DDG 51 Flight III Update

Presented to:

American Society of Naval Engineers (ASNE)

19 January 2017

Presented by:

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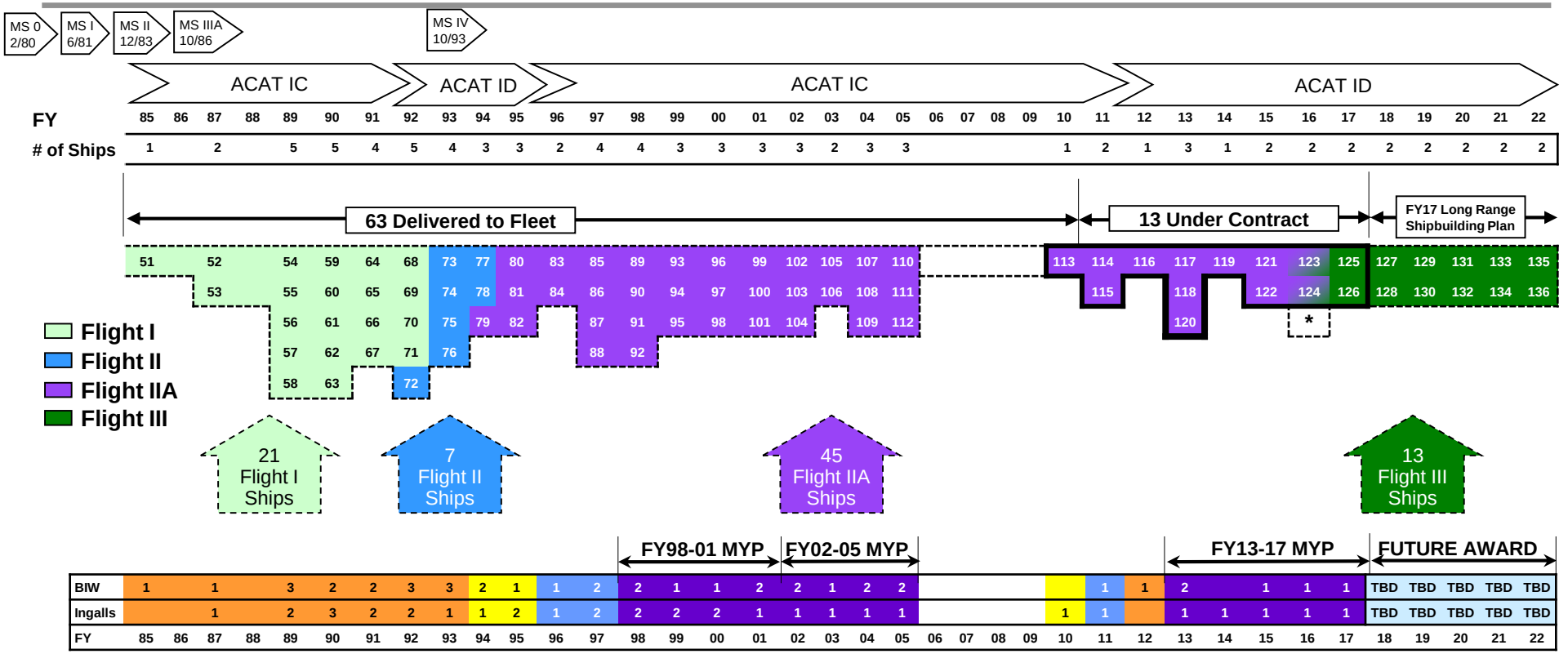
PMS 400D

Agenda

- **DDG 51 Class Shipbuilding Profile**
- **DDG 113 – 121 Production Status**
- **Flight III Introduction**
- **Flight III Design Review Progression**
- **Flight III Core IAMD Change Status**
- **Base FY16 and Follow Changes**
  - AN/SPY-6(V) (AMDR-S) Overview/Status
  - AEGIS Combat Systems
  - Electrical Plant Upgrade Status
  - AC Plant Upgrade Status
  - Weight and KG Modification Status
- **Technical Performance Measures**

DDG 51 Class Shipbuilding Profile



ACQUISITION STRATEGIES	
Competition For Work	27
Negotiated Allocation	7
Competition for Profit (PRO)	8
Multi-Year (PRO)	34
TBD	10
Total	86

	DELIVERED	UNDER CONTRACT	TOTAL
BIW	34	7	41
Ingalls	29	6	35

*** Congress authorized and appropriated incremental funding for an additional DDG 51 class ship in FY16 which the Navy plans to procure in the Flight III configuration pending negotiations and receipt of FY17 appropriations. Hull numbers will also be determined based on negotiations and FY17 appropriations**

DDG 113, 114, 117, 119, 121 Status (HII)

- **DDG 113 (Delivered)**
  - Trial ALPHA completed 29 Aug 2016
  - Trial BRAVO completed 26 Oct 2016
  - Trial CHARLIE completed 04 Nov 2016
  - Delivery completed 7 Dec 2016

- **DDG 114 (88% complete)**
  - ALO completed 06 Jun 2016
  - MELO planned Jan 2017
  - ALPHA/BRAVO trials planned May 2017

- **DDG 117 (61% complete)**
  - Lay Keel completed 11 Sept 2015
  - Launch completed 11 Nov 2016
  - ALO planned July 2017

- **DDG 119 (37% complete)**
  - Start Fab completed 06 July 2015
  - Lay Keel completed 23 May 2016

- **DDG 121 (19% complete)**
  - Start Fab achieved 27 Apr 2016
  - Lay Keel planned Feb 2017

DDG 115, 116, 118, 120 Status (BIW)

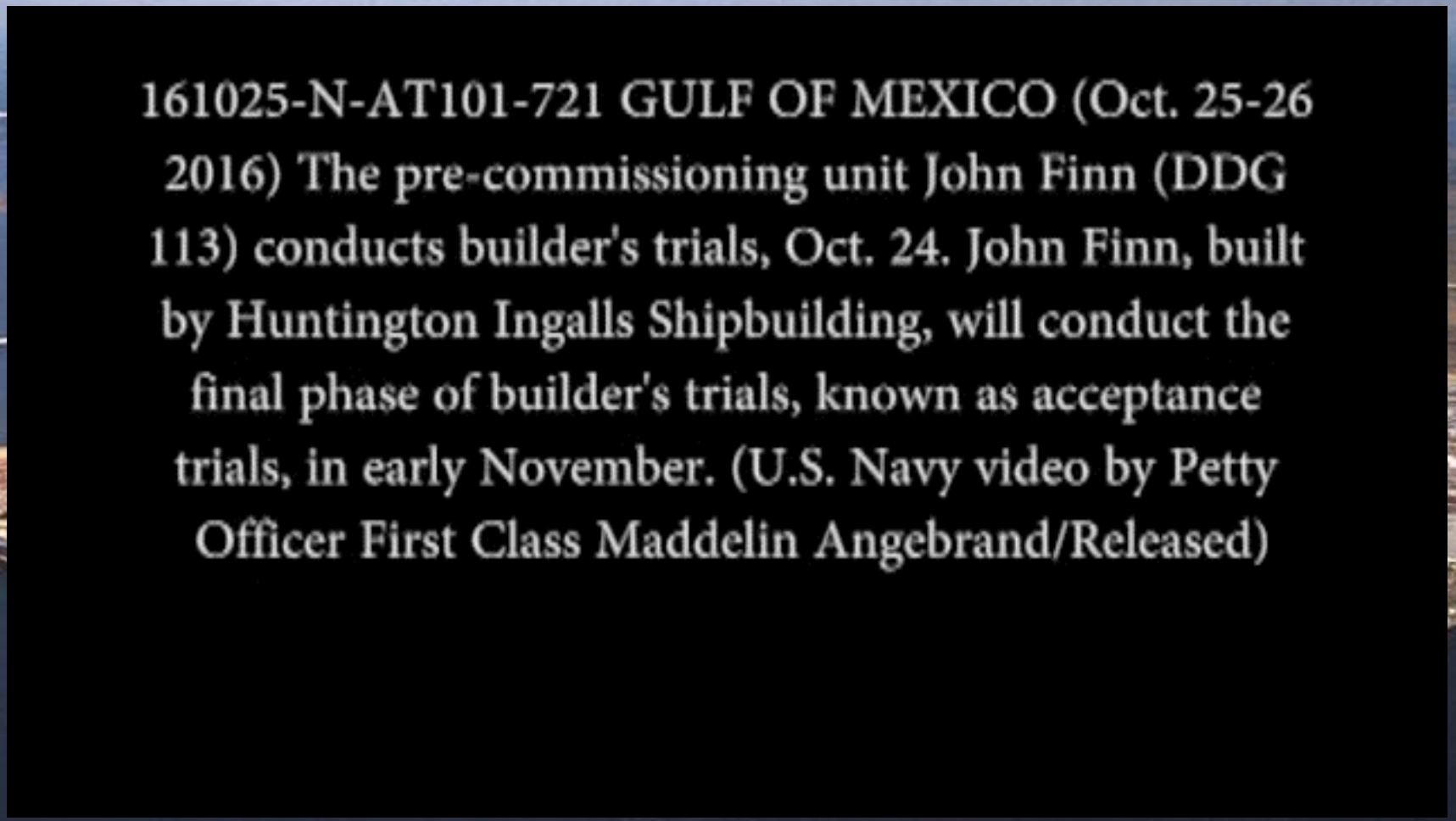
- **DDG 115 (98% complete)**
  - Trial ALPHA completed 18 Oct 2016
  - Trial BRAVO completed 17 Nov 2016
  - Trial CHARLIE completed 16 Dec 2016
  - Delivery planned Feb 2017

