Development of Hull, Mechanical and Electrical Autonomy to enable Medium and Large Unmanned Surface Vessels

David Forster

April 26th

Drivers for Unmanned Vessels and Power System Candidates

Maximize availability of HM&E systems with no man-in-the-loop

- Safely operate ship systems (unmanned) with no degradation in operations
  - Operate propulsion plant in alignment with EOSS, EOCC and MLOC
- Maintenance
  - Remove non-essential maintenance actions and investigate duplex systems where possible
- Redundancy & Availability
  - Recovery of failed prime movers needs to be autonomous
  - Install redundancy as economically/volumetrically viable
  - Design-in power and propulsion capacity for future growth

SySML Solution Domain Definition

Artificial Chief Engineer® performs the unmanned execution of EOCC and EOSS

Artificial Chief Engineer® uses rules-based decision making to define the solutions

Current Naval Engineers reference documents:

- EDORM: Engineering Department Organization & Regulation Manual
- EOCC: Engineering Operating Casualty Control
- EOSS: Engineering Operating Sequencing System
- Manufacturer's Operating & Maintenance Manuals

Artificial Chief Engineer® completes the functionality of Naval Engineers

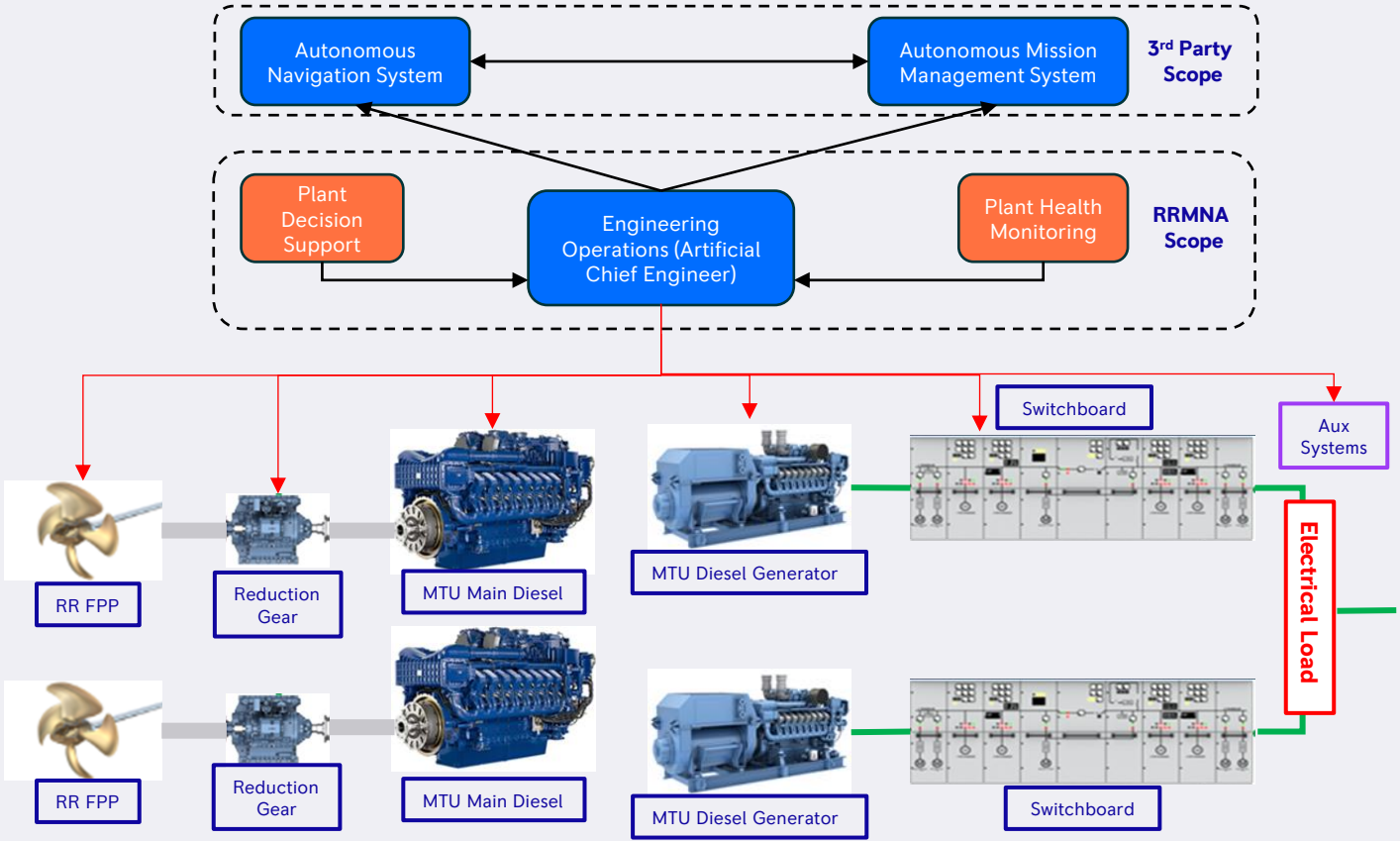
- Solutions designed for unmanned applications with streamlining and simplification embraced
- It uses existing documents as a reference point for autonomous HM&E system solution development

