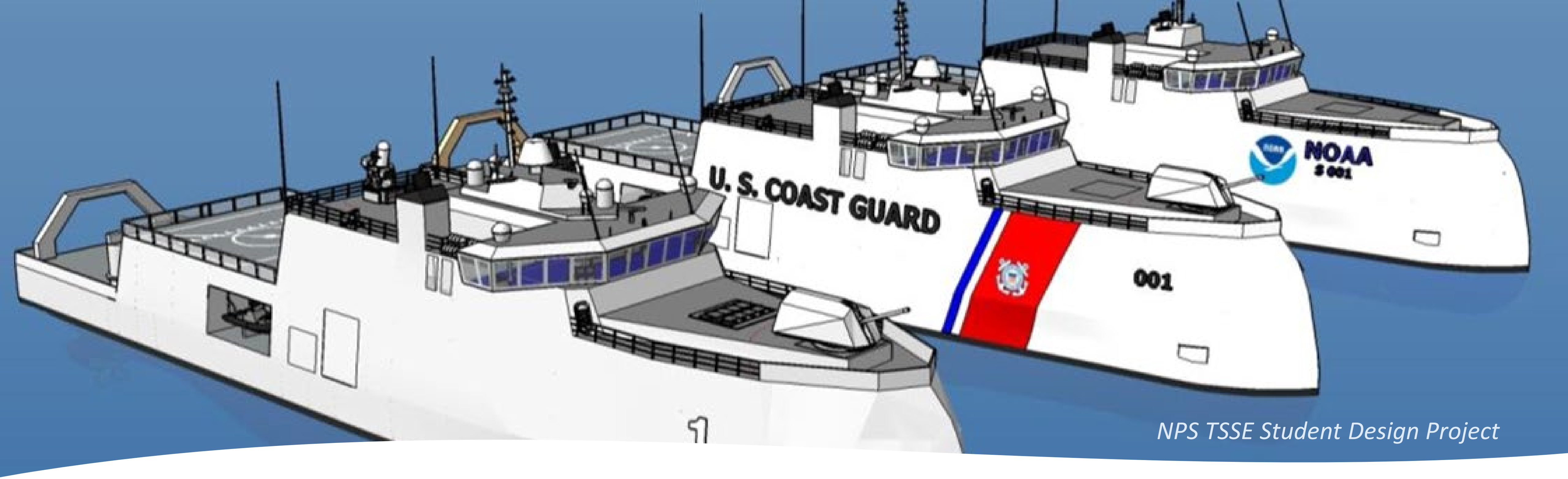


Motivation

- **Applications**
  - Major Systems Upgrades throughout the ship lifecycle as technology advances
  - Exchange of weapons systems to match changing mission needs
  - Maintenance Swap-out
  - Battle Damage Repair/Refit
- **Acquisition Impact**
  - Deliberate Design & Planning for future capability enhancement
  - Investment in ship infrastructure to facilitate major systems refresh
  - Up front cost implications

Study Overarching Questions

- Based on updated information and M&S techniques in shock survivability, are the conclusions of the 1997 modularized 5"/54 Mk45 naval gun mount testing still sound?
- Were the shock loads applied during previous modular testing and analysis comparable to physical loading experienced during full ship shock trials conducted at sea?
- Is re-assessment of the previously conducted testing for the 5"/54 Mk 45 recommended?
- What are the technical recommendations resulting from shock hardness evaluation of candidate weapon and sensor payloads as described by the PEO Ships S&T team that employ the SEAMOD and/or MEKO design approaches?