- **DDG 116 (75% complete)**
  - Lay Keel completed 06 Nov 2015
  - ALO scheduled Apr 2017
  - Launch scheduled Apr 2017

- **DDG 118 (20% complete)**
  - Start Fab completed Aug 2015
  - Lay Keel planned Feb 2018

- **DDG 120 (3% complete)**
  - Start Fab milestone achieved on 11 Sep 2016
  - Lay Keel planned Jan 2019

DDG 113 Bravo Trials Video



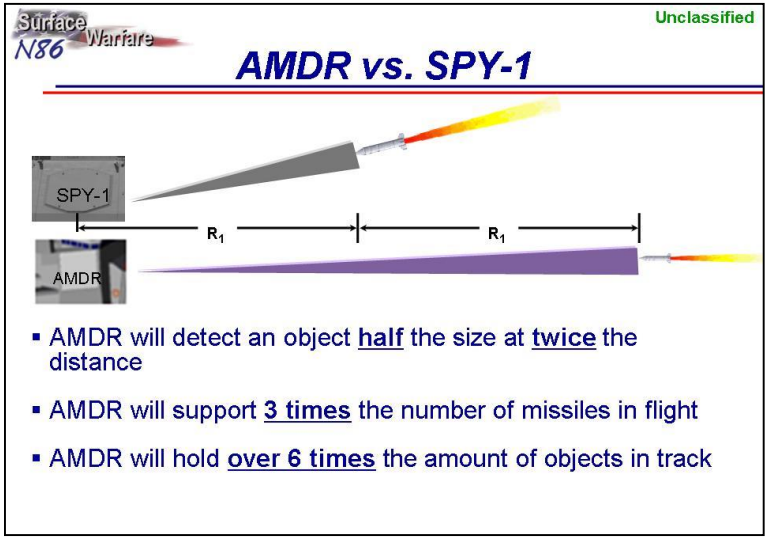
Flight III Introduction

- **Flight III with AN/SPY-6(V) (AMDR-S) employs a Digital Beamforming (DBF) architecture**
  - More than doubles the range over SPY-1 or VSR
  - Provides advanced robust BMD detection & discrimination
  - Efficient, precise search & track using multi-beam operation

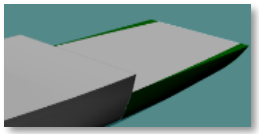
- **SPQ-9B is proven phased-array technology**
  - Robust AAW horizon detection
  - Supports Navigation
  - Potential Upgrades for Periscope and Mine Detection

- **Suite coordination compensates for challenging multi-mission environments**

- **Open systems approach allows AN/SPY-6(V) to scale & adapt to future platforms**



Flight III Changes



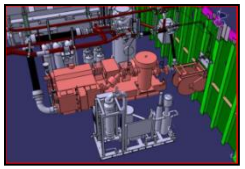
Full Load Operational Displacement Enhancement System (FLODES)

Enclosures
- Added starboard enclosure and stacked RHIBs

AN/SPY-6(V)1; AMDR-S SPY+15dB
- 14.1 ft x 13.6 ft x 5 ft Array Structure
- Replaces AN/SPY-1D(V)

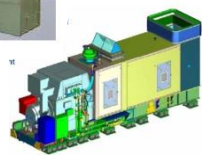
BL 10 / TI 16 for Flight III Upgrade to AWS
- Remaining obsolescence and roll-down impact changes are TBD

Water Mist
- Baseline change to install Water Mist in Machinery Spaces to replace Halon 1301

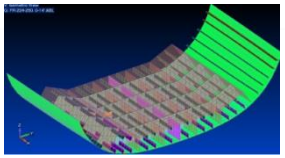


AC Plant
- 5 x 300 Ton HES-C AC Plants Replacing 5 x 200 Ton AC Plants

4160VAC Electric Plant
- 3 x 4MW, 4160 VAC SSGTGs replacing 3 x 3MW, 450 VAC SSGTGs
- Add transformers, PCMs, modified switchgear
- Modified controls for MCS and MFMs



Heptafluoropropane (HFP)
- HFP in Gas Turbine Modules & Flammable Liquid Storerooms



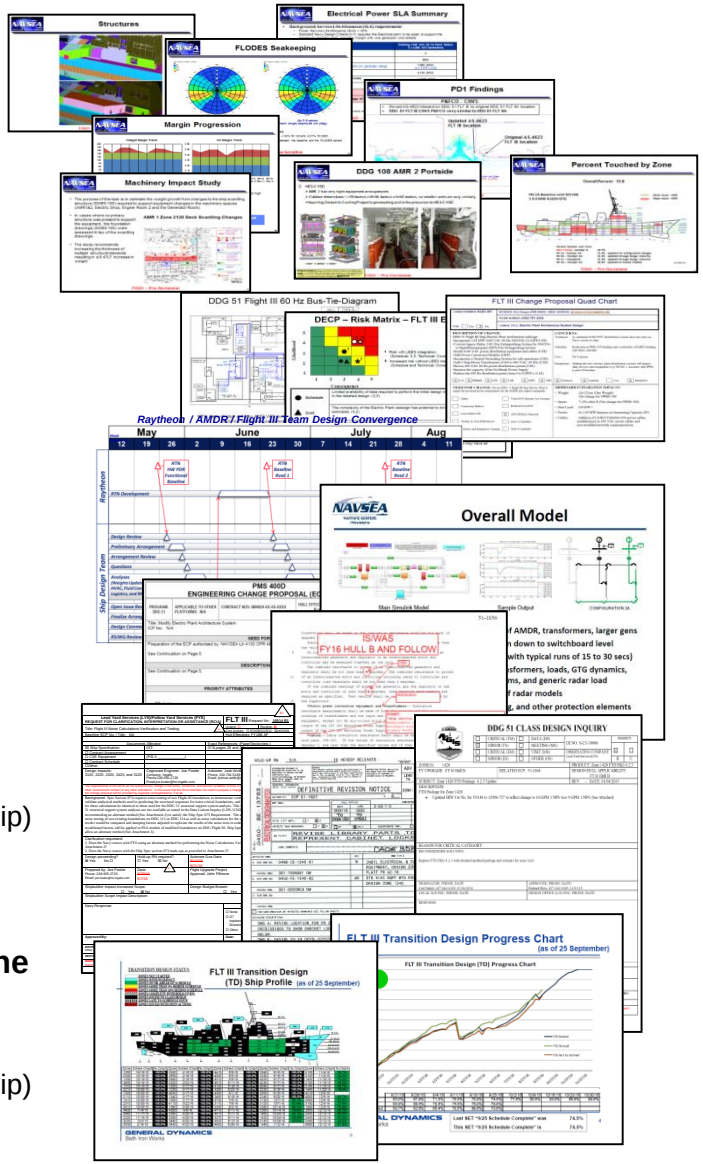
Increased Innerbottom Scantlings
- Adds 90 LT to improve KG