Autonomous Engineering Management System

Engines
- Gas Turbines
- Medium & High Speed Diesel

Propulsion
- Mechanical
- Hybrid
- Integrated Fully Electric Propulsion

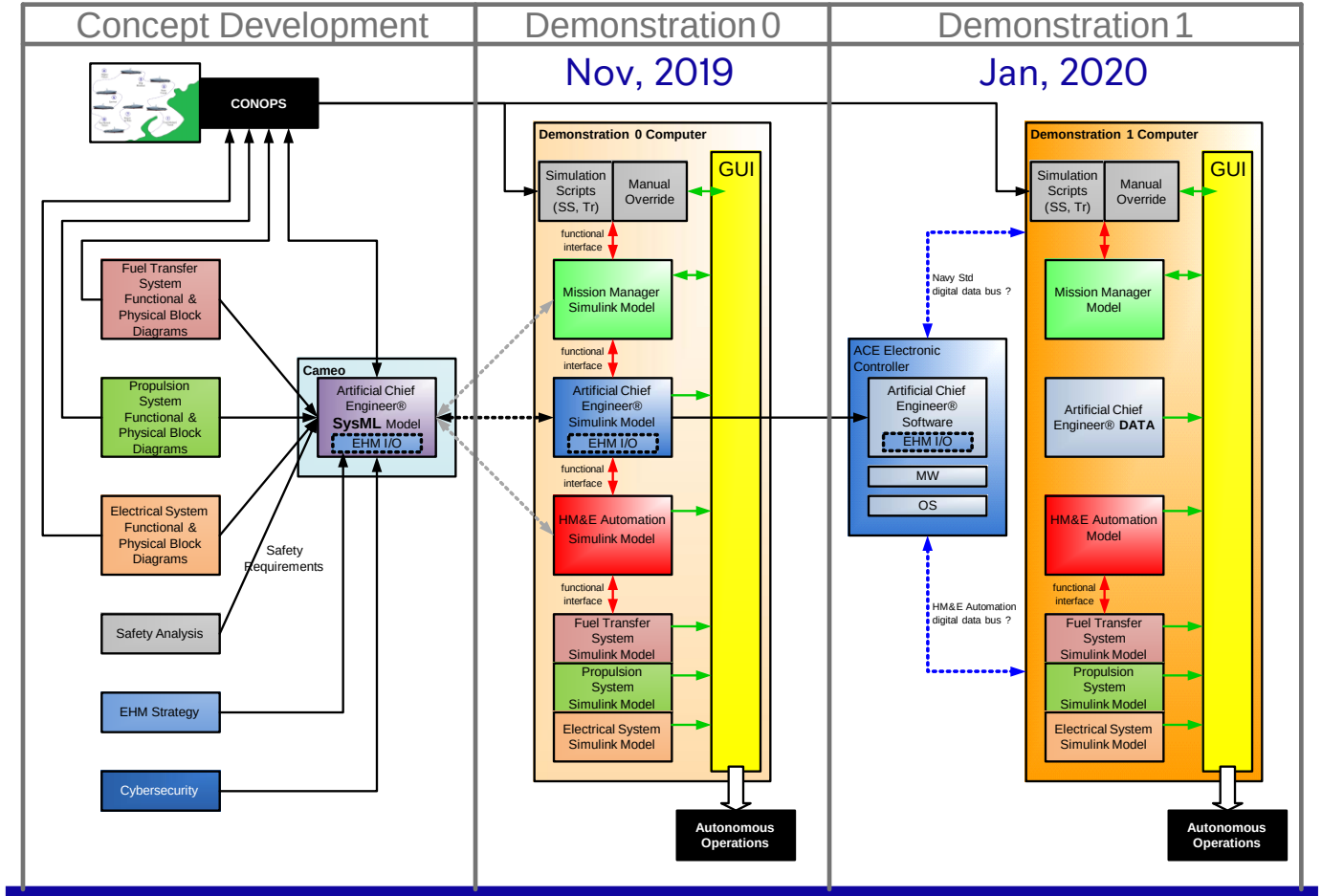
Artificial Chief Engineer® interfaces with Mission Manager and Autonomous Navigation System



