NAVAL POSTGRADUATE SCHOOL

Recapitalization of Amphibious Operations & Lift

SEA 18A Capstone Project

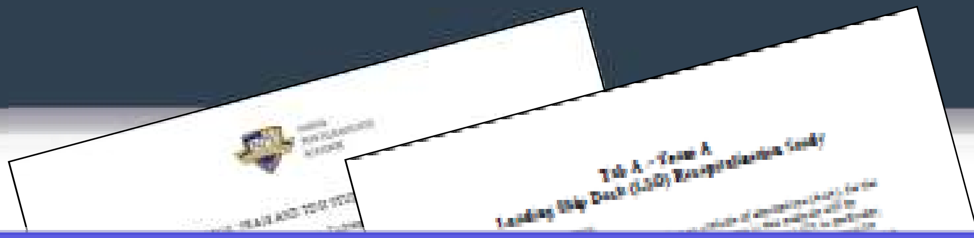
Final Progress Review

May 31, 2012

Agenda

- Introduction & Background Information
- Analysis Summaries
  - Performance
  - Cost
  - Risk
- Recommendations
- Panel Questions & Discussion

Tasking

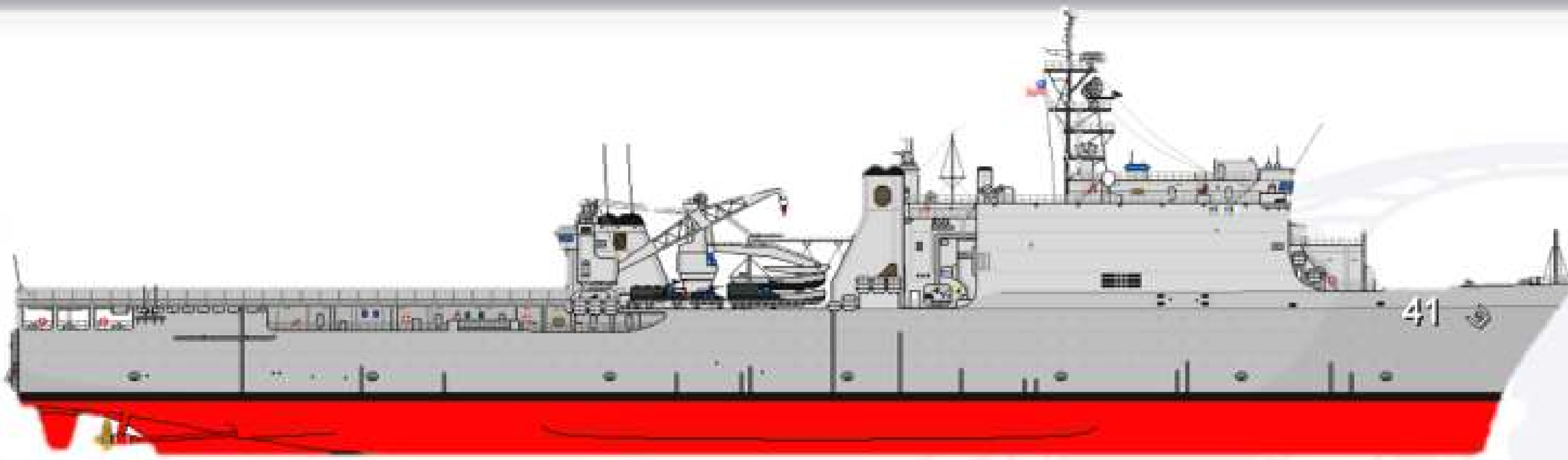


"Conduct a recapitalization analysis, including an analysis of alternatives (AoA), for the follow-on ships to LSD 41/49…

… Develop a "big picture", system-of-systems approach to provide for all amphibious lift missions commensurate with current and reasonably anticipated future needs."

- **Develop CONOPS for the examined range of missions.**
- **Develop alternative fleet architectures.**
- **Produce a coherent vision of amphibious lift missions.**
- **Provide a feasible roadmap to improve the effectiveness of amphibious lift ships.**

Dock Landing Ship (LSD)



LSD 41 Whidbey Island Class	LSD 49 Harpers Ferry Class
• 8 hulls • 4 LCACs • 5,100 ft^3 for marine cargo • 17,266 ft^2 for vehicles	• 4 hulls • 2 LCACS • 50,700 ft^3 for marine cargo • 17,599 ft^2 for vehicles