- **Capability Increase**
- **Enabling Changes**
- **Other Changes**

Habitability Changes and roll-down impacts to incorporate AN/SPY-6(V)1 and equipment

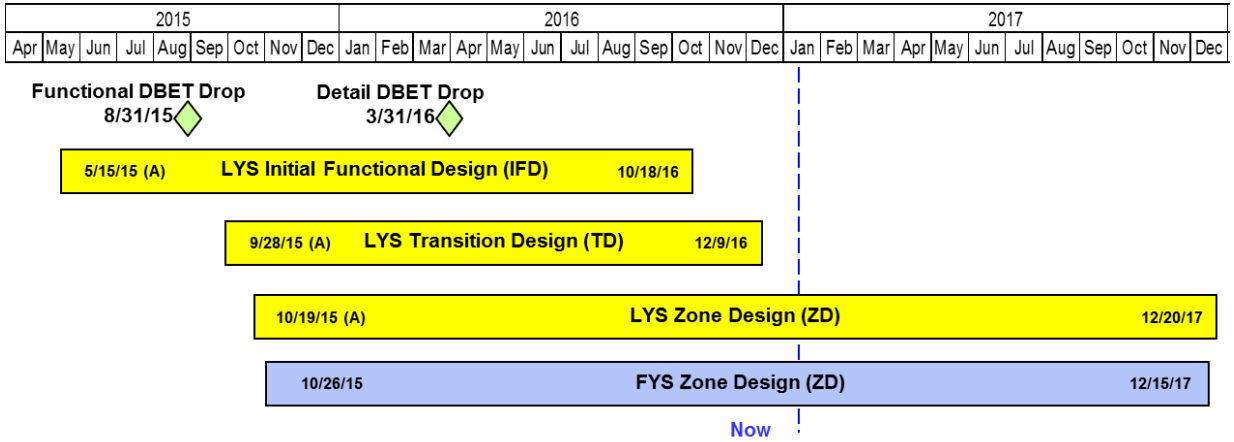
Design / Review Progression (2012 – 2016)

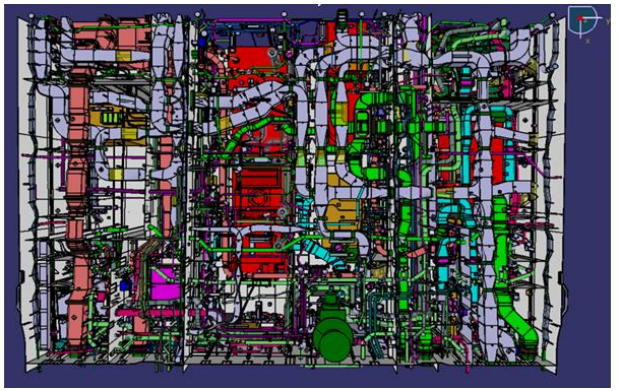
- ✓ **Preliminary Design PD 1 is complete** ***[June 2012 – Dec 2013]***
  - Completed PD1D IPR #4 on 11 December 2013
  - Data for Draft Engineering Change Proposals (DECPs)
- ✓ **Total Ship Design Review (TSDR); SEA 05 approval of Flight III Feasible Baseline** ***[March 2014]***
- ✓ **Gate 4/5 ECP CCB concurrence** ***[March 2014]***
- ✓ **Flight III DAB approval to proceed with Detail Design** ***[June 2014]***
- ✓ **PD 2 Total Ship Design Refinement** ***[December 2013 – October 2014]***
  - Programmatic Decision – proceed with available vendor data
  - AMDR HW PDR
  - Balanced / Integrated Design (Flight III Functional Baseline)
- ✓ **CD 2 DECP Development** ***[April 2014 – October 2014]***
  - Technical Data Package to support Change Package RFP
- ✓ **System Functional Review (SFR); SEA 05 approval of Flight III Functional Baseline** ***[October 2014]***
- ✓ **CD 3 ECP Development Oversight** ***[November 2014 – August 2015]***
  - DAB ADM specifying Change Package / Biddable Technical Data Package
    - TWH Approved Ship Spec change packages & Flight III Allocated Baseline (total ship)
- ✓ **Preliminary Design Review (PDR); SEA 05 approval of Flight III Allocated Baseline** ***[September 2015]***
- ✓ **Critical Design Review (CDR); SEA 05 approval of Flight III Product Baseline** ***[November 2016]***
  - Continue with Government oversight of Design Agent Detail Design effort
    - TWH Approved Ship Spec change packages & Flight III Allocated Baseline (total ship)



Flight III Design / Review Progression

- Flight III Preliminary Design Review (PDR) complete September 2015
- Critical Design Review (CDR) complete November 2016
- Initial Functional Design and Transition Design complete; Zone Design in progress; Will be complete before start of construction



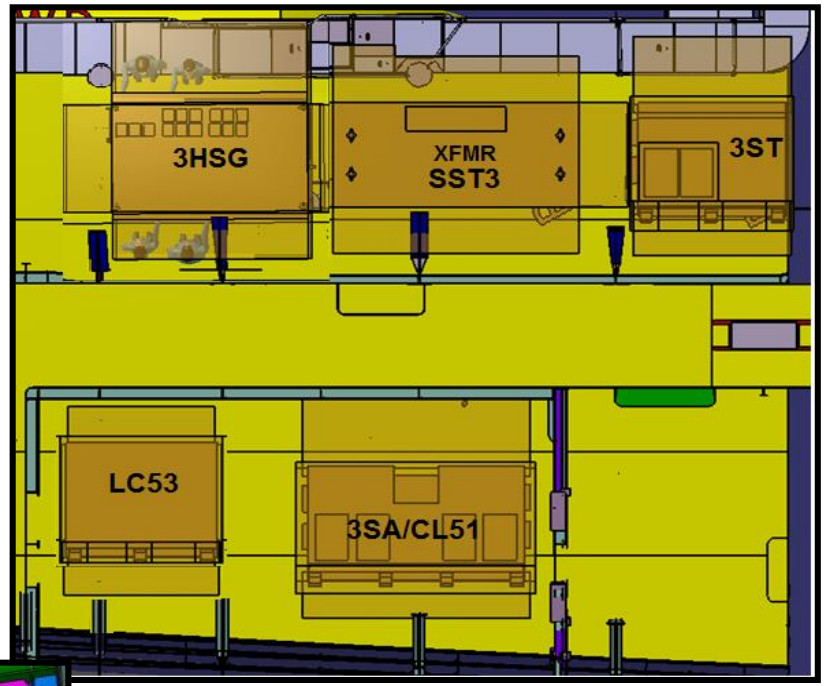


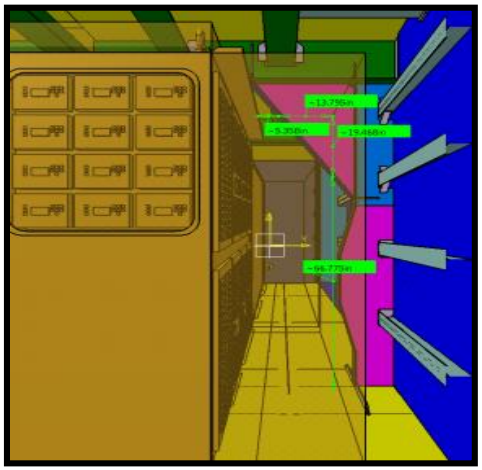
Flight III Design Progressing to Support Start of Construction with a Mature / Stable Design

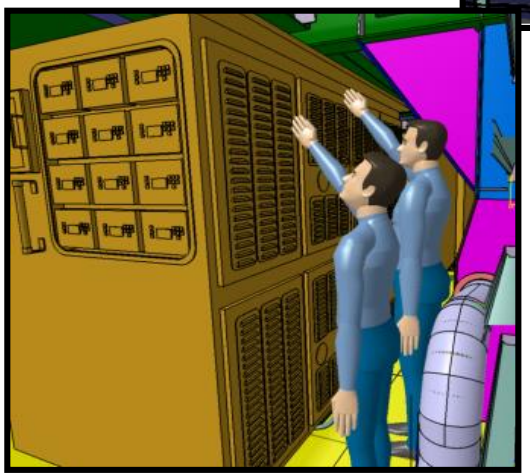
Transition Design Focus: Equipment Arrangements