Artificial Chief Engineer®: 2019 Development & Demonstration

2 Milestones:
Demo 0 in Nov 2019
Demo 1 in Jan 2020

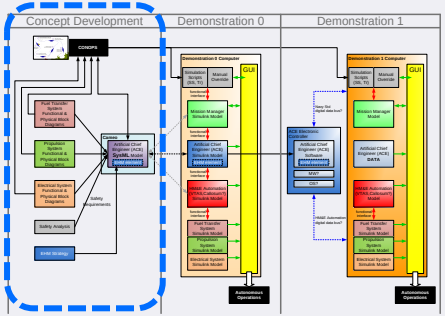
1 Deliverable:
Control Hardware-in-the-Loop Demo results in Jan 2020



Maturation Through Successive Demonstrations

Concept Development = Model-Based Systems Engineering

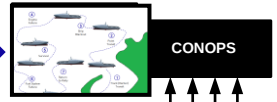
Artificial Chief Engineer: 2019 Development & Demonstration



CONOPS and vignettes defined to demonstrate critical USV functionality

Ships systems define system context in SysML model

System safety analysis defines safety requirements



Fuel Transfer System Functional & Physical Block Diagrams

Propulsion System Functional & Physical Block Diagrams

Electrical System Functional & Physical Block Diagrams

Cameo

Artificial Chief Engineer® SysML Model

EHM I/O

95% Complete

Safety Requirements

Safety Analysis — In Process

EHM Strategy — In Process

Cybersecurity — In Process

SysML model used to capture requirements, problem domain, and solution domain

EHM strategy feeds algorithm development

CONCEPT DEVELOPMENT OBJECTIVE = Define preliminary ACE algorithm for hardware-in-the-loop (HIL) demonstration in Q1 2020

