27th annual INCOSE international symposium

Adelaide, Australia

July 15 - 20, 2017

A Model-Based Method for Design Option Evaluation of Off-the-Shelf Naval Platforms

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Outline

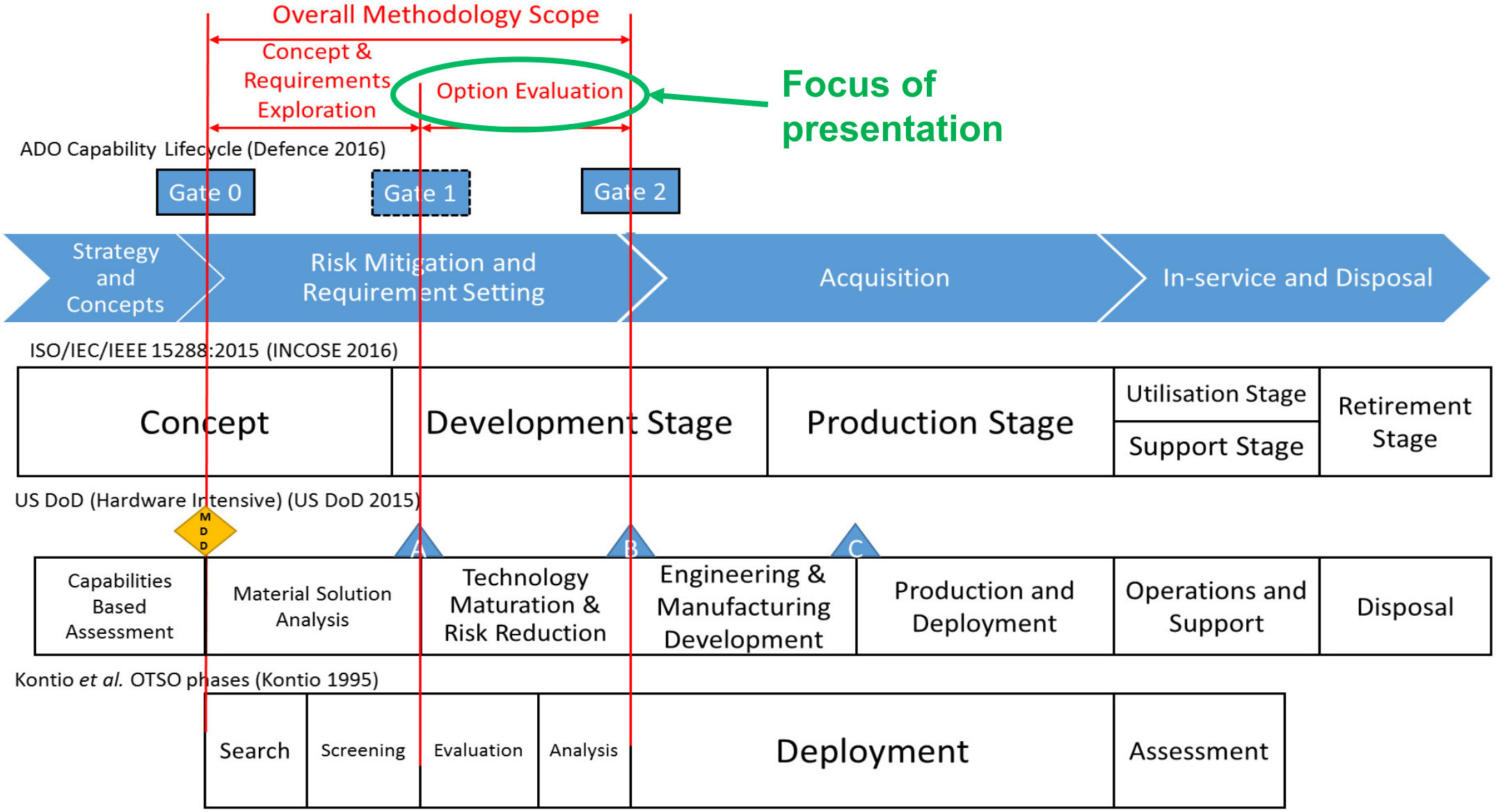
- Background
- Option Evaluation
- Resources to support option evaluation
- Proposed model-based naval platform option evaluation method
- Offshore Patrol Vessel pilot study

Background

- Off-the-shelf strategy typical in Australian naval platform acquisitions.
  - Small design and engineering workforce.
  - Perceived as low-risk.

- Options need to be evaluated during tender evaluation.
  - Typically evaluate overall platform design

Background


Overall Methodology Scope
Concept & Requirements Exploration
Option Evaluation
Focus of presentation
ADO Capability Lifecycle (Defence 2016)
Gate 0
Gate 1
Gate 2
Strategy and Concepts
Risk Mitigation and Requirement Setting
Acquisition
In-service and Disposal
ISO/IEC/IEEE 15288:2015 (INCOSE 2016)
Concept
Development Stage
Production Stage
Utilisation Stage
Support Stage
Retirement Stage
US DoD (Hardware Intensive) (US DoD 2015)
MDD
A
B
C
Capabilities Based Assessment
Material Solution Analysis
Technology Maturation & Risk Reduction
Engineering & Manufacturing Development
Production and Deployment
Operations and Support
Disposal
Kontio et al. OTSO phases (Kontio 1995)
Search
Screening
Evaluation
Analysis
Deployment
Assessment

General Approach to Option Evaluation

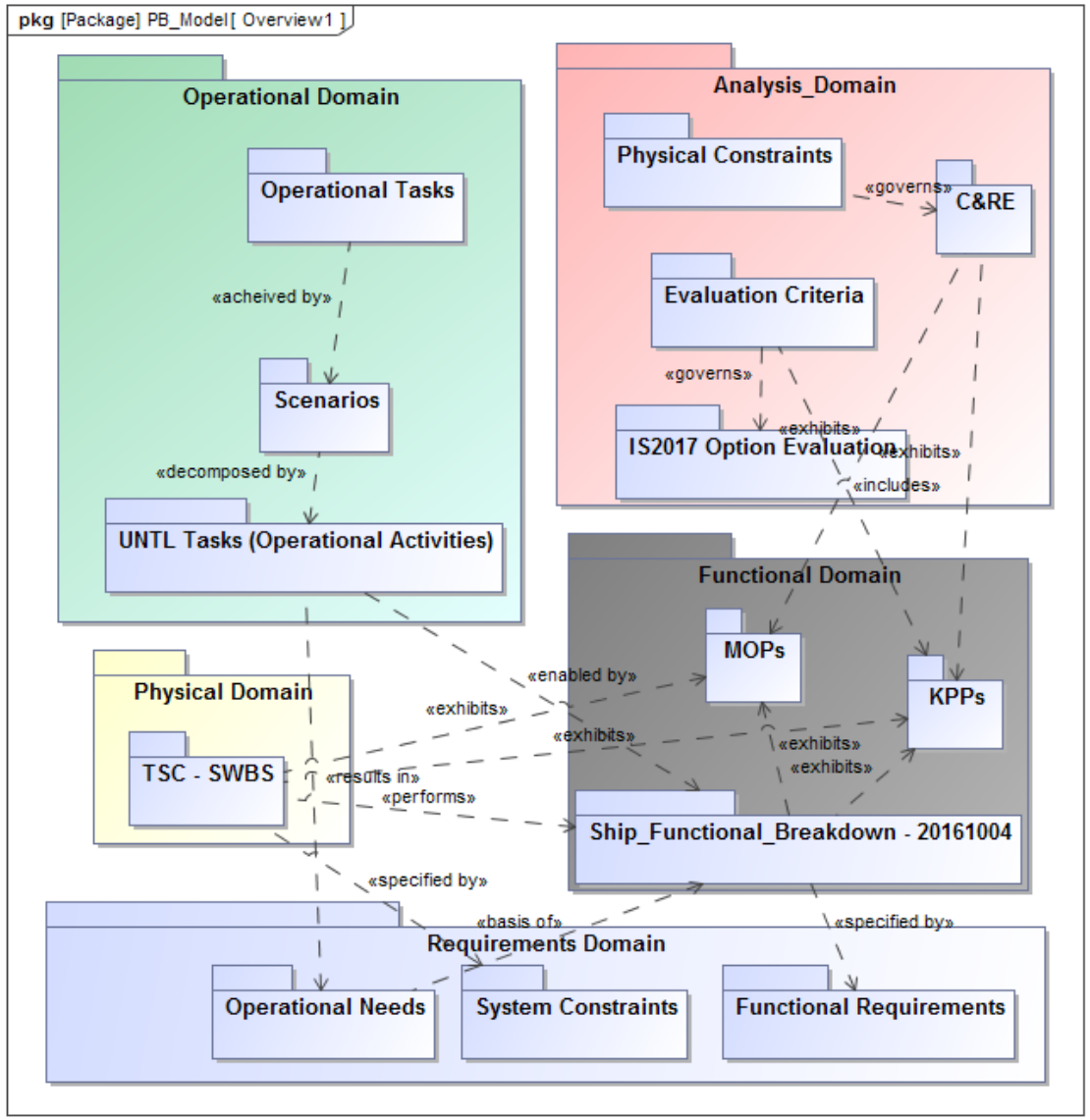
- A generic approach to option evaluation comprises the steps:
  - Define the objectives (evaluation criteria).
  - Define a value scale and value function for the evaluation criteria.
  - Assign value weights.
  - Aggregate the weighted evaluation criteria values into an overall score for each option.