Equipment Access & Arrangements

- Space constraints and Equipment Access Envelopes complicated the arrangements
- Work to minimize exceptions and maximize safety of access was a primary focus for all stakeholders and regular topic at the weekly Electric Plant Design Working Group (EPDWG) sessions
- Tailored Switchboard internal component locations to allow for improved access opportunities for initial safety voltage verification, grounding, and maintenance conditions meeting NSTM 300 requirements







The EPDWG continues to leverage Subject Matter Experts in Electrical Systems across the Total Ship stakeholder communities to collaboratively solve design and technical issues before they become cascading problems

AN/SPY-6(V) System Overview

NAVSEA NAVAL SEA SYSTEMS COMMAND

PEO SHIPS

Array Subsystems (4X)

Radiator (37x)

Radar Modular Assembly (RMA) (37x)

Calibration ¼ RMA (2x)

Inertial Navigation System (1x)

4 Faces
37 RMAs per Face
144 T/R Modules per RMA
5,328 T/R Modules per Face

AN/SPQ-9B Tracks

I&Q Data

Signal & Data Processing Subsystems

Array Control

Beams

Detections

Tracks

Combat System

SIM

Antenna Interface

Digital Beamforming

Real Time Simulator

Digital Signal Processing

Radar Control Processor / Radar Suite Controller

Power Subsystems

208VAC

Uninterruptable Power Supply

Battery

Array Power Distribution

Main Power Distribution

1,000VDC

1,000VDC

450VAC

1,000VDC

Ship's Power

Common Array Cooling System (2 Units)

Cooling Subsystems

(4 Units)

(1 Units)

EDM Array in Far Field Range

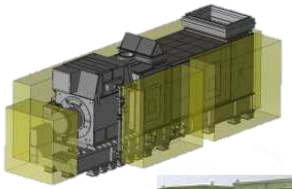
PMRF Advanced Radar Detection Lab (Kauai, HI)

Summary / Way Forward

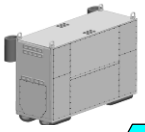
- ✓ System CDR - Apr 2015
- ✓ NFR testing completed - May 2016
- ✓ EDM Array installed at PMRF - Jun 2016
- ✓ Tracking satellite and air targets - Oct 2016
- ✓ LLMs on order for 1st DDG 51 FLT III - 13 Dec 2016
- ❑ Testing at PMRF in progress

Base FY16 and Follow Changes (Flight III)

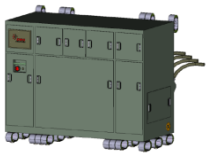
4160VAC Electric Plant

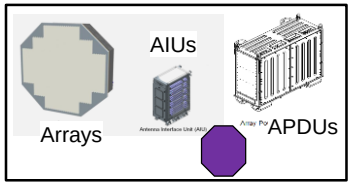


MPDU

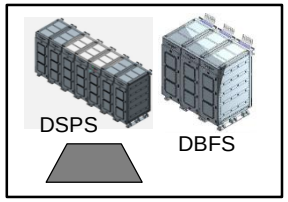


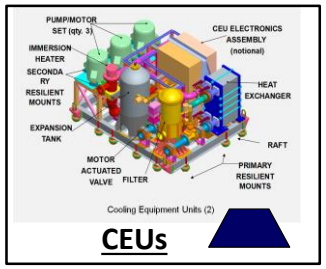
PCMs



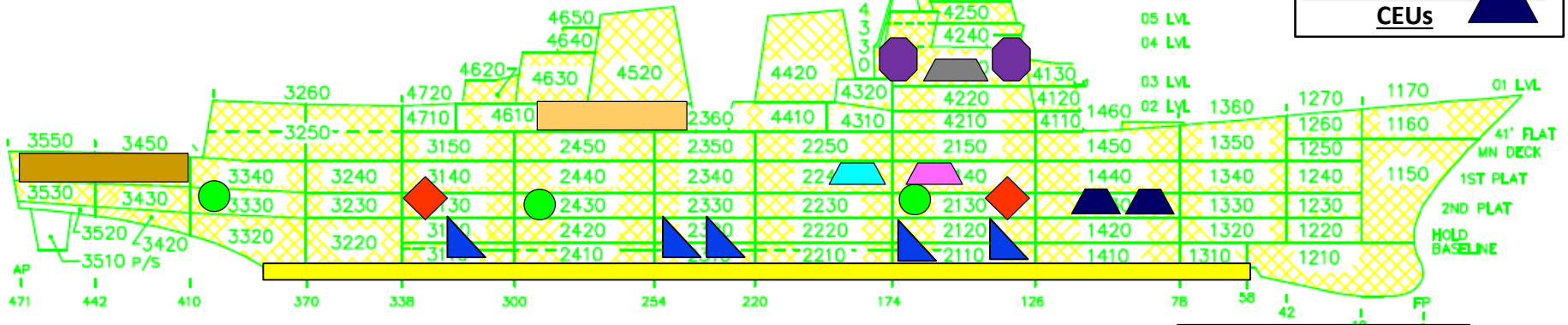


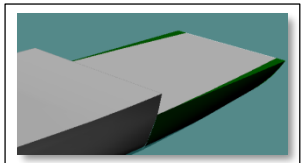
AN/SPY-6(V) SPY+15dB





CEUs

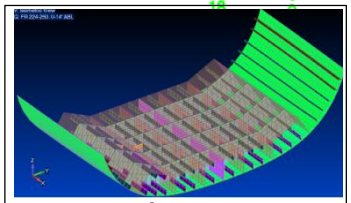




FLODES

STBD Enclosure

HES-C AC Plant



Inner bottom Structure

AEGIS Combat System Evolution

Improved Multi Mission & IAMD

Programmatic Vision, Pending Funding Decisions

AEGIS B/L 9

Integrated Air & Missile Defense

SPY-1

Radar
- SPY-1 Open Architecture
- MMSP
- AAW, BMD & IAMD Modes

Combat System
- AEGIS OA
- BMD 5.0
- NIFC-CA
- I/O Trident Warrior
- TI-12 Equipment

Missiles
- ESSM, SM-2
- SM-3 BLK IA/IB
- SM-6

EW
- SLQ-32

Mission Planning
- BMD 5.0 Mission Planner

Fielding
- AMOD CG / DDG
- New Construction DDGs
- AEGIS Ashore

ACB-16 B/L 9

Improved Coordination of Netted Force Operations to Counter Mid-Term Threats

SPQ-9B

SPY-1

Radar
- Layered Defense Sensor Integration –SPQ-9B

Combat System
- AWSC Integration
- Combat ID Improvements (IFF Mode 5/S)
- C5I Upgrades (CANES, JTT-M, GCCS-M, CDL, CDLMS)
- Improved BMD with EOR and SBT

CIWS

Missiles
- ESSM, SM-2
- SM-3 BLK IA/IB
- SM-3 BLK IIA
- SM-6

EW
- SEWIP BLK II & III Integration (w/RDDL)

SEWIP BLK II

ASW
- Periscope Detection (SPQ-9B)
- Open ASW Interface with MH-60R Integration

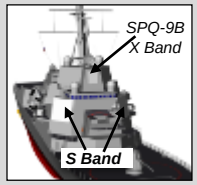
Readiness
- Total Ship Training Capability

Fielding
- AMOD CG / DDG
- New Construction DDGs
- AEGIS Ashore

ACB-20 B/L 10

Improved Joint Weapon & Sensor Coordination to Counter Far-Term Threats

AMDR



Radar
- AMDR, SPY-6, S Band

Combat System
- AMDR SPY-6 Ships
- Improved IAMD raid handling capability
- BMD 6.X
- Multi-Sensor Integration
- PLA Components & Arch
- Sensor Coordination
- TI-16 Equipment

SPY-1

Missiles
- ESSM, SM-2
- SM-3 BLK IA/IB
- SM-3 BLK IIA
- SM-6

Multi –Ship IAMD Coord.