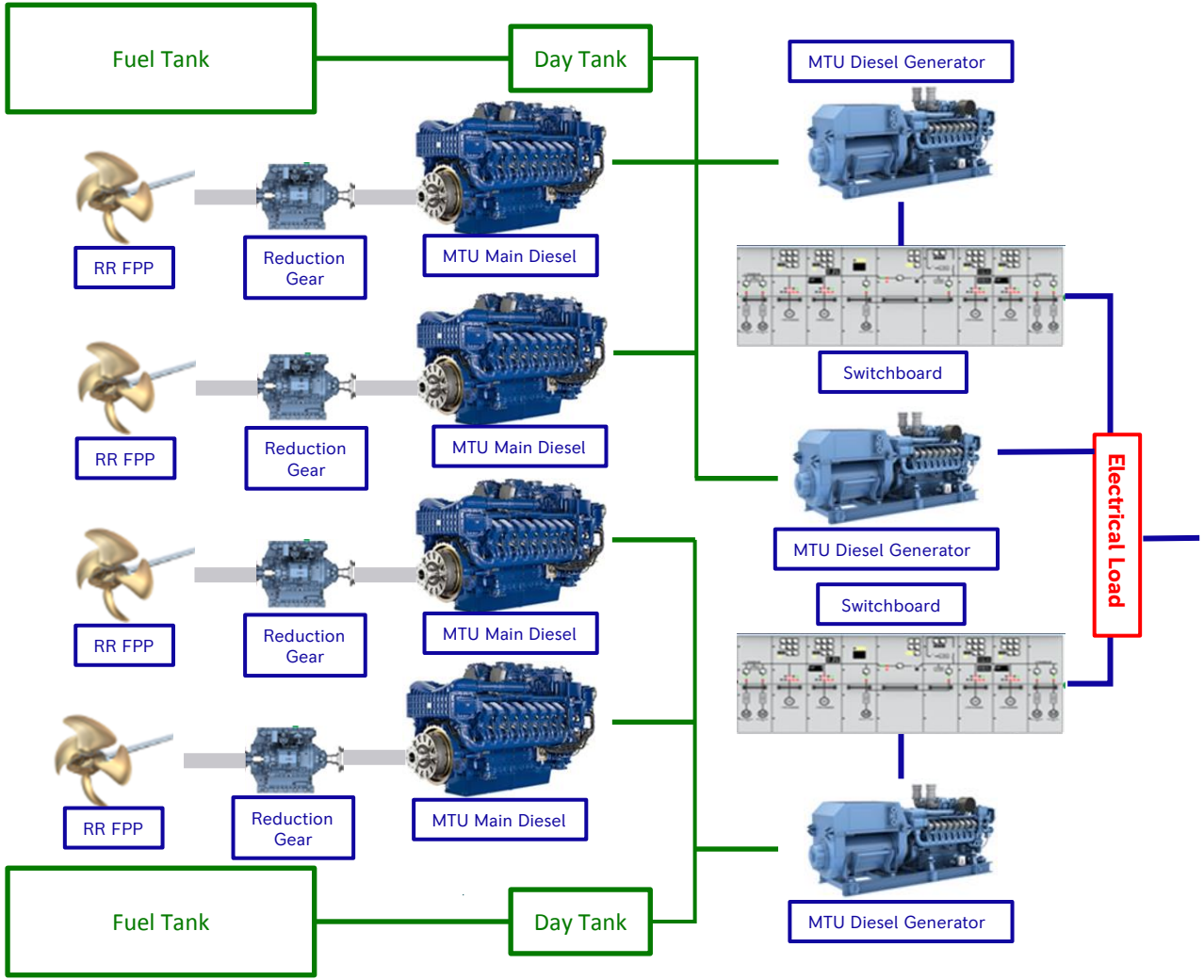
Modelling the ‘problem’:

Example USV Mechanical Propulsion System

Main Engine:
- MTU 4000 Series

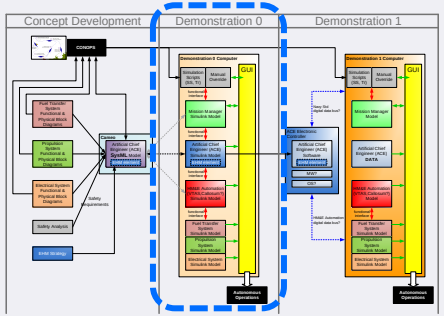
Diesel Gen:
- MTU 4000 Series GenSet

FPP: RRMNA



Demonstration 0 = Desktop Simulations

Artificial Chief Engineer®: 2019 Development & Demonstration

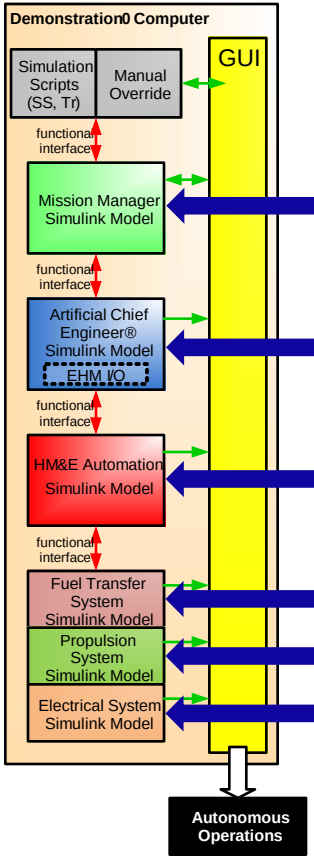


Milestone 1:
Demo 0 in Nov 2019

USV CONOPS and vignettes define desktop simulations (nominal & faulted)