Resources to Support OTS Naval Platform Option Evaluation

- Guiding principles:
  - Maintain traceability of evaluation criteria.
  - Assist the stakeholders to make defensible decisions, in a structured manner, that account for competing goals and objectives.
  - Maximise the capacity to reuse elements.

Resources to Support OTS Naval Platform Option Evaluation

1. MBSE



Resources to Support OTS Naval Platform Option Evaluation

2. Multi-Criteria Decision Making (MCDM)

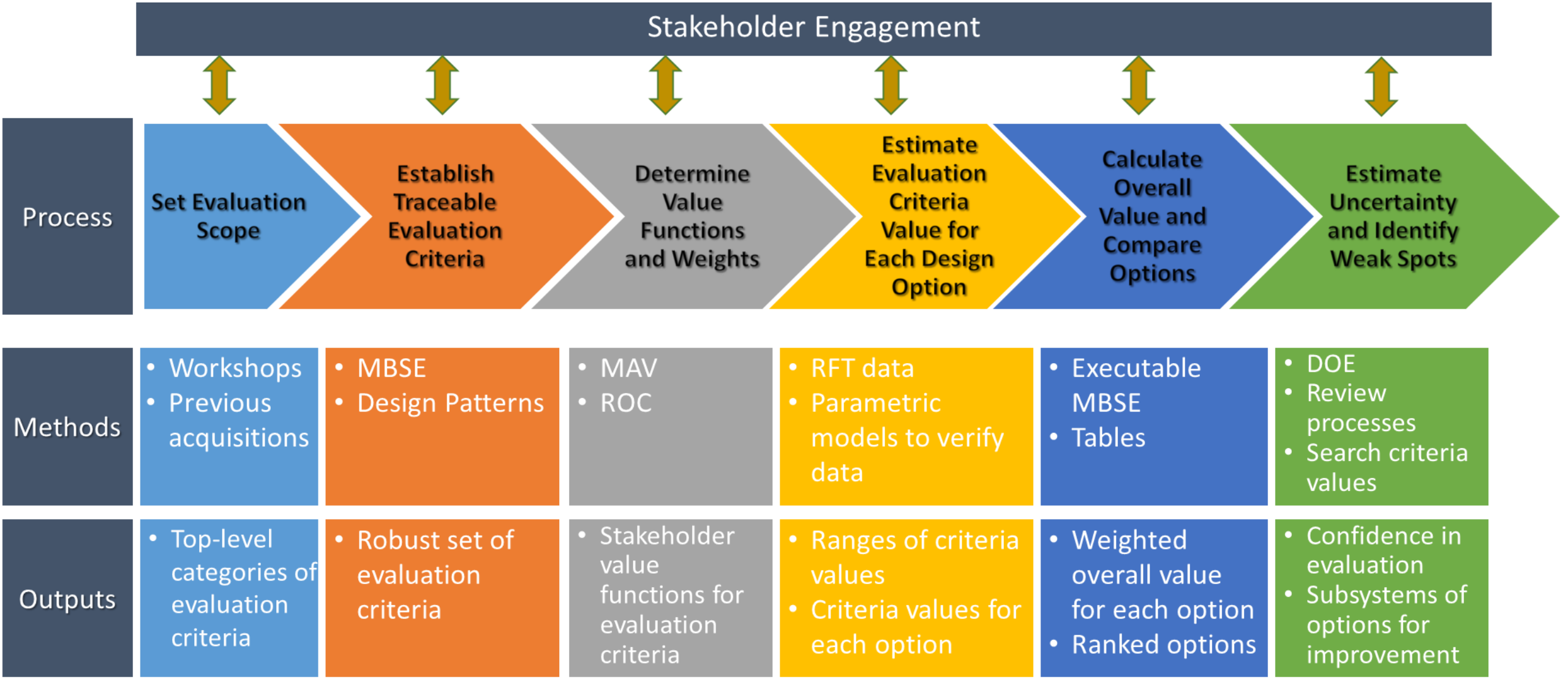
- Naval platform acquisition has competing objectives and a range of stakeholders.
- MCDM provides systematic approach
- Multi-objective vs. multi-attribute
- Naval platform acquisition:
  - multi-attribute – e.g. MAV, AHP

Resources to Support OTS Naval Platform Option Evaluation

- Pattern-Based Methods

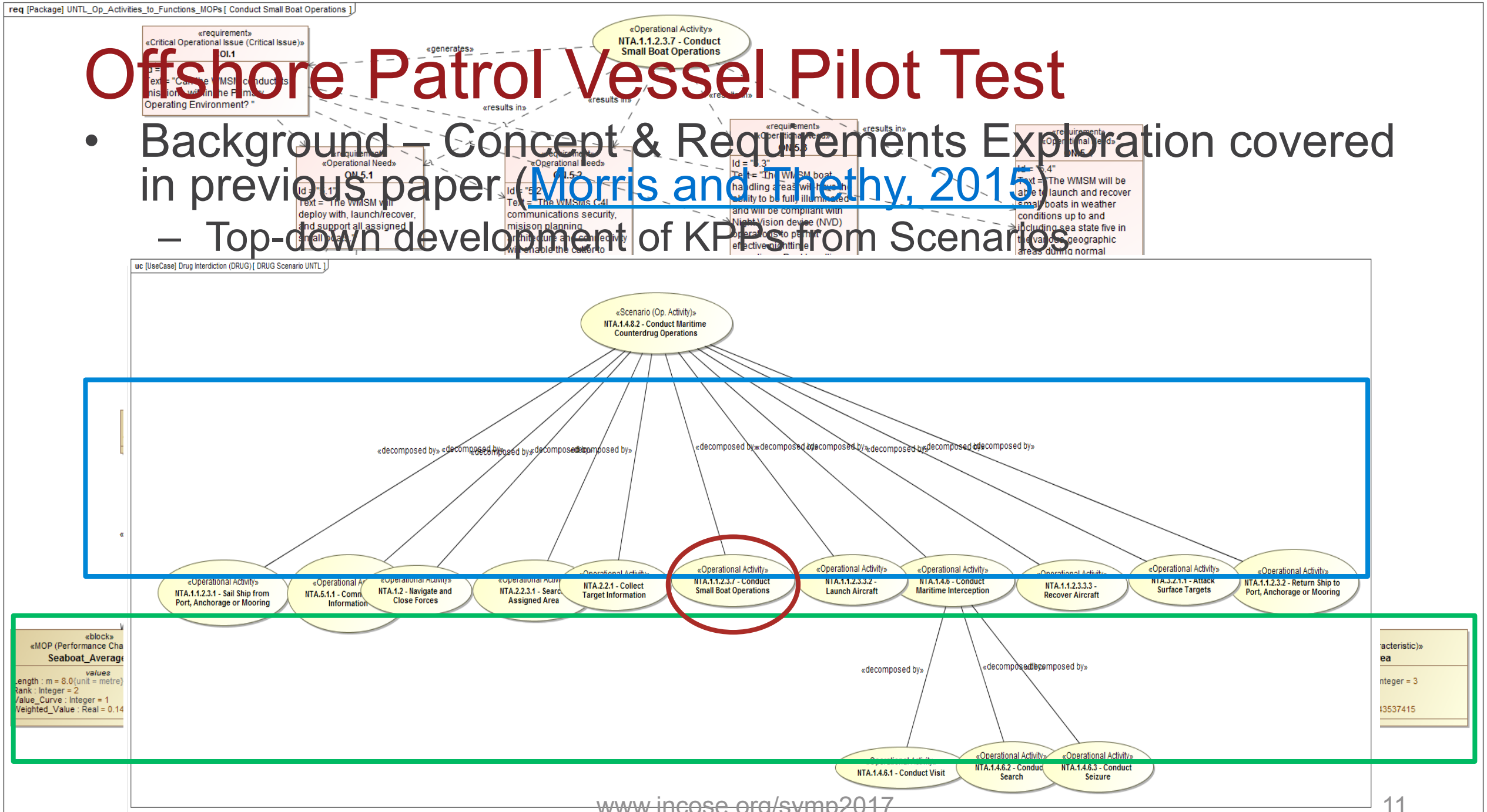
Design Pattern	Pattern Describes	Uses
Universal Naval Task List (UNTL) (CNO, 2007), RAN Mission Essential Task List (RANTEAA, 2014)	Hierarchy of naval operational activities and measures	Building mission scenarios, Critical Operational Issues and performance evaluation criteria (KPPs)
Design Building Blocks (DBB) (Andrews and Pawling, 2003)	Naval platform functional architecture	Generic breakdown of naval platform functions into categories of fight, move, float and infrastructure
Extended Ship Work Breakdown Structure (ESWBS) (SAWE, 2007)	Naval platform physical architecture	Generic breakdown of physical naval platform components, including loads and margins