EW
- AN/SLQ-32(V)6, SEWIP BLK II
- SEWIP BLK III (future)

Mission Planning
- Advanced AAW & BMD Mission Planner

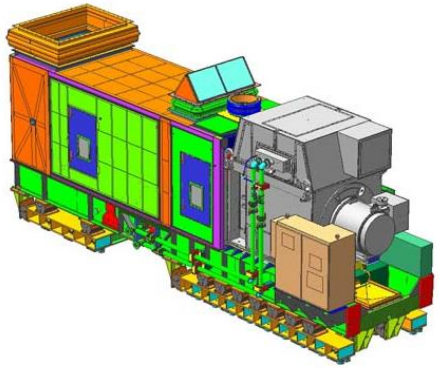
Fielding
- DDG Flight III
- AEGIS Ashore Upgrade

Integrated Air & Missile Defense
- Multi-Mission Radar Utilization
- Active missile with OTH Targeting
- Improved Fleet Interoperability

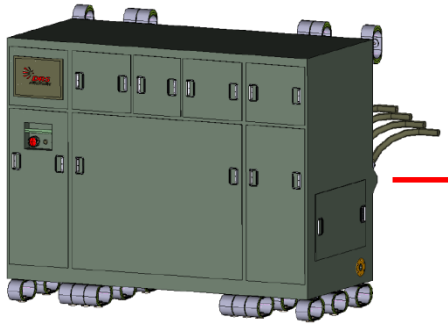
Improved Coordination of Netted Force Operations to Counter Mid-Term Threats
- Multi-Sensor Coordination
- Extended Range BMD Engagement
- Multi-Ship Engagement Coordination
- Increased ASW/SUW Surveillance
- Deployment of Advanced EW
- Coordinated IAMD Tracking

Improved Joint Weapon & Sensor Coordination to Counter Far-Term Threats
- Advanced Force Level Resource Management (Radar/EW)
- Integrated Active and Electronic Defense
- IAMD Mission Planning
- Joint Integrated Fire Control

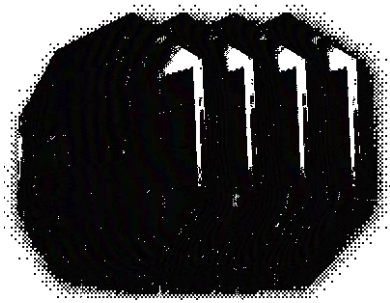
Electric Plant Architecture

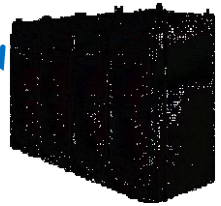


4160 VAC Power Generation



1000 VDC Power Conversion in PCM for AN/SPY-6(V) Arrays

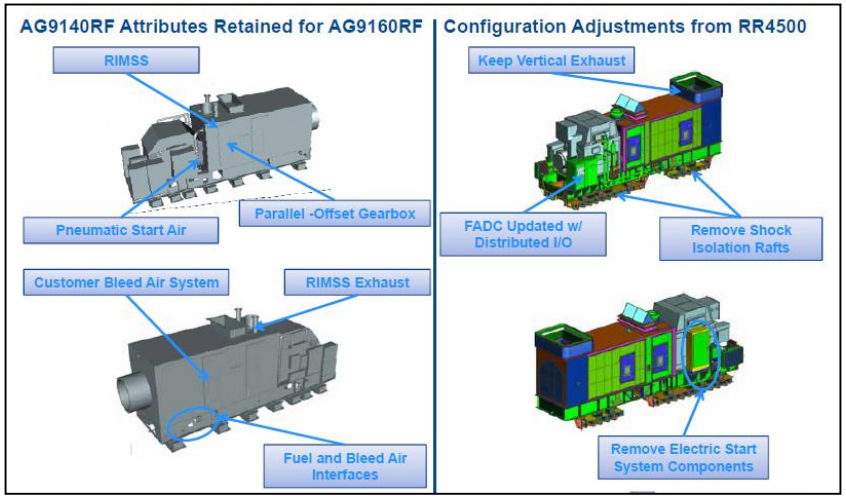


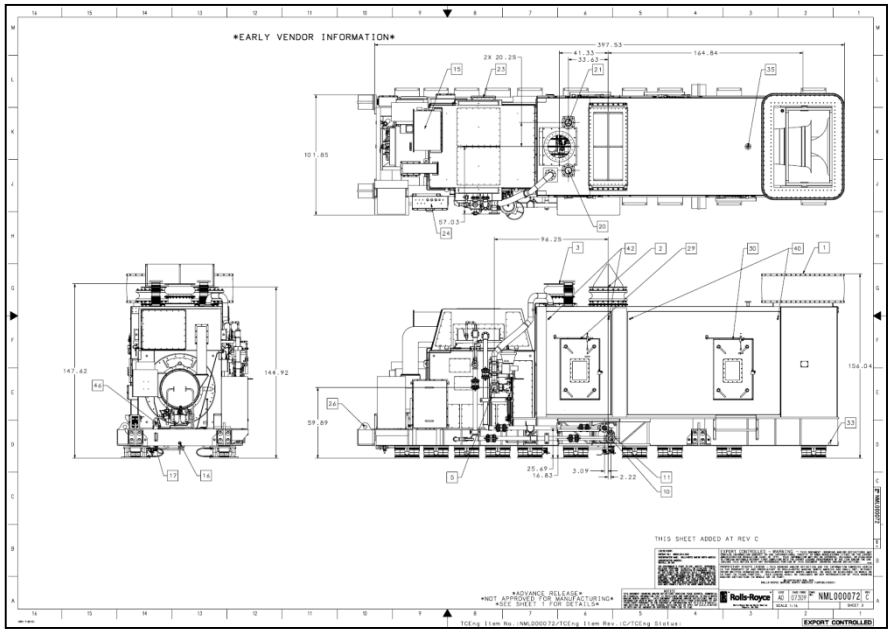


4160/450VAC Step Down Transformer for Legacy ZEDS Distribution

Ship Service Gas Turbine Generator (SSGTG)

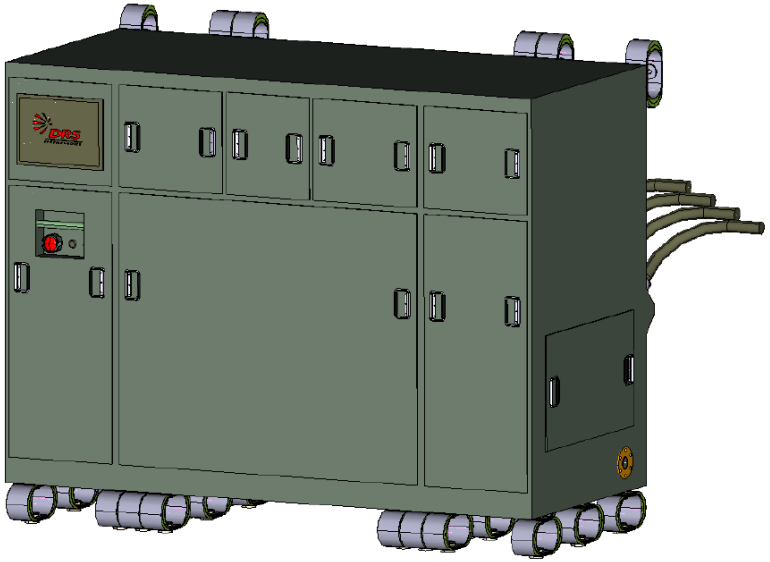
- **Based on RR4500 (DDG 1000 ATG)**
- **PMS 320 managing effort**
  - Prime is Rolls Royce
- **Generates 4.0MW electrical power**
- **Designed to meet DDG 51 MIL-STD shock, noise, vibe, & generator performance (i.e. THD)**
- **Dual Start System - Air and RIMSS**
- **Full Authority Digital Control (FADC)**
- **Provides 4160 VAC to:**
  - PCM for 1000 VDC
  - Ship Svc Transformers (SST) for 450 VAC
- **Completed PDR: September 2015**
- **Completed CDR: March 2016**
- **First Delivery to LBES: September 2017**