Algorithm model tuned and verified in desktop simulations

Models of mission manager, HM&E automation, and ship's systems running on desktop computer



Models 80% integrated

90% modeled, 90% verified

75% modeled, 30% verified

80% modeled, 80% verified

100% modeled, 100% verified

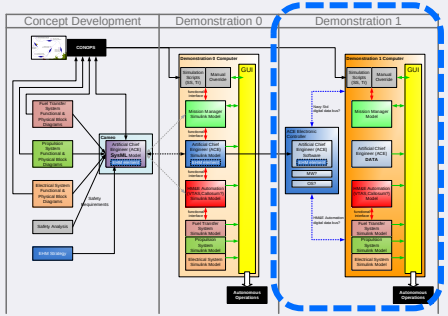
100% modeled, 70% verified

100% modeled, 65% verified

DEMONSTRATION 0 OBJECTIVE = Tune and demonstrate autonomous operations in desktop simulation environment

Demonstration 1 = Hardware-In-the-Loop (HIL) Simulations

Artificial Chief Engineer®: 2019 Development & Demonstration

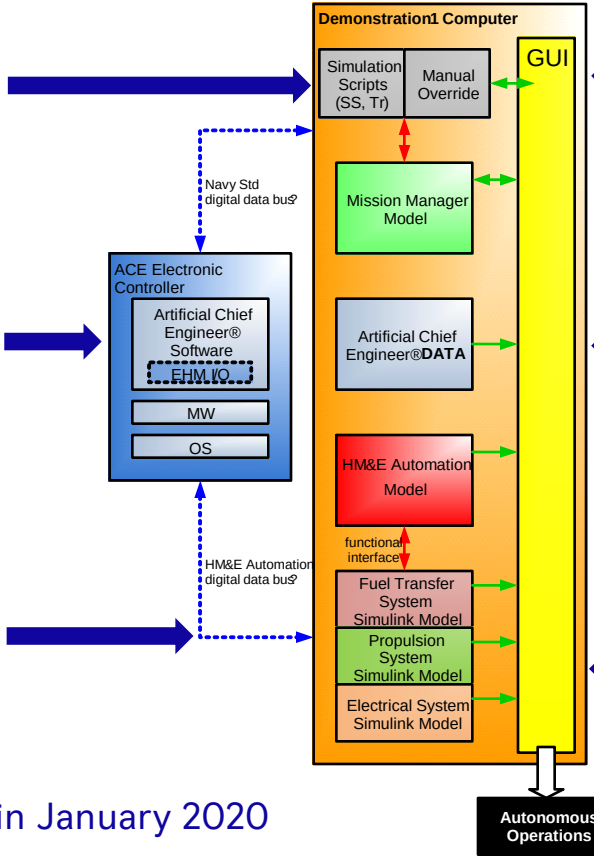


Milestone 2:
Demo 1 in Jan 2020

USV CONOPS and vignettes define HIL simulations (nominal & faulted)