Proposed Model-Based Option Evaluation Method



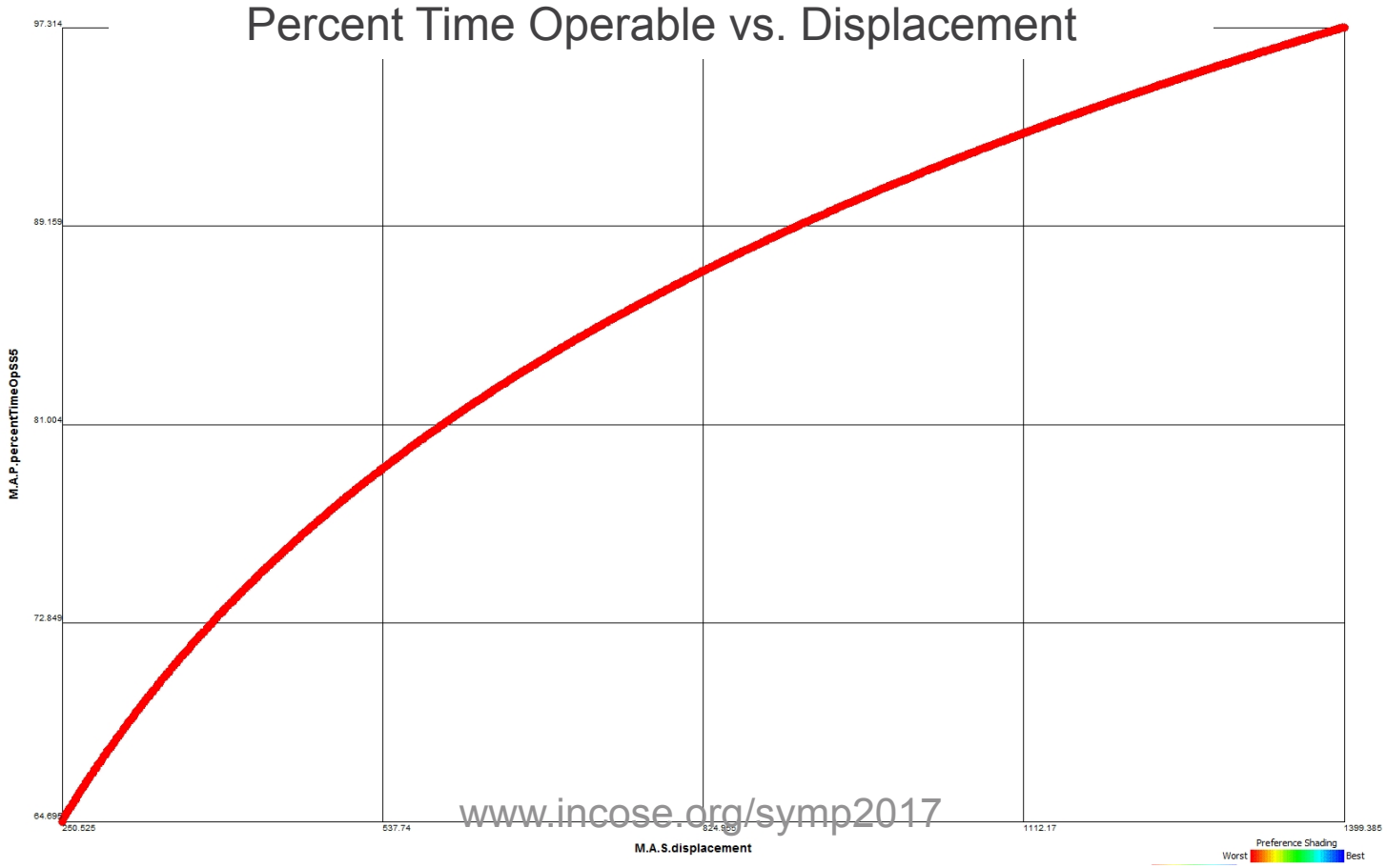
Offshore Patrol Vessel Pilot Test

- Background – Concept & Requirements Exploration covered in previous paper (Morris and Tilbury, 2015)
  - Top-down development of KPPs from Scenarios



Offshore Patrol Vessel Pilot Test

- Background – C&RE supports requirements development
  - ➢ Key constraint – vessels of around 80 metres length



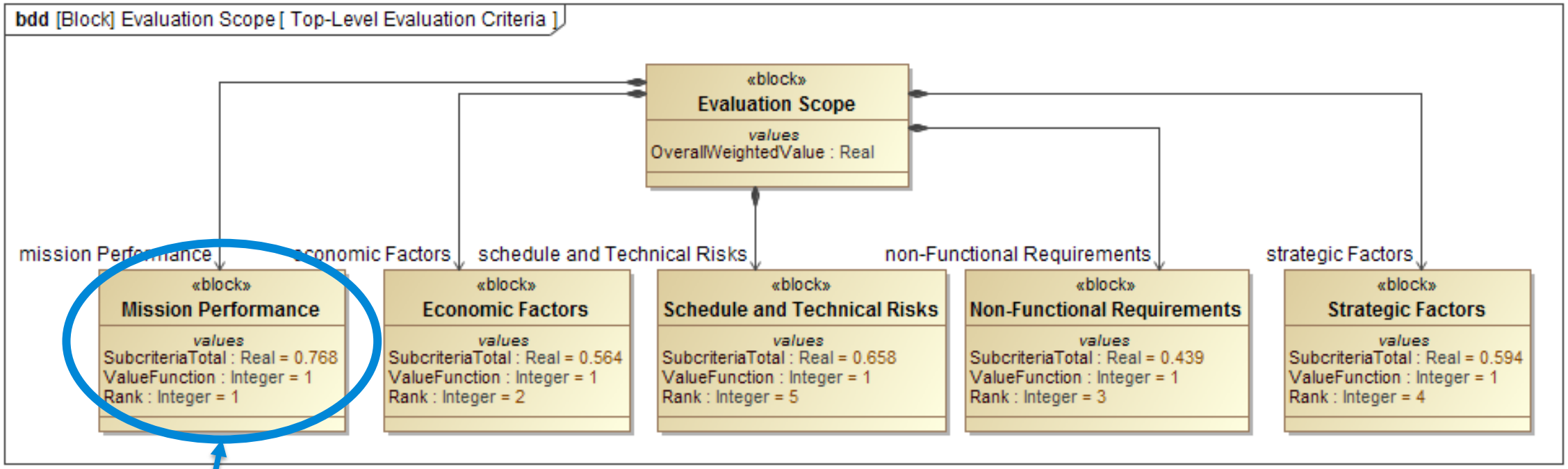
Offshore Patrol Vessel Pilot Test

- "Responses" from RFT

Particular	Option A	Option B
Length	80m	80m
Beam	13m	13m
Draft	3.0m	3.8m
Displacement	1625 tonnes	1753 tonnes
Sprint Speed	20 knots	22 knots
Endurance	21 days	30 days
Number of RHIBS	2	2
RHIB Length	6 metres	8 metres