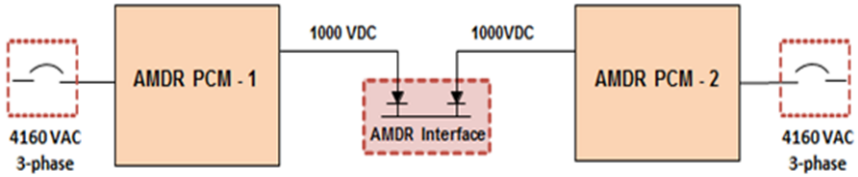




Power Conversion Module (PCM)

- **4160 VAC to 1000VDC at 1.4 MW**
- **2 per ship**
- **Contract Awarded to DRS; 11 Sep 14**
- **PDR: March 2015**
- **CDR: September 2015**
- **Current Status:**
  - LRIP Units support multiple locations for Electrical, Environmental, and Flight III Integration Testing
  - Awarded 2 LRIP Units for CSEDS
  - Awarded 2 LRIP Units for LBES





Two continuous sources of AN/SPY-6(V) Power

DMA Overview

DMA Study Tasking

- **Study = 6 tasks: (Final Report Dates)**
  - ✓ **Task 1: Model Prep & development (January 2014)**
  - ✓ **Task 2: Power Transient (July 2014)**
  - ✓ **Task 3: Power Quality (Dec 2014)**
  - ✓ **Task 4: Power Continuity (May 2016)**
  - ✓ **Task 5: Electric Power Survivability (November 2016)**
  - – **Task 6: DMA Final report (January 2017)**

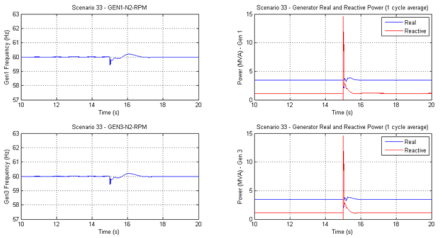
Summary of Dynamic Modeling

Objective is to de-risk FLT III upgrade

– (but not a replacement for operational testing)

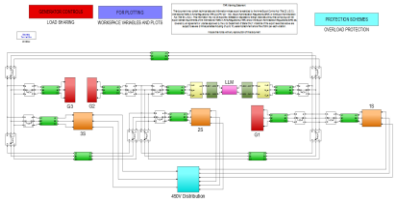
Uses dynamic modeling to examine situations that are taxing to the power system:

– Shifts in power
– Startup of equipment
– Losses of equipment
– Radar operations
– Faulted conditions

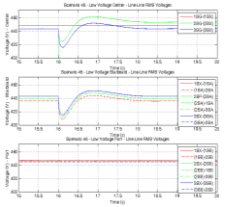


Example: Generator Frequency and Power During Faulted Condition

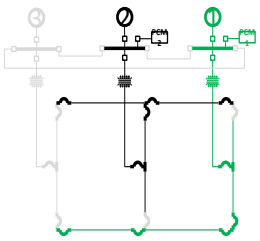
Overall Model



Main Simulink Model



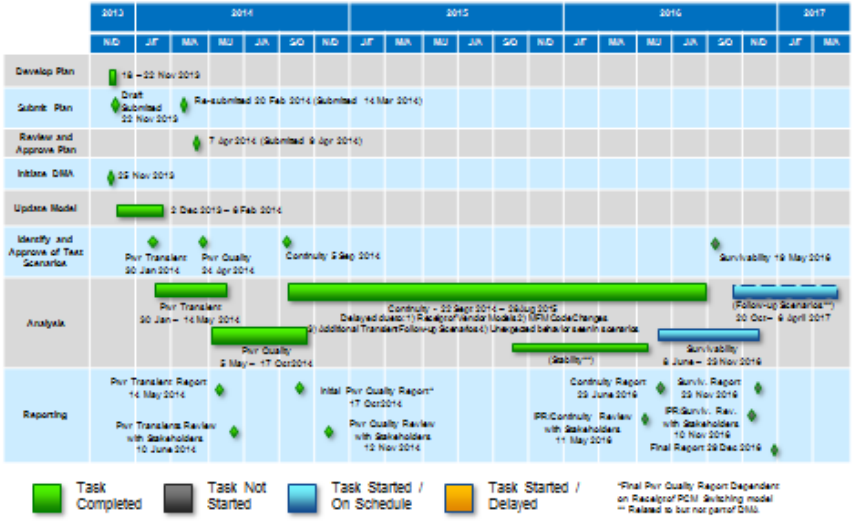
Sample Output



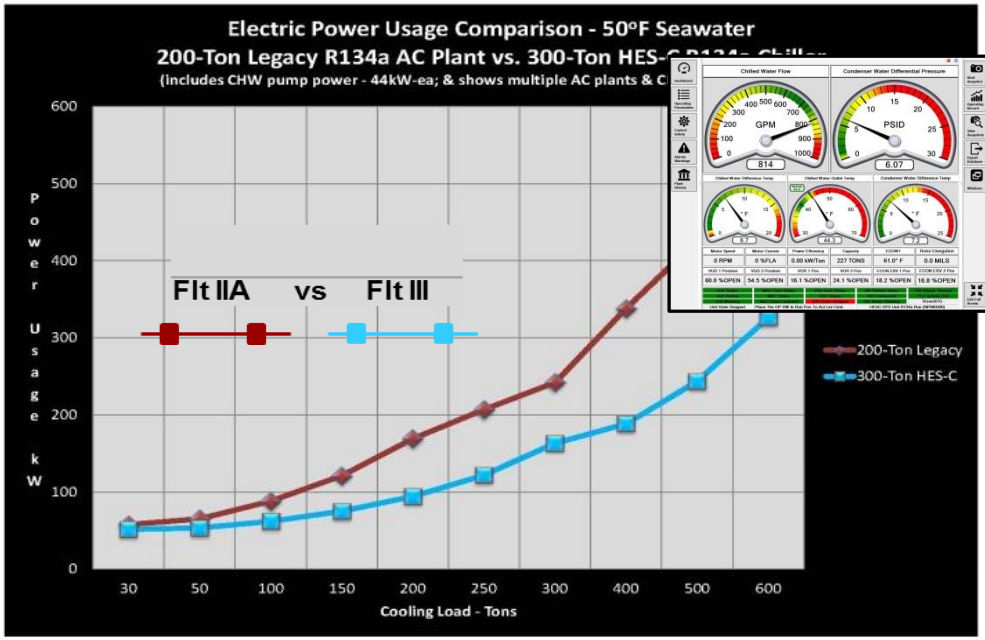
CONFIGURATION 2A

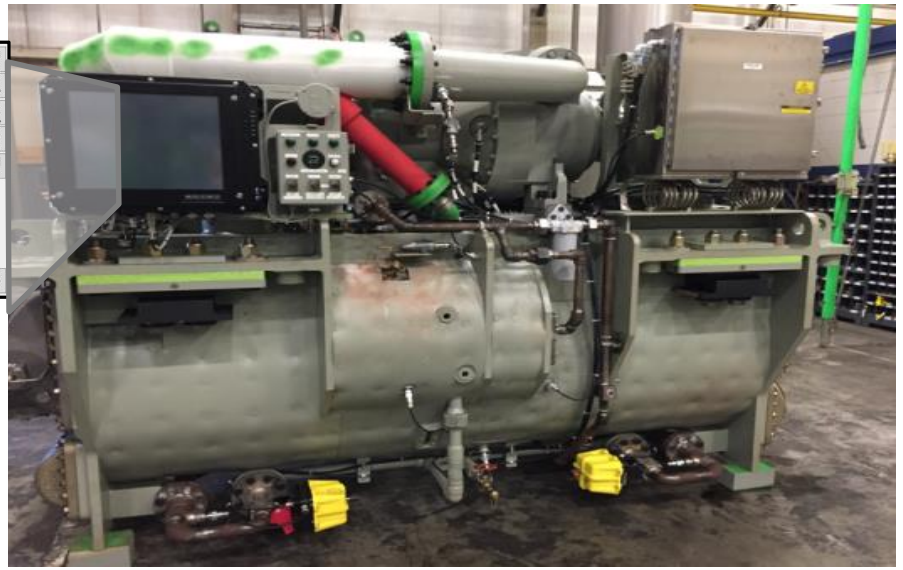
- **FLT III System similar to FLT IIA – Addition of AMDR, Xformers, larger gens**
- **Model covers HV and LV (4160/450) system down to switchboard level**
- **Matlab Simulink model (timestep of 50µs, w/ typical runs of 15 to 30 secs)**
- **Base model includes: Sources, cabling, transformers, loads, GTG dynamics, paralleling controls, bus transfer mechanisms, and generic radar load**
- **Power quality analysis included a variety of radar models**
- **Continuity analysis adds load shed, relaying, and other protection elements**