software integrated with COTS control hardware

controller interfaced with HIL computer



GUI used to control simulations and display results

software created via code generation of desktop model

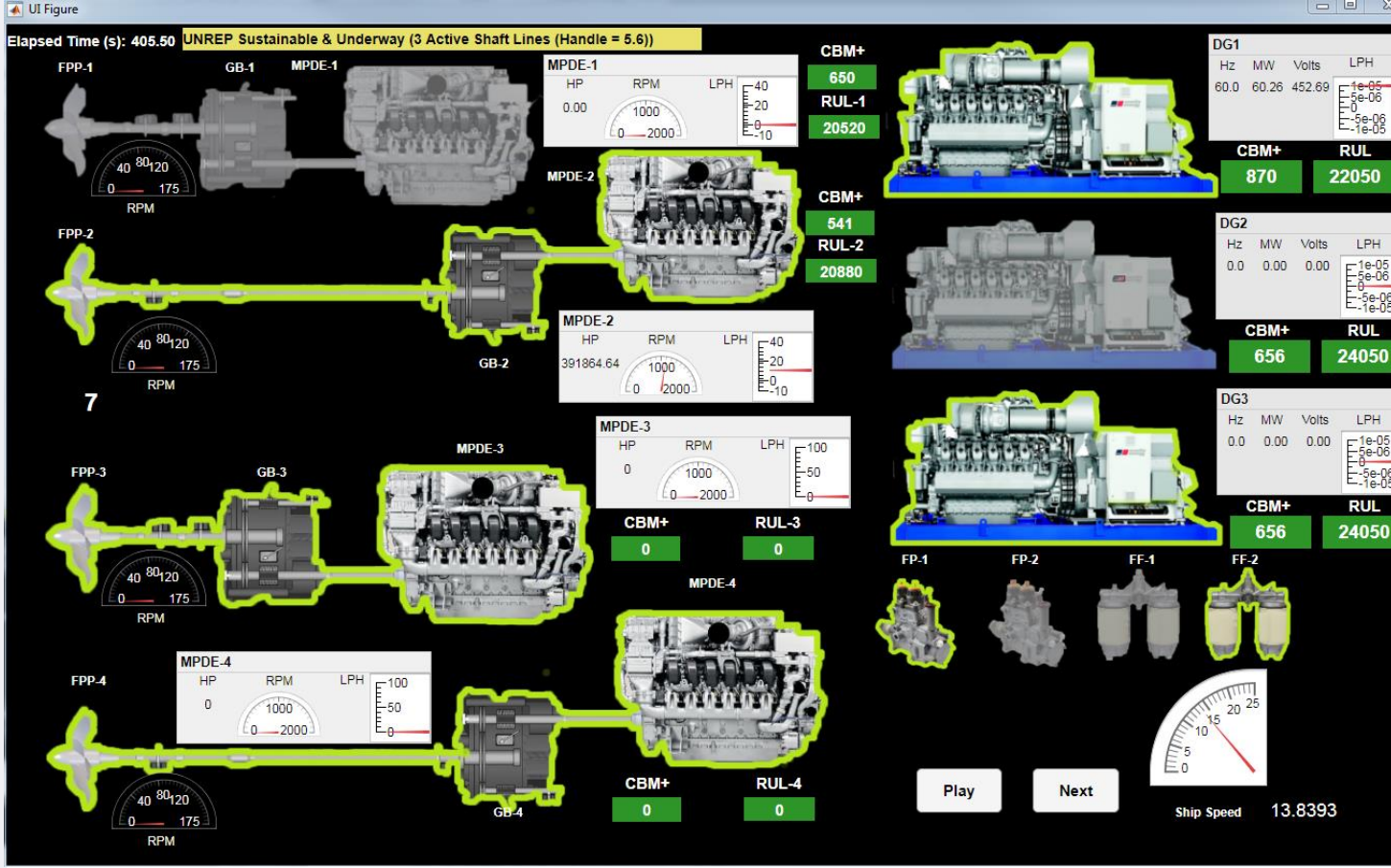
Demonstration 0 models reused for HIL simulations

Deliverable 1:
HIL Demo results in January 2020

DEMONSTRATION 1 OBJECTIVE = Demonstrate autonomous operations in control hardware-in-the-loop laboratory environment

Demonstration GUI

- 1-Sprint + Plugged Fuel Filter-
- 2-Sprint + MPDE-1 Derated
- 3-Threat Level to Battle-ON
- 4-Battle Damage; DG-2 down
- 5-Mission reduced to HS Stationing
- 6-Threat Level reduced to Basic OPS
- 7-MPDE-1Failure; Mission Restriction
- 8-DG-1 & DG-2 Failure; Mission Retriction
- 9-MPDE-1,2,3 Failure; Mission Retriction



Redefining naval operations