Offshore Patrol Vessel Pilot Test

- Step 1 - Set Evaluation Scope

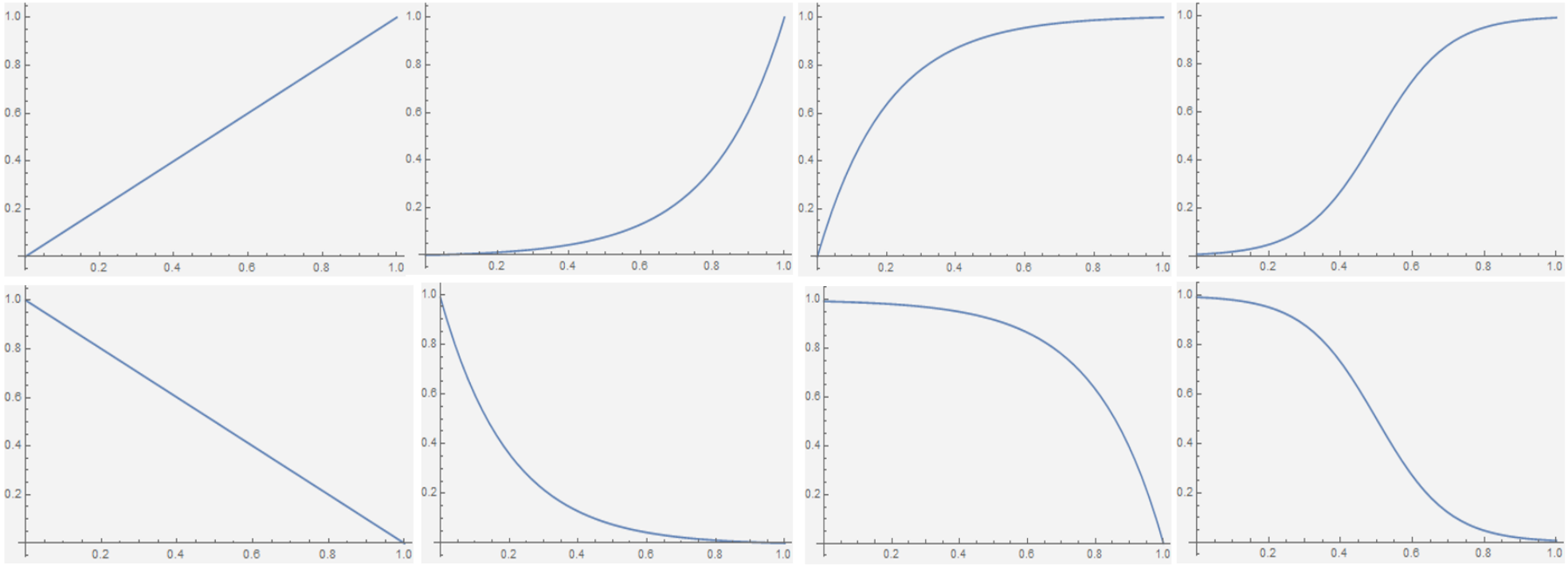


Offshore Patrol Vessel Pilot Test

- Step 2 – Establish Traceable Evaluation Criteria
  - KPPs from C&RE are also mission performance evaluation criteria
  - Risks linked to COIs
  - Economic factors always present
  - NFRs from a pattern?
  - Strategic factors