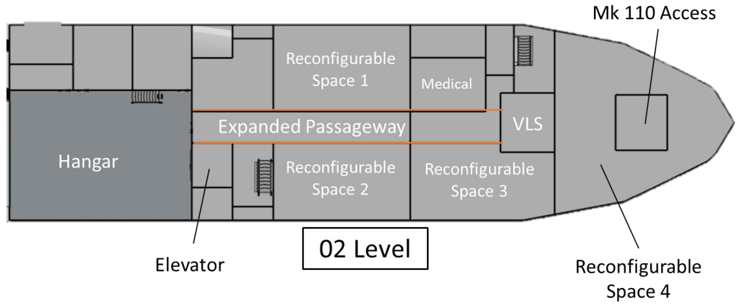
NPS TSSE Student Design Project

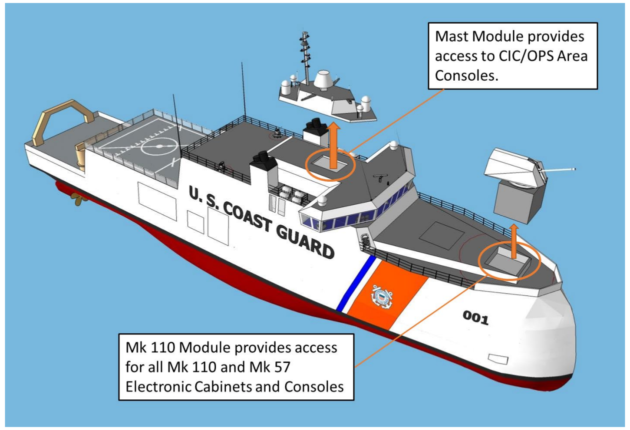
Approach to Modularity

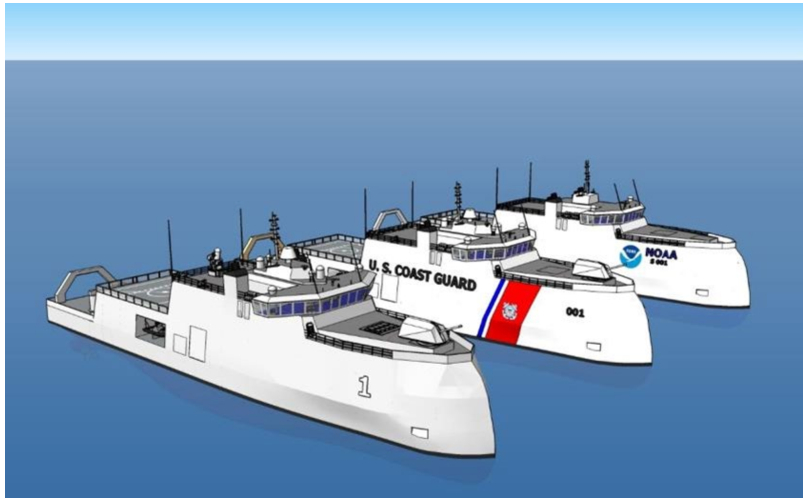
Flexible ship design is based on five primary tenets:

- Decoupled Payloads (capabilities) from Platforms (ships)
- Standard Platform-to-Payload Interfaces
- Rapid Reconfiguration
- Pre-Planned Access Routes
- Sufficient Service Life Allowance Growth Margins

Sturtevant (2017)

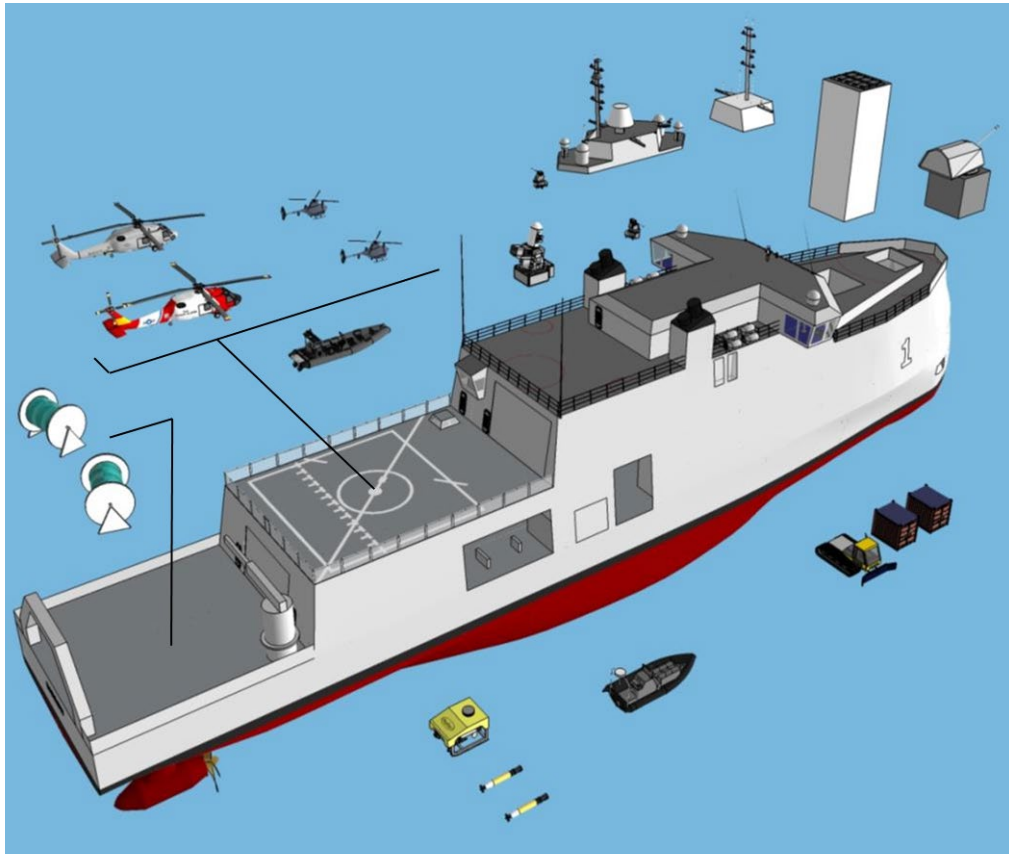






NPS TSSE Student Design Project – not endorsed by any service

Module	USN	USCG	NOAA
Mast w/ SPS-77 and SPS-73	X	X	
Plain Mast			X
Mk 110	X	X	
Mk 57 VLS	X		
Mk 38 (x2)	X	X	
SeaRam	X		
Trawling Reels			X
Other Assets	**USN**	**USCG**	**NOAA**
Small Boats (x2)*	X	X	X
UAV/Aviation Asset*	X	X	X
UUV/ Hydrographic Survey Equip*	X	X	X
Mission Bay Payload*	X	X	X