DMA Tasking & Review Schedule



HES-C 300 Ton A/C & VSD

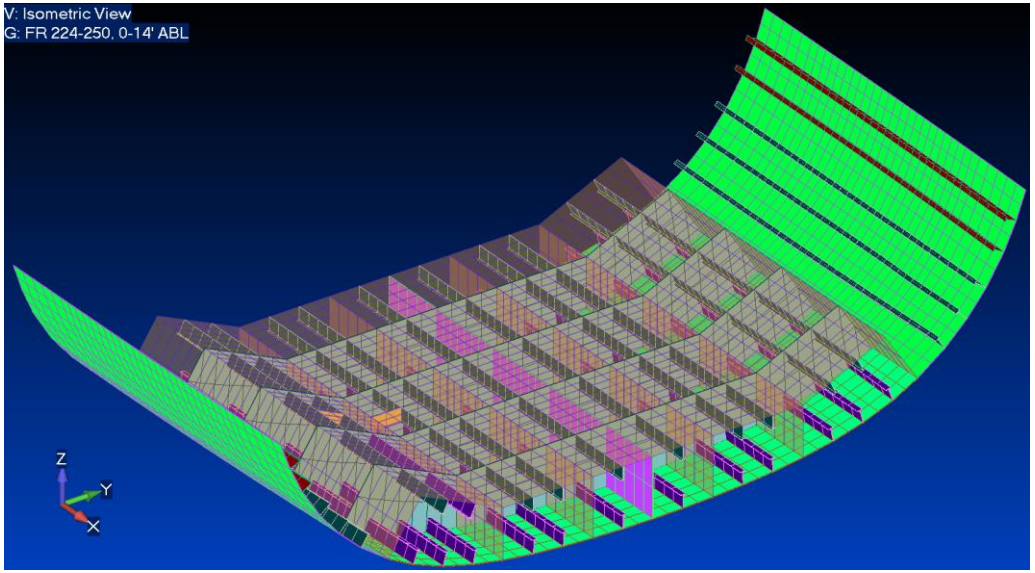


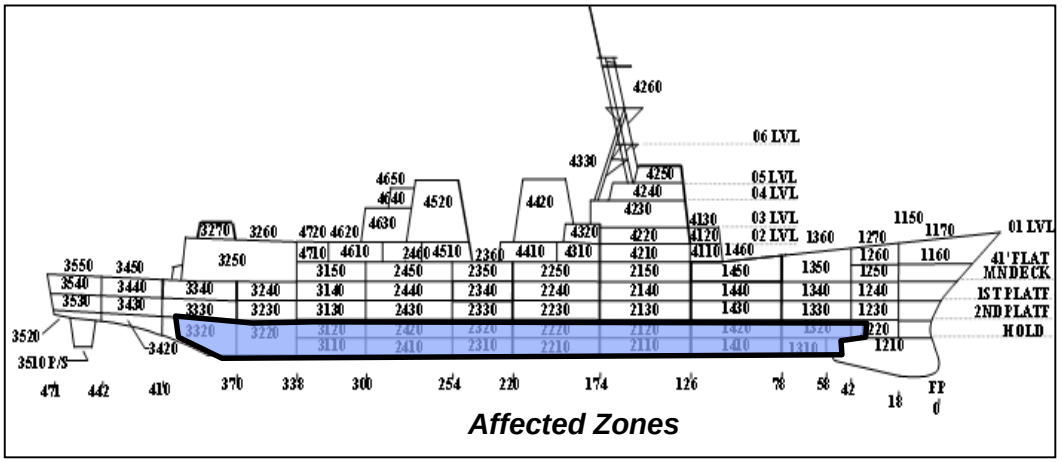


- **High Efficiency Small Capacity (HES-C) with Variable Speed Drive (VSD)**
  - 2 Stage compressor with oil-free magnetic bearings, high speed Permanent Magnet Motor (PMM)
  - Mates to legacy shell
  - Variable speed drive to reduce in-rush current, improves reliability
  - VSD necessary to achieve efficiencies
  - Chiller First Article Test (FAT) ongoing (vibration and shock testing)

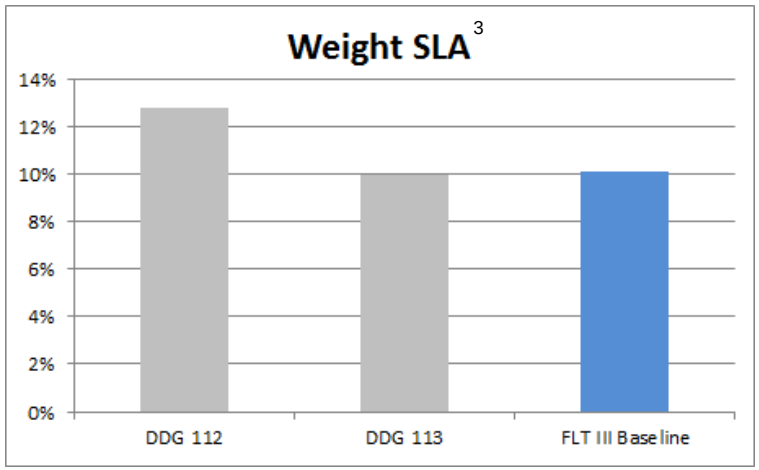
Inner bottom Structure

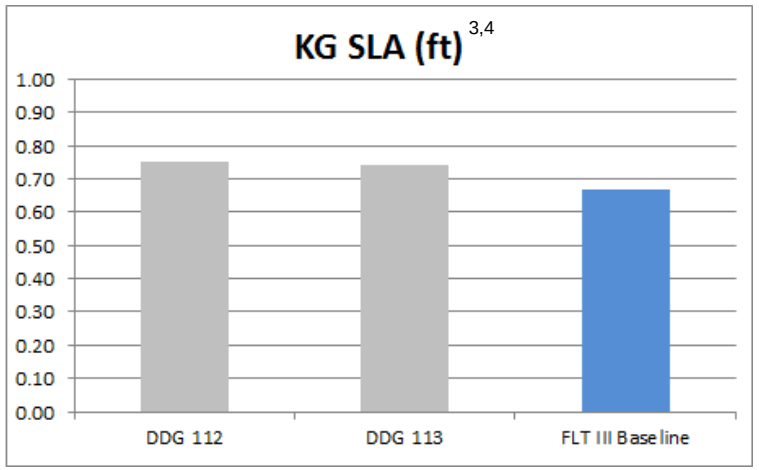
- **Purpose:**
  - Increase thickness of inner bottom structures to lower VCG and increase KG SLA
    - Add 90 Ltons steel
    - Reduces VCG approx. 0.1 ft
- **Secondary benefits:**
  - Increases hull strength
  - Reduces Effects of Corrosion
- **Addition of 90LT to reduce KG and provide TCG correction**
  - Increased plate thickness of port side B-Strake and C- Strake
  - Increased plate thickness of A-Strake (P&S), keel and CVK
  - Increased thickness of L2 and L5 longitudinal girders, (P&S)