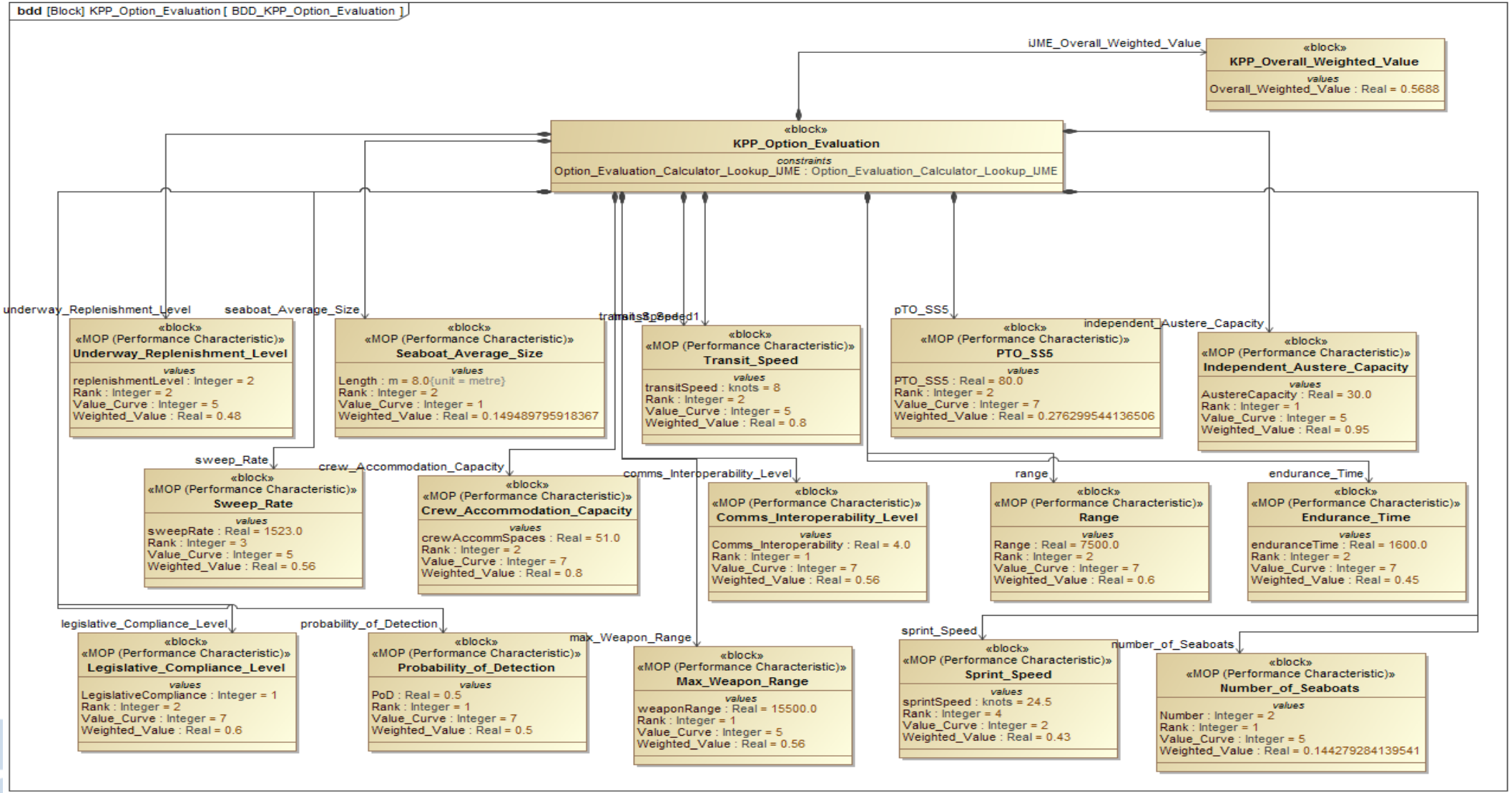
Offshore Patrol Vessel Pilot Test

- Step 3 – Determine Evaluation Criteria Weights and Value Functions



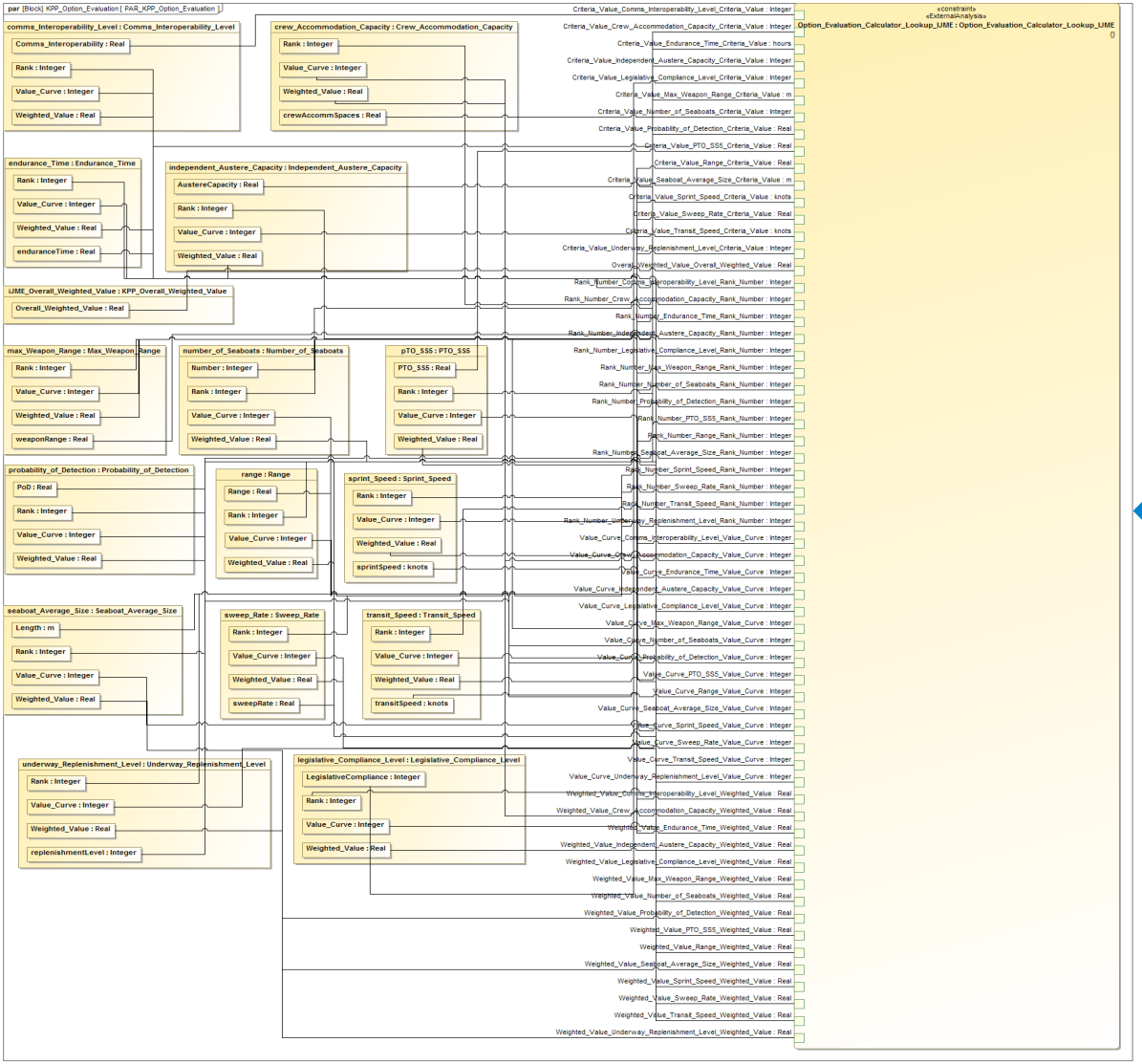
Offshore Patrol Vessel Pilot Test

- Step 4 – Estimate Evaluation Criteria Values



Offshore Patrol Vessel Pilot Test

- Step 5 – Calculate overall value and compare options



MOP	Rank		Criteria (criteriaValue)			Subsystems	Option A	
Name	Number	ROC Weight (w)	Units	Threshold	Objective	Value Curve	ESWBS	criteriaValue	w*criteriaValue(v)
Seaboat_Average_Size	3	0.0929	Metres	5	11	1		11	0.09288
Comms_Interoperability_Level	3	0.0929	Ordinal Scale: 1 - Poor 5 - Excellent	2	5	5		3	0.07585
Independent_Austere_Capacity	15	0.0044	Persons	20	50	1		35	0.00222
Range	3	0.0929	Nautical Miles	5	25		Propulsion/ 7hullform	20	0.08584
Crew_Accommodation_Capacity	7	0.0342	Persons	30	50	1		35	0.00854
Endurance_Time	1	0.1879	Hours	336	504	7		336	0.00126
Sweep_Rate	7	0.0342	km^2/hr	100	400	7		200	0.00543
Number_of_Seaboats	3	0.0929	Number	1	3	7		3	0.09226
PTO_SS5	1	0.1879	Percent	50	90		Hullform/L&R 7Gear	80	0.17363
Probability_of_Detection	7	0.0342	Probability	0.3	0.75		7UAV/Radar	20	0.03415
Transit_Speed	7	0.0342	Knots	2	5	5		3	0.02789
Legislative_Compliance_Level	7	0.0342	Ordinal Scale: 1 - Poor 5 - Excellent	2	5	5		3	0.02789
Underway_Replenishment_Level	14	0.0092	Ordinal Scale: 1 - Poor 5 - Excellent	1	5	1		4	0.00690
Sprint_Speed	7	0.0342	Knots	20	30	5		25	0.03156
Max_Weapon_Range	7	0.0342	Metres	6500	15500	5		12500	0.03316

Offshore Patrol Vessel Pilot Test

- Step 6 – Estimate uncertainty and identify weak spots

KPP	Rank		KPP				Option A		Option B	
Name	Number	ROC Weight	Units	Threshold	Objective	Value Curve	KPP	*w*KPP(v)*	KPP	*w*KPP(v)*
Seaboat_Average_Size	2	0.1944	Metres	5	11	1	8	0.09722	6	0.03241
Number_of_Seaboats	1	0.6111	Number	1	3	5	2	0.56475	3	0.61111
PTO_SS5	2	0.1944	Percent	50	90	7	80	0.17969	80	0.17969
						TOTALS		**0.84167**		**0.82321**

Conclusions

- Proposed model-based method for conducting OTS naval platform option evaluations.
- Pilot test found method to be useful as a means of managing the evaluation criteria traceability, maintaining design data and identifying weak spots in OTS design options.
  - Some overhead in terms of effort vs. traceability and rapid update if requirements change.
- Need to refine method through further implementations.