Modular Design Concept

Selectable payload modules with deliberate detailed planning & design

SEAMOD

- Sea Systems Modification and Modernization by Modularity
- Introduced to mitigate the disconnect between 30 year ship life and 5-10 year Combat Systems (mission capability) lifespan
- Approach
  - Implement standard weapon system interfaces
  - Payload modules are installed after ship initial build
  - Systems are “exchanged” as time goes on
- Method
  - Standard ship service outlets sized for the current and foreseeable future systems
  - Establishes comprehensive interface design standards
  - Looks to achieve physical and functional separation of a ship platform and its payloads

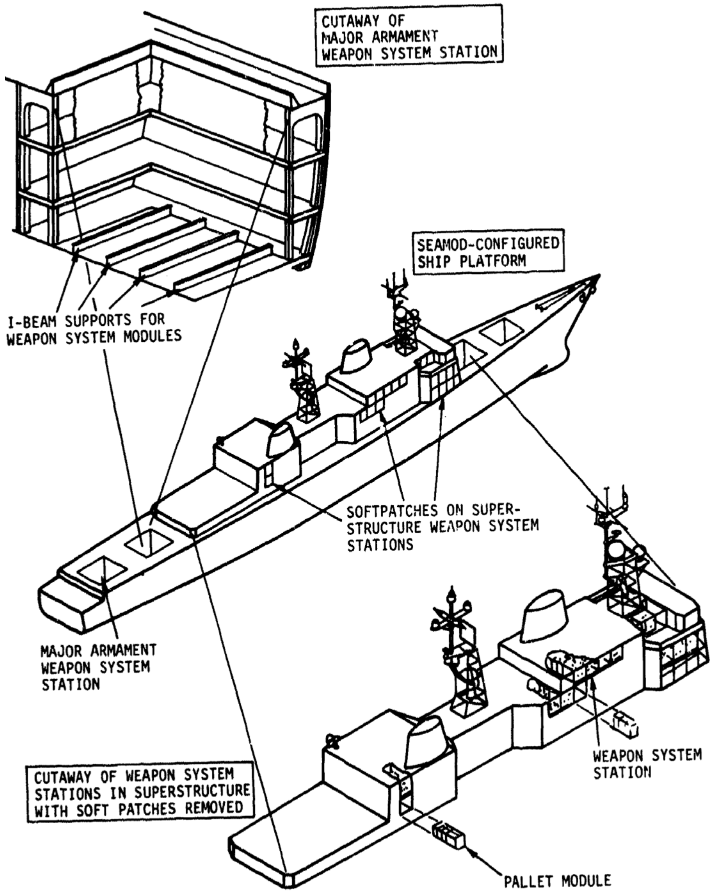


FIGURE 1
SEAMOD-CONFIGURED SHIP PLATFORM DESIGN CONCEPTS

Weapons systems payloads and platform independence – variable payloads

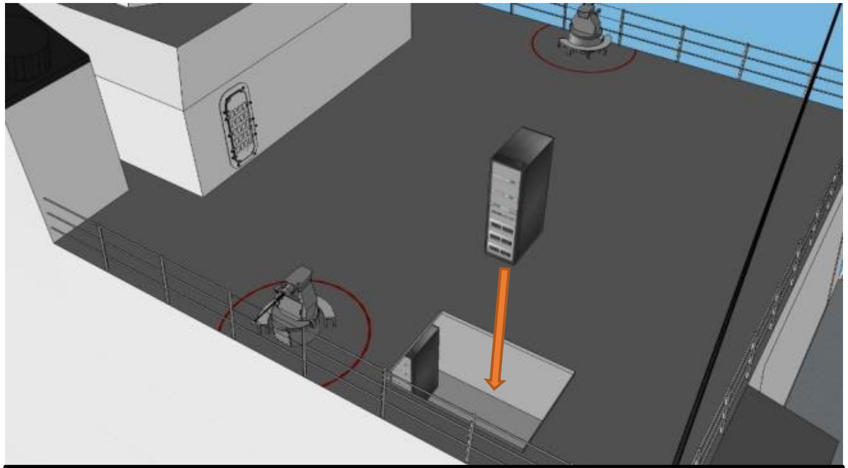
MEKO

- Multi-purpose combination "Mehrzweck-Kombination"
- Modularity of armament, electronics and other equipment
- Goal is the ease of maintenance and cost reduction