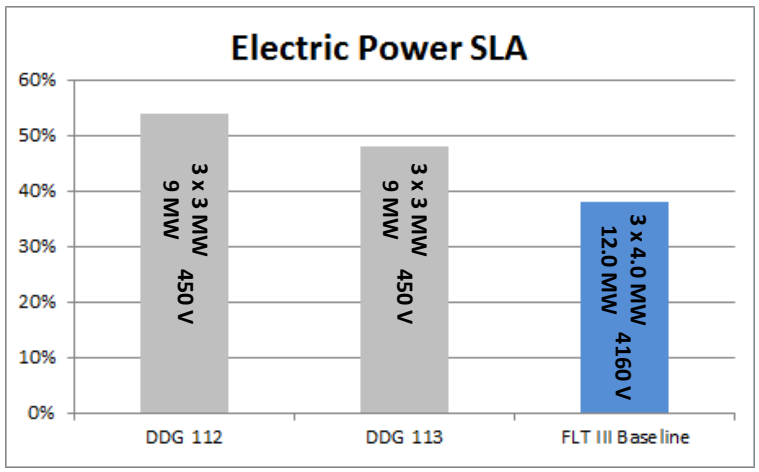


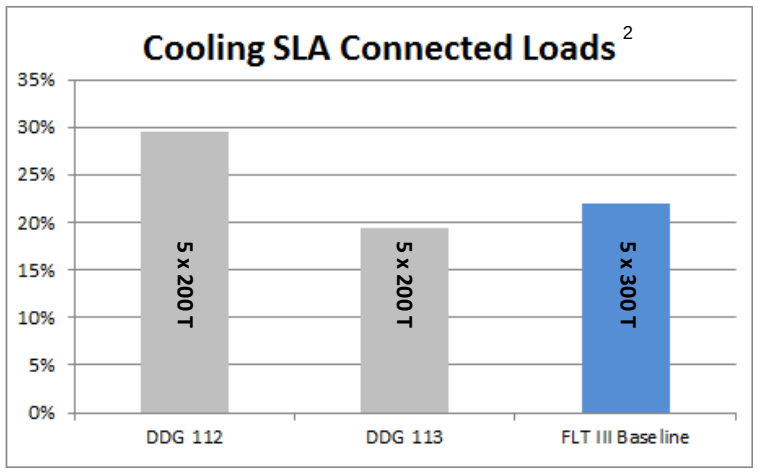


Flight IIA – Flight III
Service Life Allowance (SLA) Comparison





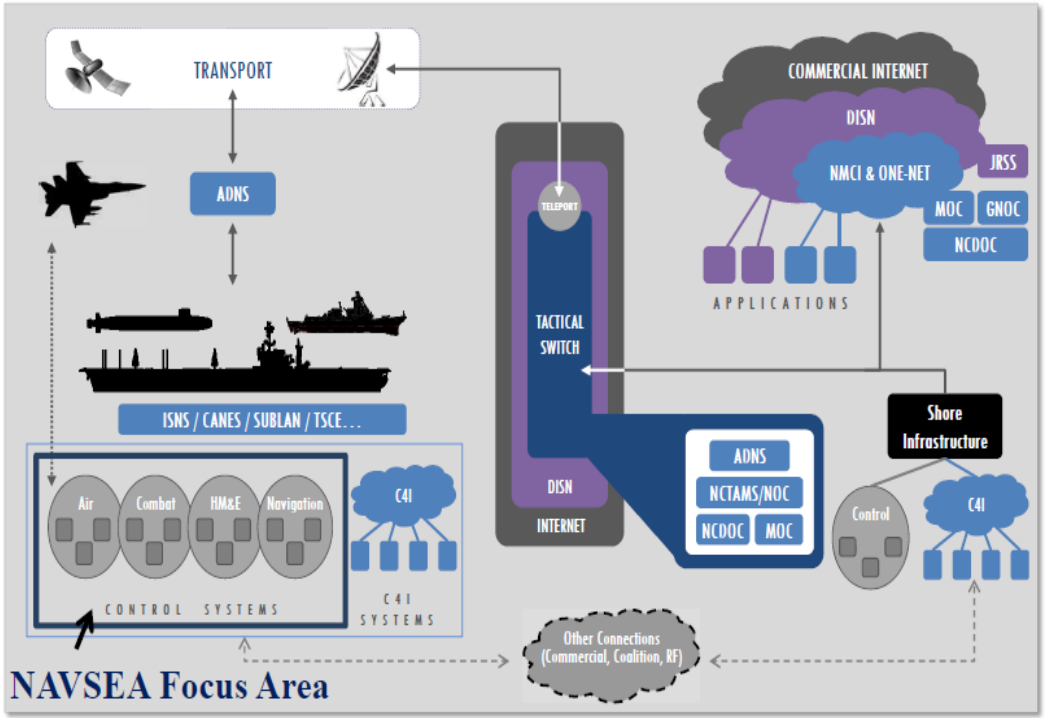




Notes:
1. – *FY10 (DDG 113) values are based on vendor data, out year values are projections based on Not to Exceed Estimates.*
2. – *Power & Cooling SLAs calculated relative to Connected Load.*
3. – *DDG 112 is based on a build up from the DDG 108 inclining. The DDG 113 was developed during the MYP Ship Impact Assessment. The FLT III KG is based on the CB3B Full Load Displacement estimate that contains 0.39 ft of KG margin. PD/CD consumed throughout design and construction as well as the FLODES enhancement.*
4. – *The DDG 113 KG is a projection, based on the margin consumption evaluated during the DDG 108 inclining.*

Cyber Security

- **With ever-increasing awareness to cyber threats, Flight III is leveraging from the near term mitigations being implemented into the fleet, as well as implementing new Cybersafe requirements through the Flight IIA baseline**



Goal: Protect, detect, respond and recover from a cyber attack to our Control Systems

Category	Information System	Control System
Performance Requirements	• Non-real-time • High delay and jitter may be acceptable • Processing can be non-deterministic	• Real-time • System behavior and response time needs to be consistent (i.e., deterministic) and is time-critical • High delay and/or jitter is not acceptable
Availability Requirements	• Responses such as rebooting are acceptable • Availability deficiencies can often be tolerated, depending on the system's operational requirements	• Many Navy Control systems require high availability • Availability requirements may necessitate redundant systems • Outages must be planned and scheduled days/weeks in advance • High availability requires exhaustive pre-deployment testing
Communications	• Standard communications protocols used • Primarily wired networks with some localized wireless capabilities • Typical IT networking practices	• Both proprietary and standard communication protocols used • Ship control systems networks are complex and require the expertise of both network and control engineers
Change Management	• Software changes are applied in a timely fashion in the presence of good security policy and procedures. The procedures are often automated.	• Software changes must be thoroughly tested and deployed incrementally throughout a system to ensure that the integrity of the control system is maintained. Navy control system outages must be planned and scheduled days/weeks/months in advance.
Managed Support	• Allow for diversified support styles	• Service support is usually via a single vendor
Component Lifetime	• Lifetime on the order of 3-5 years	• Lifetime on the order of 15-20 years

NSWC / NUWC Cyber Security Priorities

- **Hull Mechanical & Electrical (HM&E):** Equipment is commercial-off-the-shelf - easily reverse engineered by an adversary, current HM&E architecture and equipment do not easily support built-in cybersecurity solutions, requires:
  - Scalable, composable, cyber-physical systems, resilience metrics, defense against insider threats, survivability of time critical systems, system / cyber state awareness, usable security
- **Navigation Systems:** Serve multiple enclaves and therefore difficult to separate into isolated enclave.
  - Presents cross boundary enclave security solution challenges.
- **Combat Systems Cyber Security:** Real time control systems with stringent latency requirements.
  - RDT&E community must develop and build combat systems that implement a defense in depth (DID) security architecture from the design phase.
- **Cybersecurity Threats:** Difficult to match known threat vectors to shipboard systems.
  - Published threats are typically focused on operating systems, software or hardware from enterprise IT systems.
- **Workforce Development:** To create an active/aggressive cyber security engineering workforce that plugs into ongoing cyber security engineering challenges and Risk Management Framework (RMF) initiatives
- **Prototyping:** Rapid deployment & employment of latest cyber security technology which includes tools, and infrastructure
- **Cyber Situational Awareness and Cyber Resiliency:** Combat, HM&E, & Navigation systems must:
  - Provide ability to notify commander when and if they were compromised
  - Identify when system is usable in full or degraded mode
  - Identify alternatives to aid the commander in completing the mission
  - Provide the ability to restore the system to a known, trusted state

5

Distribution Statement A – Approved for Public Release

Summary

- **Initial DDG 51 Restart Ships at each shipyard have completed successful trials, and first ship delivered**
- **Shipyards reestablishing serial DDG 51 production, 13 more ships on contract through FY17**
- **Flight III Detail Design efforts on track for start of construction**
- **Flight III acquisition efforts in progress with shipbuilders**

Delivering capability to the fleet for current and future missions

Questions