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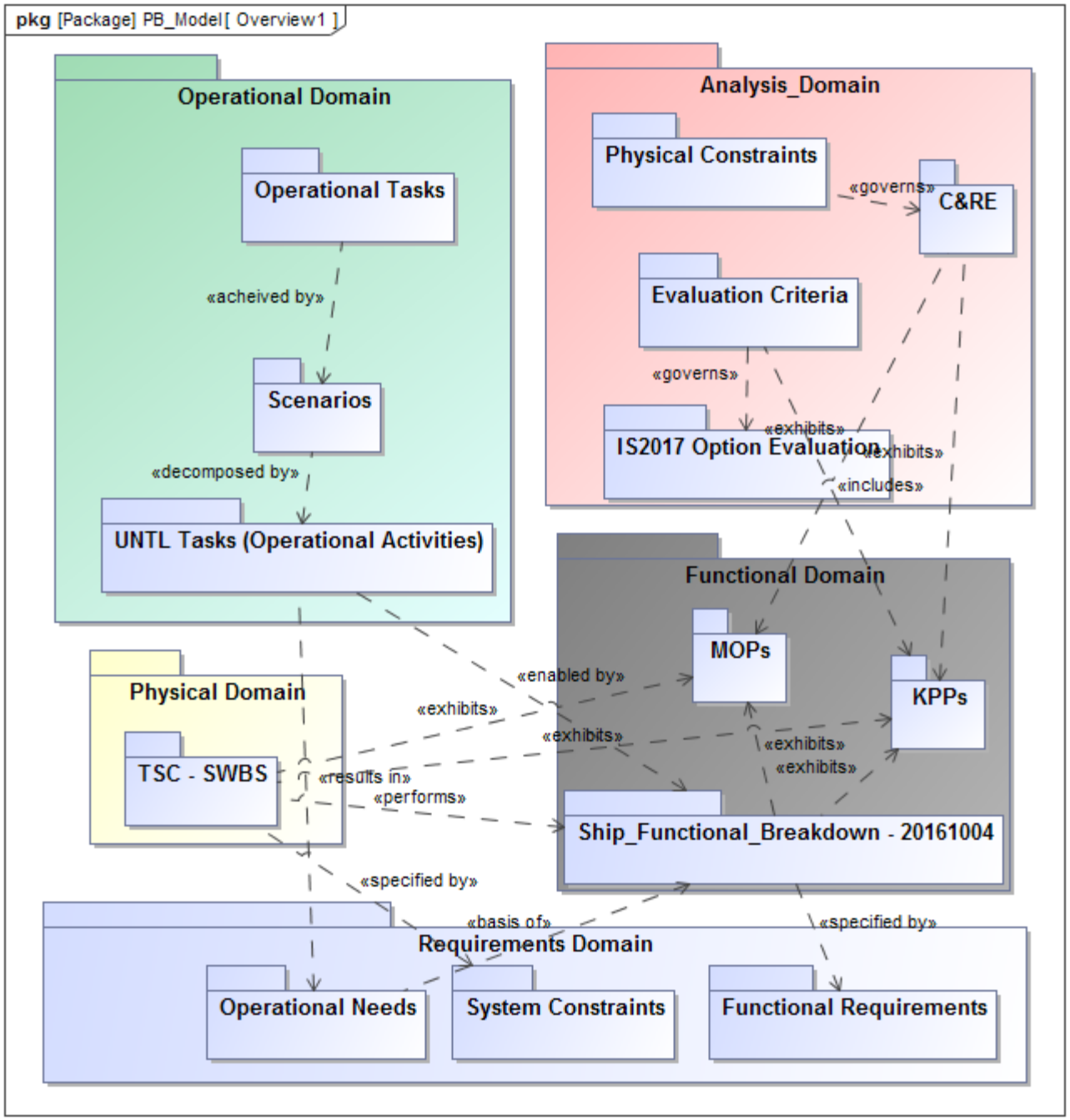
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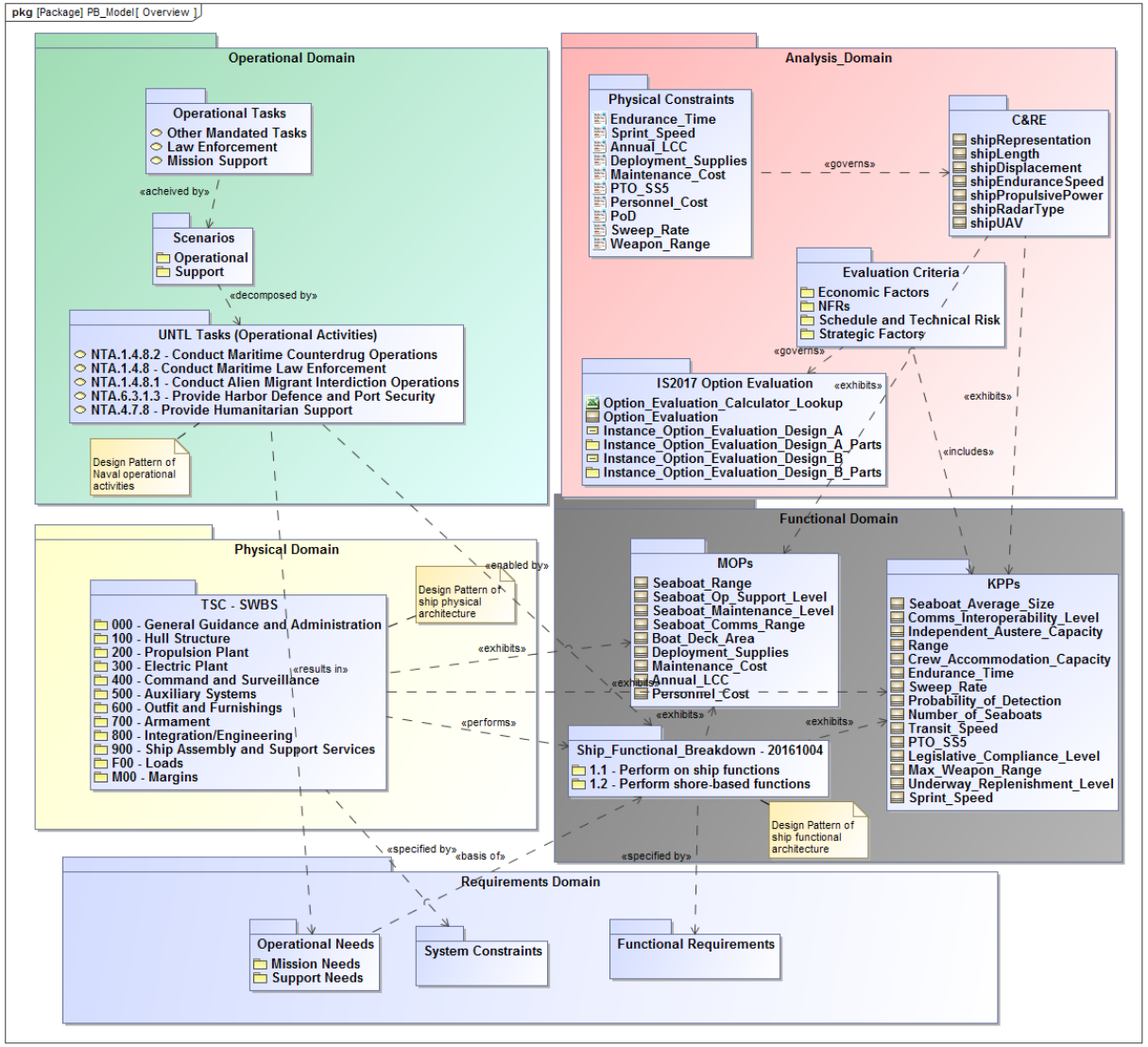
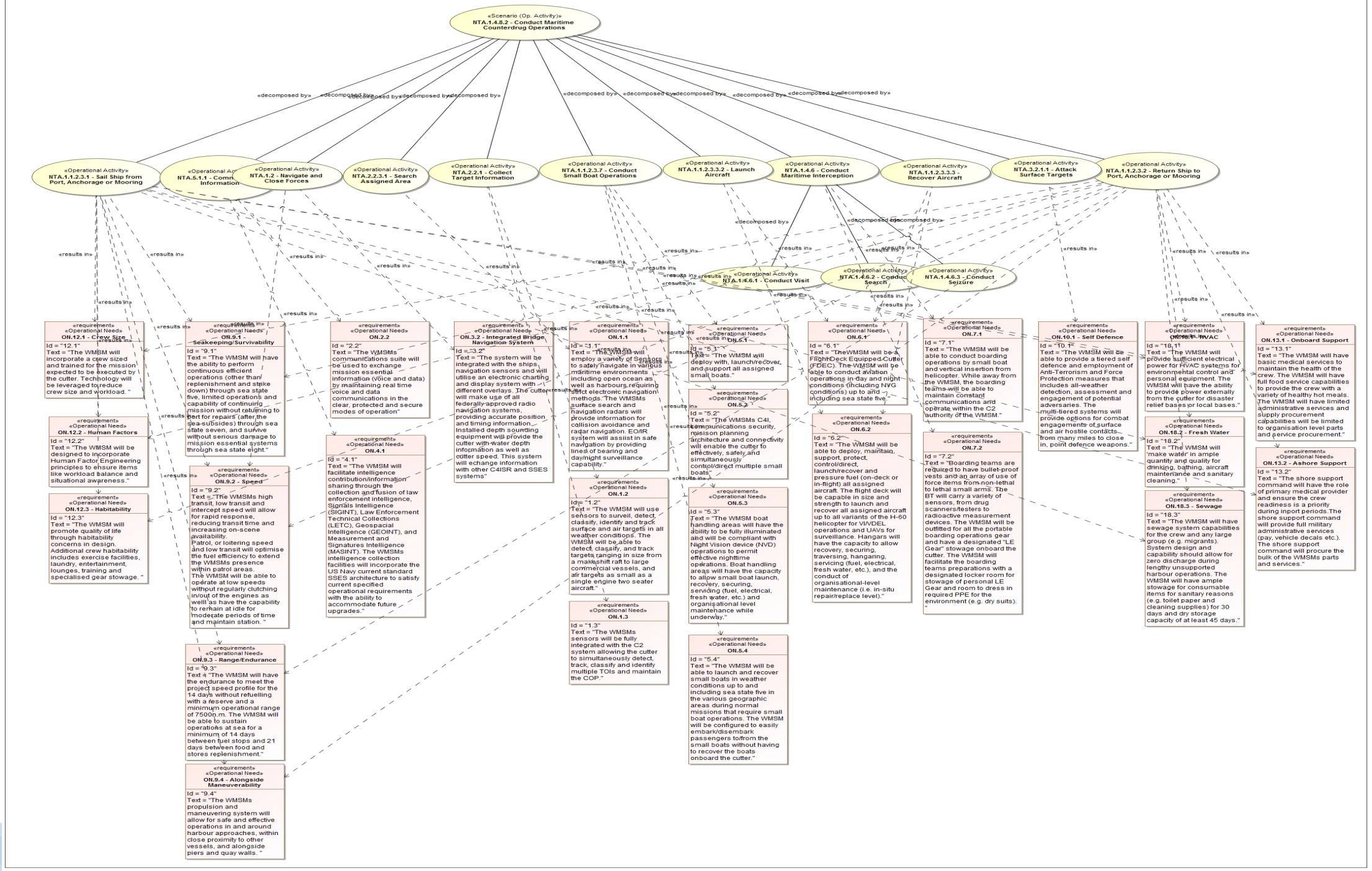
Operational Domain
Operational Tasks
«acheived by»
Scenarios
«decomposed by»
UNTL Tasks (Operational Activities)
Analysis_Domain
Physical Constraints
«governs»
C&RE
Evaluation Criteria
«governs»
IS2017 Option Evaluation
«exhibits»
«exhibits»
«includes»
Functional Domain
MOPs
KPPs
Physical Domain
TSC - SWBS
«enabled by»
«exhibits»
«exhibits»
«exhibits»
«exhibits»
«results in»
«performs»
Ship_Functional_Breakdown - 20161004
«specified by»
«basis of»
«specified by»
Requirements Domain
Operational Needs
System Constraints
Functional Requirements