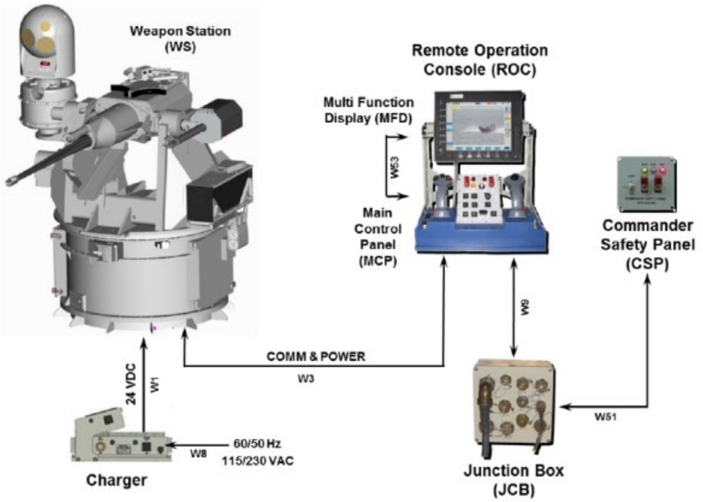
"nearly identical ship platforms, but very different combat systems from different suppliers"

Multi-purpose combination ships with modular weapons and electronics systems - international standards

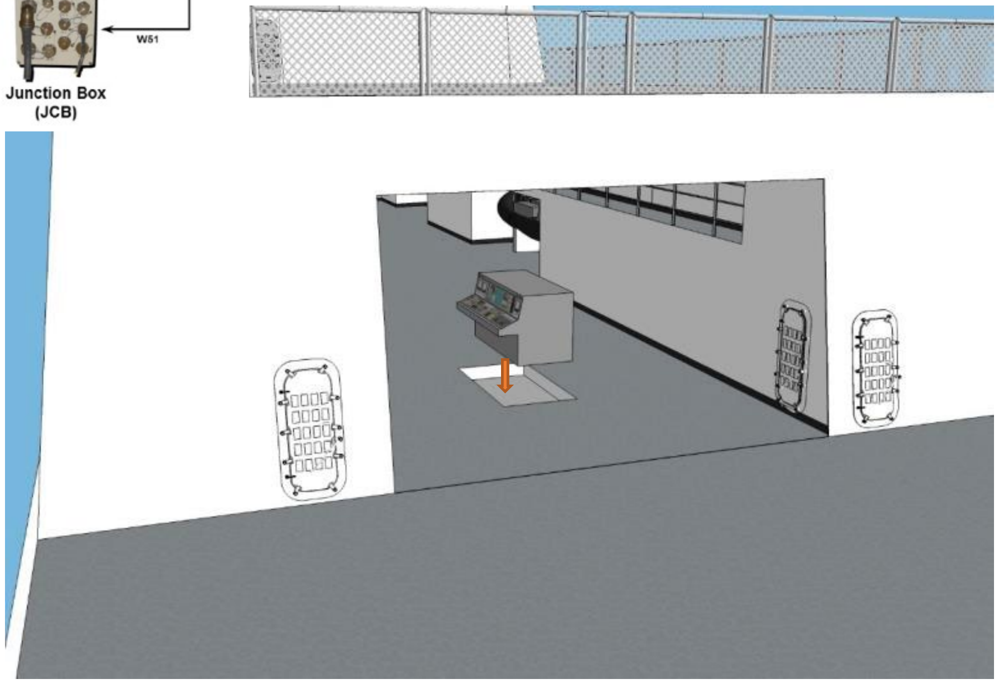
Beyond Basic Interfaces



Overhead access to install/remove all Mk38 and SeaRam below deck components.



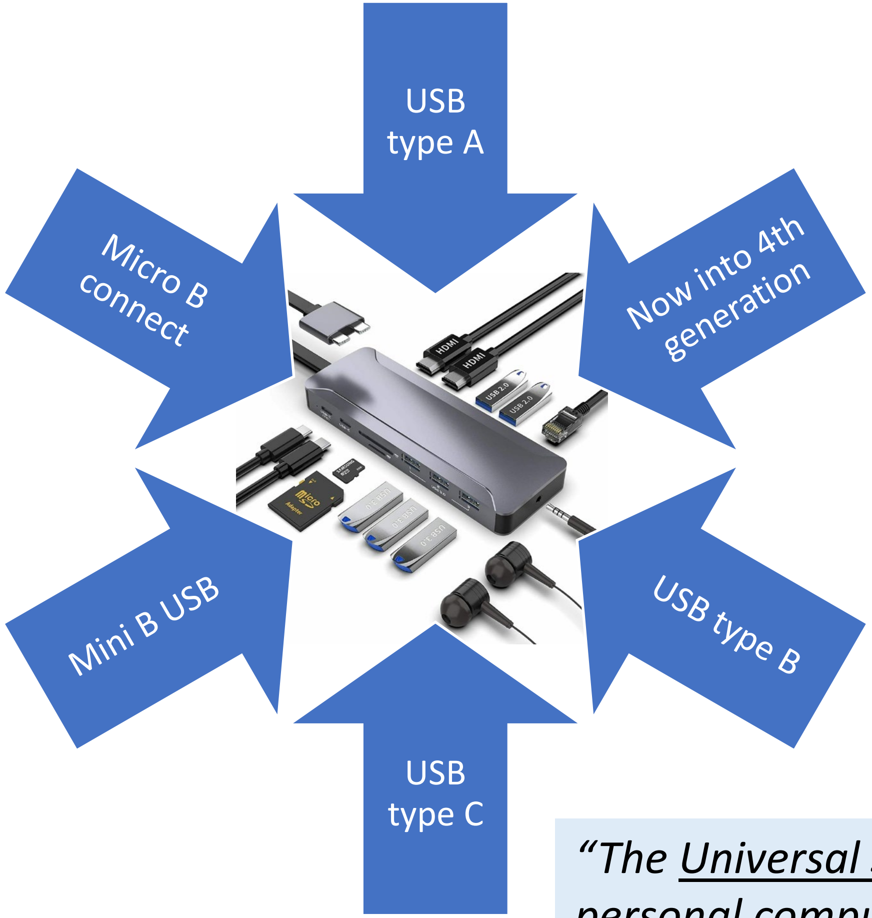
Overhead access to install/remove all engineering and DC consoles.