pkg [Package] PB_Model[Overview]
Operational Domain
Operational Tasks
Other Mandated Tasks
Law Enforcement
Mission Support
«acheived by»
Scenarios
Operational
Support
«decomposed by»
UNTL Tasks (Operational Activities)
NTA.1.4.8.2 - Conduct Maritime Counterdrug Operations
NTA.1.4.8 - Conduct Maritime Law Enforcement
NTA.1.4.8.1 - Conduct Alien Migrant Interdiction Operations
NTA.6.3.1.3 - Provide Harbor Defence and Port Security
NTA.4.7.8 - Provide Humanitarian Support
Design Pattern of Naval operational activities
Analysis_Domain
Physical Constraints
Endurance_Time
Sprint_Speed
Annual_LCC
Deployment_Supplies
Maintenance_Cost
PTO_SS5
Personnel_Cost
PoD
Sweep_Rate
Weapon_Range
«governs»
C&RE
shipRepresentation
shipLength
shipDisplacement
shipEnduranceSpeed
shipPropulsivePower
shipRadarType
shipUAV
Evaluation Criteria
Economic Factors
NFRs
Schedule and Technical Risk
Strategic Factors
«governs»
IS2017 Option Evaluation
«exhibits»
Option_Evaluation_Calculator_Lookup
Option_Evaluation
Instance_Option_Evaluation_Design_A
Instance_Option_Evaluation_Design_A_Parts
Instance_Option_Evaluation_Design_B
Instance_Option_Evaluation_Design_B_Parts
«exhibits»
«includes»
Functional Domain
Physical Domain
«enabled by»
Design Pattern of ship physical architecture
TSC - SWBS
000 - General Guidance and Administration
100 - Hull Structure
200 - Propulsion Plant
300 - Electric Plant
400 - Command and Surveillance
500 - Auxiliary Systems
600 - Outfit and Furnishings
700 - Armament
800 - Integration/Engineering
900 - Ship Assembly and Support Services
F00 - Loads
M00 - Margins
«results in»
«exhibits»
«performs»
MOPs
Seaboat_Range
Seaboat_Op_Support_Level
Seaboat_Maintenance_Level
Seaboat_Comms_Range
Boat_Deck_Area
Deployment_Supplies
Maintenance_Cost
Annual_LCC
Personnel_Cost
KPPs
Seaboat_Average_Size
Comms_Interoperability_Level
Independent_Austere_Capacity
Range
Crew_Accommodation_Capacity
Endurance_Time
Sweep_Rate
Probability_of_Detection
Number_of_Seaboats
Transit_Speed
PTO_SS5
Legislative_Compliance_Level
Max_Weapon_Range
Underway_Replenishment_Level
Sprint_Speed
Ship_Functional_Breakdown - 20161004
1.1 - Perform on ship functions
1.2 - Perform shore-based functions
Design Pattern of ship functional architecture
«specified by»
«basis of»
«specified by»
Requirements Domain
Operational Needs
Mission Needs
Support Needs
System Constraints
Functional Requirements