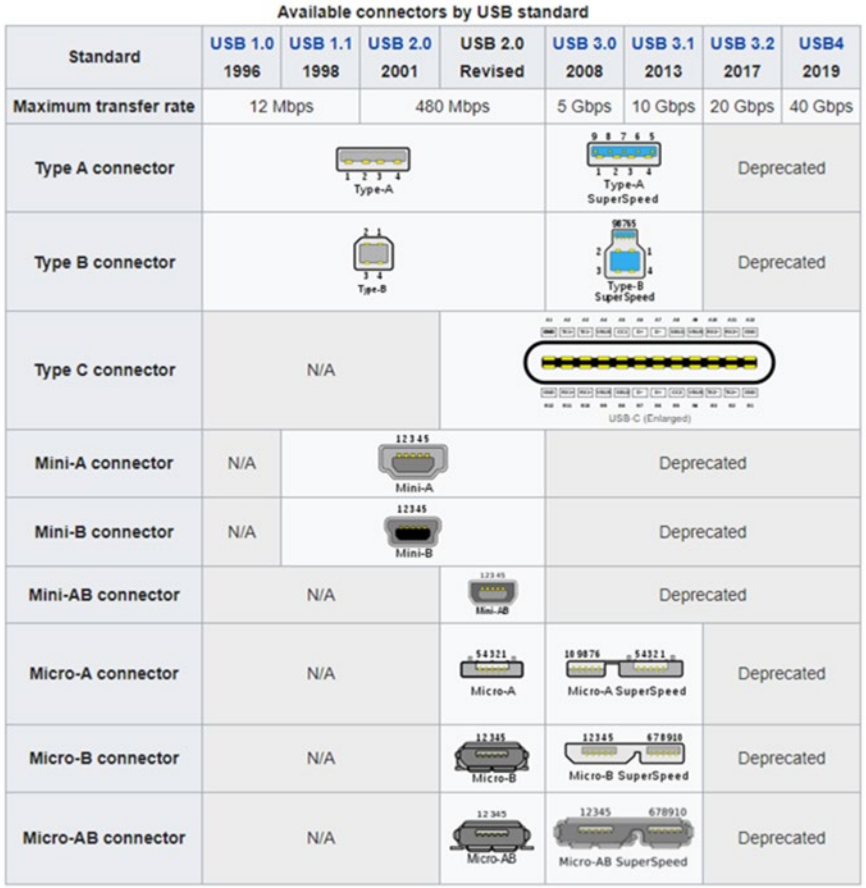
- Much work has been accomplished in the planning of:
  - Ship Design Margins (SWAP-C)
  - Removal Routes
  - Access Points
- Challenges remain at the integration level

Form-Fit-Function

Engineering Standards?