«Scenario (Op. Activity)»
NTA.1.4.8.2 - Conduct Maritime Counterdrug Operations
«decomposed by»
«Operational Activity»
NTA.1.1.2.3.1 - Sail Ship from Port, Anchorage or Mooring
«Operational Activity»
NTA.5.1.1 - Comm Information
«Operational Activity»
NTA.1.2 - Navigate and Close Forces
«Operational Activity»
NTA.2.2.3.1 - Search Assigned Area
«Operational Activity»
NTA.2.2.1 - Collect Target Information
«Operational Activity»
NTA.1.1.2.3.7 - Conduct Small Boat Operations
«Operational Activity»
NTA.1.1.2.3.2 - Launch Aircraft
«Operational Activity»
NTA.1.4.6 - Conduct Maritime Interception
«Operational Activity»
NTA.1.1.2.3.3 - Recover Aircraft
«Operational Activity»
NTA.3.2.1.1 - Attack Surface Targets
«Operational Activity»
NTA.1.1.2.3.2 - Return Ship to Port, Anchorage or Mooring
«results in»
«Operational Activity»
NTA.1.4.6.1 - Conduct Visit
«Operational Activity»
NTA.1.4.6.2 - Conduct Search
«Operational Activity»
NTA.1.4.6.3 - Conduct Seizure
«requirement»
«Operational Need»
ON.12.1 - Crew Size
Id = "12.1"
Text = "The WMSM will incorporate a crew sized and trained for the mission expected to be executed by the cutter. Technology will be leveraged to reduce crew size and workload. "
«requirement»
«Operational Need»
ON.12.2 - Human Factors
Id = "12.2"
Text = "The WMSM will be designed to incorporate Human Factor Engineering principles to ehsure items like workload balance and situational awareness."
«requirement»
«Operational Need»
ON.12.3 - Habitability
Id = "12.3"
Text = "The WMSM will promote quality of life through habitability concerns in design. Additional crew habitability includes exercise facilities, laundry, entertainment, lounges, training and specialised gear stowage. "
«requirement»
«Operational Need»
ON.9.1 - Seakeeping/Survivability
Id = "9.1"
Text = "The WMSM will have the ability to perform continuous efficient operations (other than replenishment and strike down) through sea state five, limited operations and capability of continuing mission without returning to port for repairs (after the sea-subsides) through sea state seven, and survive without serious damage to mission essential systems through sea state eight."
«requirement»
«Operational Need»
ON.9.2 - Speed
Id = "9.2"
Text = "The WMSMs high transit, low transit and intercept speed will allow for rapid response, reducing transit time and increasing on-scene availability.
Patrol, or loitering speed and low transit will optimise the fuel efficiency to extend the WMSMs presence within patrol areas.
The WMSM will be able to operate at low speeds without regularly clutching in/out of the engines as well as have the capability to remain at idle for moderate periods of time and maintain station. "
«requirement»
«Operational Need»
ON.9.3 - Range/Endurance
Id = "9.3"
Text = "The WMSM will have the endurance to meet the project speed profile for the 14 days without refuelling with a reserve and a minimum operational range of 7500n.m. The WMSM will be able to sustain operations at sea for a minimum of 14 days between fuel stops and 21 days between food and stores replenishment."
«requirement»
«Operational Need»
ON.9.4 - Alongside Maneuverability
Id = "9.4"
Text = "The WMSMs propulsion and maneuvering system will allow for safe and effective operations in and around harbour approaches, within close proximity to other vessels, and alongside piers and quay walls. "
«requirement»
«Operational Need»
ON.2.2
Id = "2.2"
Text = "The WMSMs communications suite will be used to exchange mission essential information (voice and data) by maintaining real time voice and data communications in the clear, protected and secure modes of operation"
«requirement»
«Operational Need»
ON.4.1
Id = "4.1"
Text = "The WMSM will facilitate intelligence contribution/information sharing through the collection and fusion of law enforcement intelligence, Signals Intelligence (SIGINT), Law Enforcement Technical Collections (LETC), Geospacial Intelligence (GEOINT), and Measurement and Signatures Intelligence (MASINT). The WMSMs intelligence collection facilities will incorporate the US Navy current standard SSES architecture to satisfy current specified operational requirements with the ability to accommodate future upgrades."
«requirement»
«Operational Need»
ON.3.2 - Integrated Bridge Navigation System
Id = "3.2"
Text = "The system will be integrated with the ships, navigation sensors and will utilise an electronic charting and display system with different overlays. The cutter will make use of all federally-approved radio navigation systems, providing accurate position and timing information. Installed depth sounding equipment will provide the cutter with water depth information as well as cutter speed. This system will echange information with other C4ISR and SSES systems"
«requirement»
«Operational Need»
ON.1.1
Id = "1.1"
Text = "The WMSM will employ a variety of Sensors to safely navigate in various maritime environments including open ocean as well as harbours requiring strict electronic navigation methods. The WMSMs surface search and navigation radars will provide information for collision avoidance and radar navigation. EO/IR system will assiist in safe navigation by providing lines of bearing and day/night surveillance capability."
«requirement»
«Operational Need»
ON.1.2
Id = "1.2"
Text = "The WMSM will use sensors to surveil, detect, classify, identify and track surface and air targets in all weather conditions. The WMSM will be able to detect, classify, and track targets ranging in size from a makeshift raft to large commercial vessels, and air targets as small as a single engine two seater aircraft."
«requirement»
«Operational Need»
ON.1.3
Id = "1.3"
Text = "The WMSMs sensors will be fully integrated with the C2 system allowing the cutter to simultaneously detect, track, classify and identify multiple TOIs and maintain the COP."
«requirement»
«Operational Need»
ON.5.1
Id = "5.1"
Text = "The WMSM will deploy with, launch/recover, and support all assigned small boats."
«requirement»
«Operational Need»
ON.5.2
Id = "5.2"
Text = "The WMSMs C4I, communications security, mission planning architecture and connectivity will enable the cutter to effectively, safely and simultaneously control/direct multiple small boats."
«requirement»
«Operational Need»
ON.5.3
Id = "5.3"
Text = "The WMSM boat handling areas will have the ability to be fully illuminated and will be compliant with Night Vision device (NVD) operations to permit effective nighttime operations. Boat handling areas will have the capacity to allow small boat launch, recovery, securing, servicing (fuel, electrical, fresh water, etc.) and organisational level maintenance while underway."
«requirement»
«Operational Need»
ON.5.4
Id = "5.4"
Text = "The WMSM will be able to launch and recover small boats in weather conditions up to and including sea state five in the various geographic areas during normal missions that require small boat operations. The WMSM will be configured to easily embark/disembark passengers to/from the small boats without having to recover the boats onboard the cutter."
«requirement»
«Operational Need»
ON.6.1
Id = "6.1"
Text = "TheWMSM will be a Flight Deck Equipped Cutter (FDEC). The WMSM will be able to conduct aviation operations in day and night conditions (including NVG conditions) up to and including sea state five."
«requirement»
«Operational Need»
ON.6.2
Id = "6.2"
Text = "The WMSM will be able to deploy, maintain, support, protect, control/direct, launch/recover and pressure fuel (on-deck or in-flight) all assigned aircraft. The flight deck will be capable in size and strength to launch and recover all assigned aircraft up to all variants of the H-60 helicopter for VI/VDEL operations and UAVs for surveillance. Hangars will have the capacity to allow recovery, securing, traversing, hangaring, servicing (fuel, electrical, fresh water, etc.), and the conduct of organisational-level maintenance (i.e. in-situ repair/replace level)."
«requirement»
«Operational Need»
ON.7.1
Id = "7.1"
Text = "The WMSM will be able to conduct boarding operations by small boat and vertical insertion from helicopter. While away from the WMSM, the boarding teams will be able to maintain constant communications and operate within the C2 authority of the WMSM."
«requirement»
«Operational Need»
ON.7.2
Id = "7.2"
Text = "Boarding teams are required to have bullet-proof vests and an array of use of force items from non-lethal to lethal small arms. The BT will carry a variety of sensors, from drug scanners/testers to radioactive measurement devices. The WMSM will be outfitted for all the portable boarding operations gear and have a designated "LE Gear" stowage onboard the cutter. The WMSM will facilitate the boarding teams preparations with a designated locker room for stowage of personal LE Gear and room to dress in required PPE for the environment (e.g. dry suits). "
«requirement»
«Operational Need»
ON.10.1 - Self Defence
Id = "10.1"
Text = "The WMSM will be able to provide a tiered self defence and employment of Anti-Terrorism and Force Protection measures that includes all-weather detection, assessment and engagement of potential adversaries. The multi-tiered systems will provide options for combat engagements of surface and air hostile contacts from many miles to close in, point defence weapons."
«requirement»
«Operational Need»
ON.18.1 - HVAC
Id = "18.1"
Text = "The WMSM will provide sufficient electrical power for HVAC systems for environmental control and personal equipment. The WMSM will have the ability to provide power externally from the cutter for disaster relief bases or local bases."
«requirement»
«Operational Need»
ON.18.2 - Fresh Water
Id = "18.2"
Text = "The WMSM will 'make water' in ample quantity and quality for drinking, bathing, aircraft maintenance and sanitary cleaning."
«requirement»
«Operational Need»
ON.18.3 - Sewage
Id = "18.3"
Text = "The WMSM will have sewage system capabilities for the crew and any large group (e.g. migrants). System design and capability should allow for zero discharge during lengthy unsupported harbour operations. The WMSM will have ample stowage for consumable items for sanitary reasons (e.g. toilet paper and cleaning supplies) for 30 days and dry storage capacity of at least 45 days."
«requirement»
«Operational Need»
ON.13.1 - Onboard Support
Id = "13.1"
Text = "The WMSM will have basic medical services to maintain the health of the crew. The WMSM will have full food service capabilities to provide the crew with a variety of healthy hot meals. The WMSM will have limited administrative services and supply procurement capabilities will be limited to organisation level parts and service procurement."
«requirement»
«Operational Need»
ON.13.2 - Ashore Support
Id = "13.2"
Text = "The shore support command will have the role of primary medical provider and ensure the crew readiness is a priority during inport periods. The shore support command will provide full military administrative services (pay, vehicle decals etc.). The shore support command will procure the bulk of the WMSMs parts and services."