Released in 1996



Available connectors by USB standard

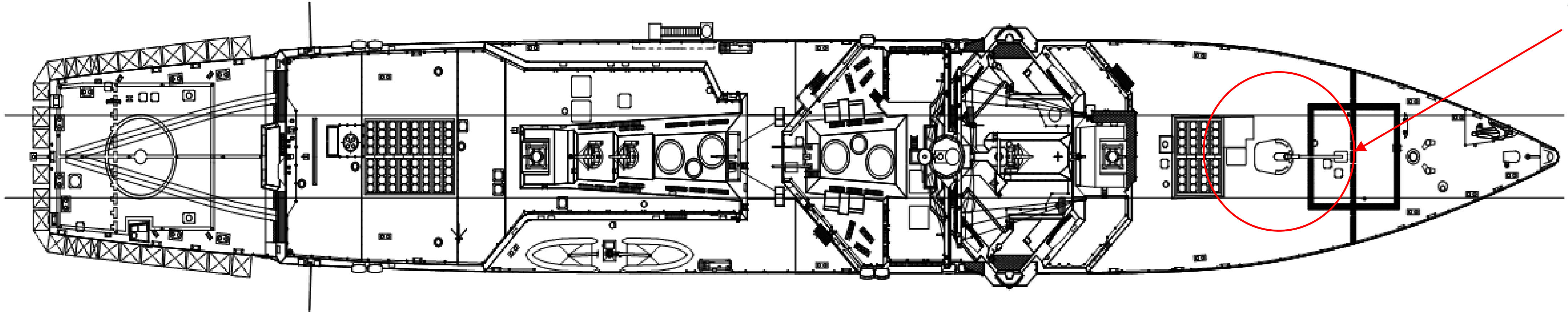
Standard	USB 1.0 1996	USB 1.1 1998	USB 2.0 2001	USB 2.0 Revised	USB 3.0 2008	USB 3.1 2013	USB 3.2 2017	USB4 2019
Maximum transfer rate	12 Mbps		480 Mbps		5 Gbps	10 Gbps	20 Gbps	40 Gbps
Type A connector	Type-A				Type-A SuperSpeed		Deprecated	
Type B connector	Type-B				Type-B SuperSpeed		Deprecated	
Type C connector	N/A			USB-C (Enlarged)				
Mini-A connector	N/A	Mini-A			Deprecated			
Mini-B connector	N/A	Mini-B			Deprecated			
Mini-AB connector	N/A			Mini-AB	Deprecated			
Micro-A connector	N/A			Micro-A	Micro-A SuperSpeed		Deprecated	
Micro-B connector	N/A			Micro-B	Micro-B SuperSpeed		Deprecated	
Micro-AB connector	N/A			Micro-AB	Micro-AB SuperSpeed		Deprecated	

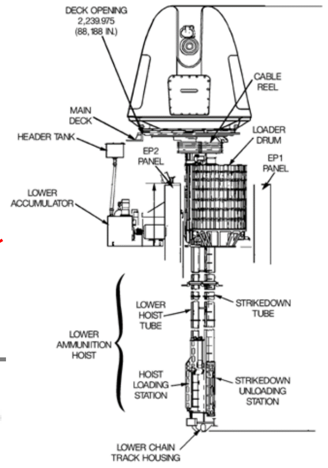
"The Universal Serial Bus was developed to simplify and improve the interface between personal computers and peripheral devices, such as cell phones, computer accessories, and monitors, when compared with previously existing standard or ad hoc proprietary interfaces"

Jan Axelson, USB Complete: The Developer's Guide, Fifth Edition

Ship Shock (UNDEX)

- Uncertainty exists in the correlation of shock experienced in equipment during each type of shock loading:
  - Full Ship Shock Trials (FSST)
  - Floating Shock Platform (FSP)
    - waterborne explosive loading
  - Hammer/drop testing (standard 901 series)
    - shore-based impact loading
- Failure on some components/equipment occurs in FSST while previously certified via 901 series





Modular Gun System

How does the mission system perform as part of the overall ship system?

Pass/Fail Criteria

Will the MGS remain operable after each test shot?

- Train and Elevate Gun, Fire 8 shots
- Based on gear adrift (visual observation), Grade B qual
- Component damage/failure limiting firing, Grade A qual

MK45/MOD1 (MGS) Shock Test

- German MGS is installed on MEKO frigates
  - Tested via Large Floating Shock Platform (LFSP) in 1997 for install verification and potential use on US ships IAW 901 series
- US MK45 5-inch 54 caliber MOD 1

  tested using LFSP with a stiffer deck
  - (25hz vs 15hz) in 1985
- Differences exist in design integration at deck
  - Welded gun ring (US)
  - Bolted container cover (Meko)
  - EPOCAST utilized to chock and align (Meko)

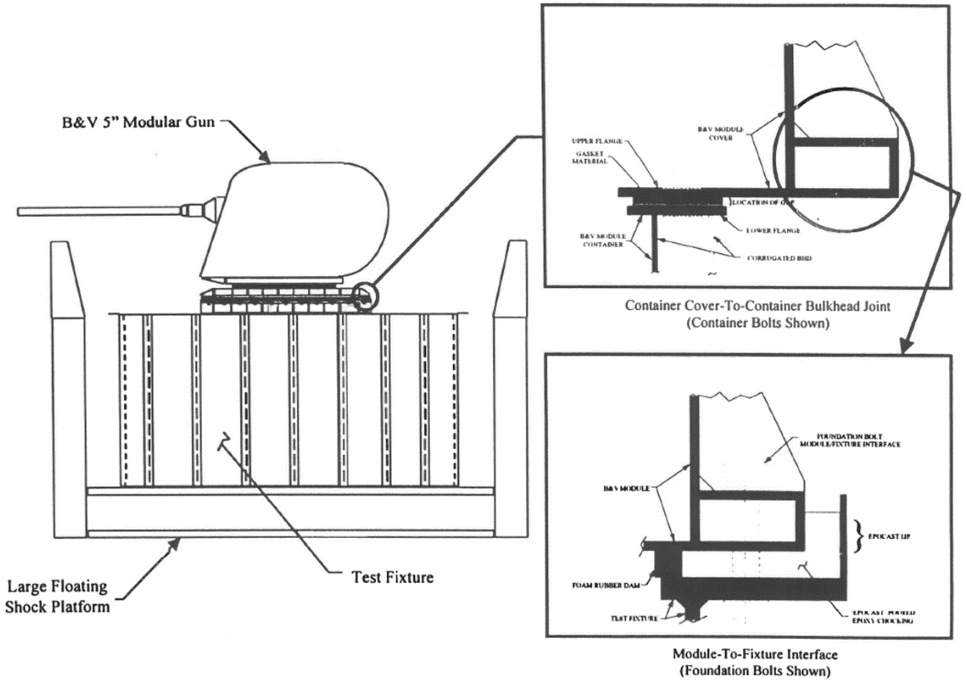


Figure 3 - Large Floating Shock Platform, Test Fixture, and Modular 5" Gun System Bow View (Shot No. 1)

NAVSEA shock standards drive requirements and qualifications

Individual Shot Results (LFSP)

Shock Severity

- Shot 1
  - EPOCAST Cracking
  - Electrical failure (offline equipment due to tripping/resetting components)
- Shot 2
  - Additional EPOCAST cracking
  - Mechanical failure of support equipment in loader
- Shot 3
  - Electrical failure (offline equipment due to tripping/resetting components)
  - Mechanical failure of support equipment in transmission
  - Higher than expected response (twisting motion, cross-axis coupling)
  - More cracking in EPOCAST material foundation
- Shot 4
  - Gear tooth broke, mechanical failure
  - Electrical failure due to shutdown/tripping of component systems
  - Mechanical subcomponent failure
  - EPOCAST foundation broken
  - Bearing/Alignment ring potentially out of spec

Failures Noted

- Electrical failure
- System shutdown (offline)
- Deformation
- Misalignment
- Cracking

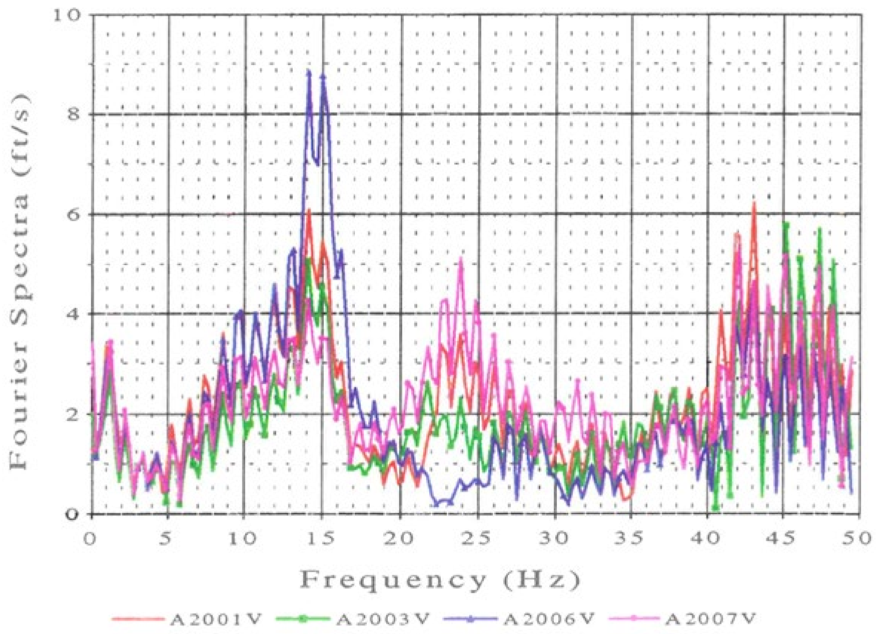


Fig. 18. (Top) Test fixture vertical velocity time FFT's.

15Hz showed a strong response, ~ 8 ft/s; as did 22Hz and 44 Hz

Previous Report Findings

History of US MK45 5-inch/54 caliber Lightweight Gun System

- Many issues were noted in early shock testing in 1980's on MK 45 MOD 0
- Shock hardening ensued, MOD1 has a 25hz base response; qualified in 1986

MIL-S-901 series requires at least 25hz primary response frequency (all 3 axes)

- Response of MGS in vertical response direction measured at about 15 hz limit

Pretest modeling showed 25Hz fixture to be insufficient

- Deviation issued for 15hz in the primary response vertical direction (PVRF)
- Stipulation for forward mount only application (i.e. location dependent)
- Velocity time histories measured at interface of coaming and fixture

Modular Gun System test performance

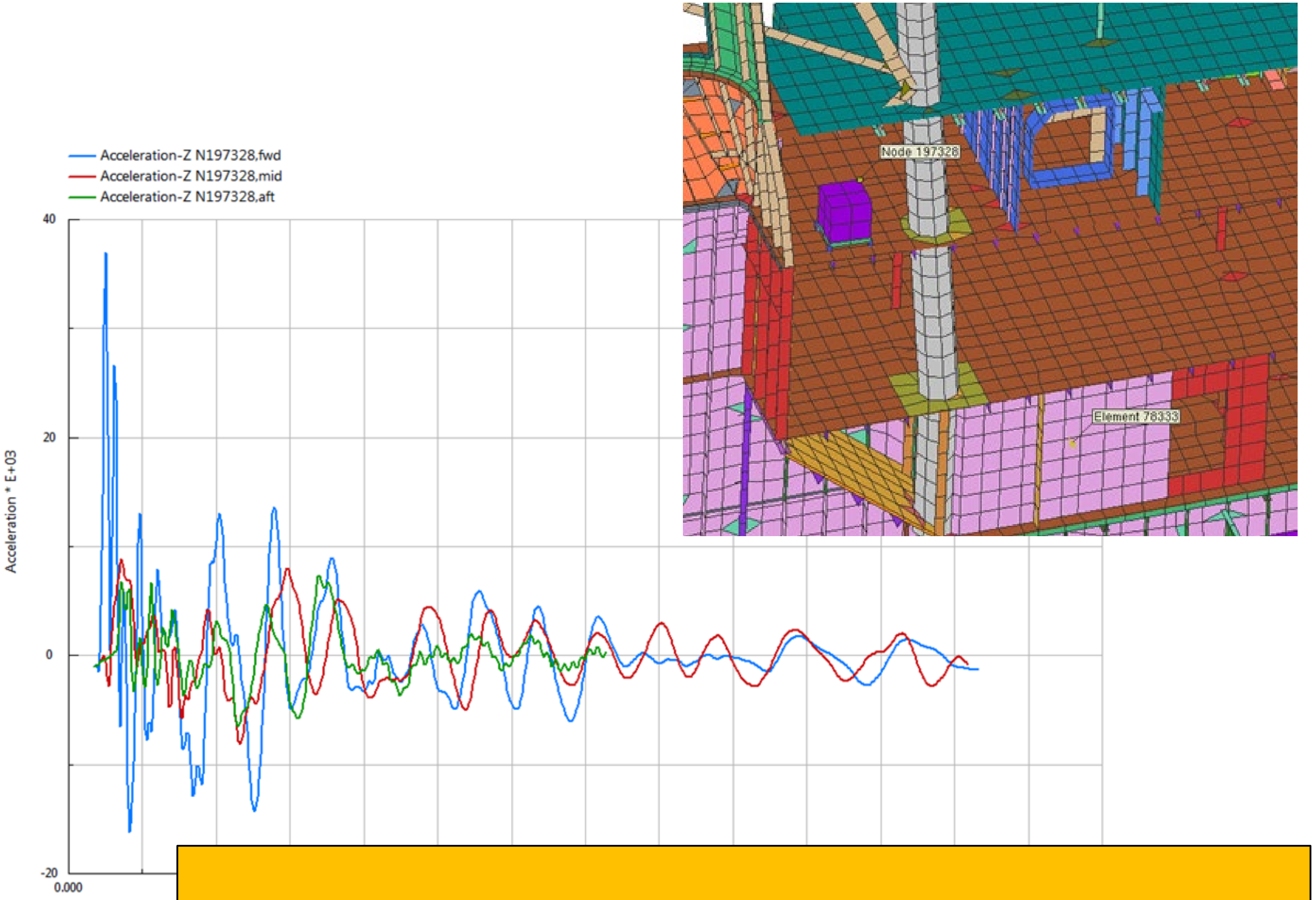
- Limited to 15hz foundation on DDGs
- Several internal components mechanically failed in MGS testing
- EPOCAST break up (cracking) observed at the base (mechanical alignment)

Installing a 5"/54 (12.7 cm) Mark 45 mount.

http://www.navweaps.com/Weapons/WNUS_5-54_mk45.php?msclkid=5c01b951cfdf11ec968f0fd6a3a93f59

Payload Module Performance

- **Structural response is coupled to:**
  - External Loading
    - Air Blast
    - UNDEX
  - Ship Structure
    - Deck frequencies
    - Adjacent masses
    - Foundations
  - Ship-System Interfaces
    - Electrical
    - Mechanical
    - Cooling
    - Interferences
    - Clearances
  - Systems Parameters
    - Internal components
    - Equipment fragility
    - Shock mounting



A detailed investigation of this topic is currently in progress

Modeling, Simulation, and Testing ahead of Future Planning, Design and Construction

Summary

- Case defined testing and models such as full ship shock models are costly to produce and maintain.
- System level models are not typically of the fidelity required for detailed analysis.
- Higher fidelity discrete models are only generated for specific equipment.
- Integration between the various types of models and interfaces is key for modular design impacts.
- Many of the parameters are unknown and even unknown – unknowns, for future systems as technology evolves.
- Component level and surrogate testing of systems of systems can still leave questions regarding performance when fully integrated into the overall ship system.
- Upfront investment is required to enable downstream flexibility.

Questions