Operations

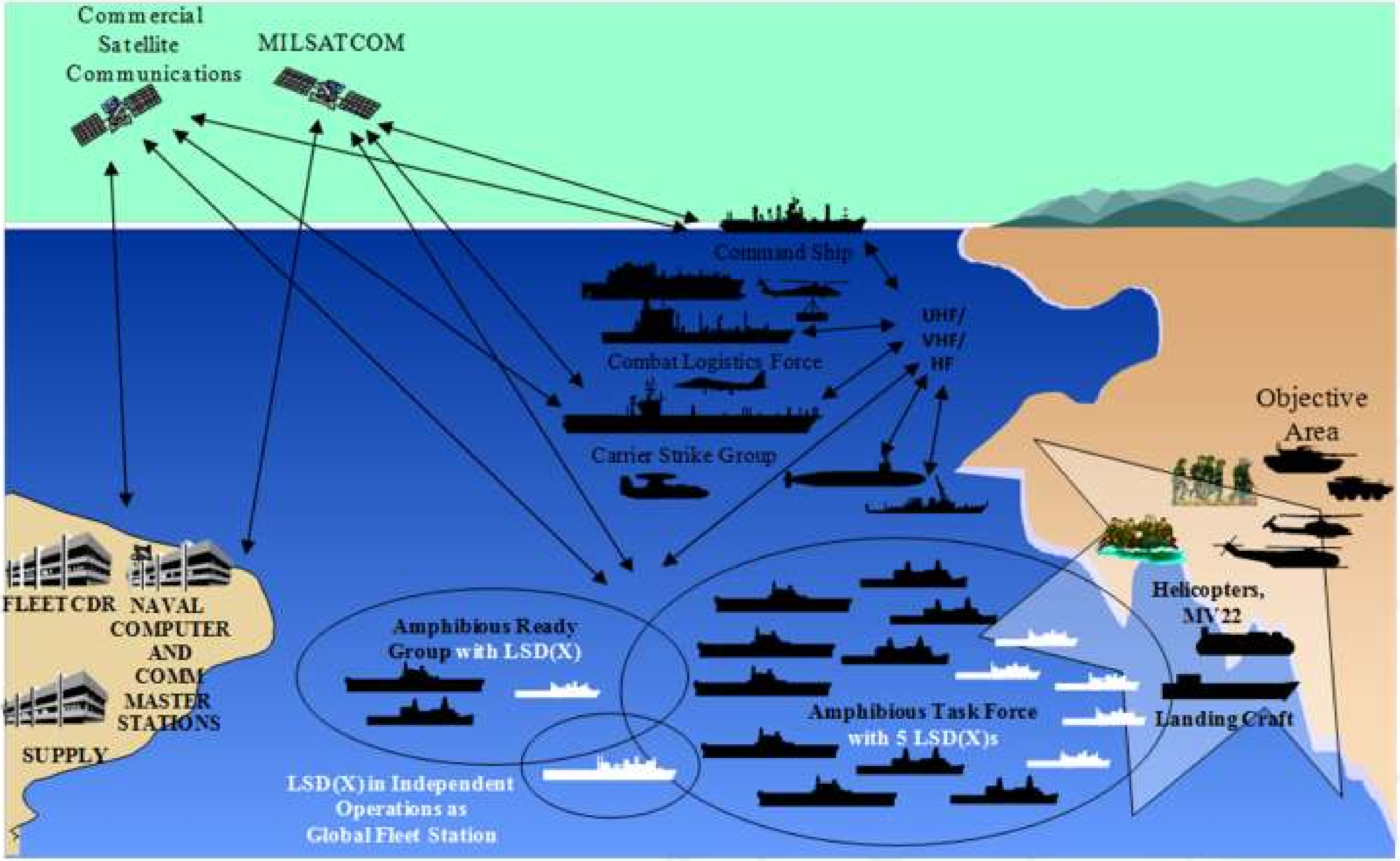
- LHD or LHA, LPD, & LSD
  - 1, 1, 1
- Marine Expeditionary Unit (MEU)
  - 2,200 Marines
- Amphibious Task Force (ATF)
  - 5, 5, 5
- Marine Expeditionary Brigade (MEB)
  - 2.0 MEBs (11, 11, 11)

MEB Lift Requirements

The Amphibious fleet is tasked with lifting these 2.0 MEB quantities:

LCACs (Total #)	54
Troops (Total #)	24,342
Vehicle (Total Sq Ft)	930,488
Cargo (Total Cu Ft)	1,861,636
Aviation (CH-53 equiv)	1,235
JP-5 (Gallons)	16,690,930

OV-1


Commercial
Satellite
Communications
MILSATCOM
Command Ship
Combat Logistics Force
UHF/
VHF/
HF
Carrier Strike Group
Objective
Area
FLEET CDR
NAVAL
COMPUTER
AND
COMM
MASTER
STATIONS
SUPPLY
Amphibious Ready
Group with LSD(X)
Helicopters,
MV22
Amphibious Task Force
with 5 LSD(X)s
Landing Craft
LSD(X) in Independent
Operations as
Global Fleet Station

BLUF

- Procurement decision is not time critical.
- If unable to wait, procure either LPD-17s or LSD(X)s roughly 30% larger than the existing classes.
  - Do not procure 11 ships.
  - Conduct further analysis to determine an amphibious fleet architecture more robust than the 11/11/11 paradigm.

Systems Engineering Process

Problem Definition

- Stakeholder
- Research
- Functional
- Requirements
- Measures

Solution Design

- Tradespace
- Alternative Generation
  - New Designs
  - Existing Designs

Decision Analysis

- Performance
- Cost
- Risk

Stakeholder Analysis

Problem Statement

- The LSD 41/49 class ships are past mid-life with no designed successor. Potential alternative solutions must be analyzed and compared with respect to their cost, performance, and risk in order to support future amphibious force requirements.

Amphibious Mission Set

Demonstration

Raid

Assault

Withdrawal

HA/DR

From these operations scenarios will be developed to evaluate the performance of the various alternatives.

Trade Space

- Two major trade spaces were identified:
  - Lift vs Size vs Cost
  - Cargo Capacity vs Vehicle Capacity

Alternatives

Option 1- LPD-17:
This alternative would maintain an open San-Antonio class production line open and replace the decommissioning LSD class ships with 11 LPDs.

Option 2 - LSD(X) clean sheet design:
This alternative would be comparable in size to the current Whidbey Island (LSD-49) class and would replace the decommissioning class with 11 new LSD(X) ships.

Option 3 - LSD(XB) clean sheet design:
A new ship larger than the current classes, but smaller than an LPD would mitigate lift capability gaps to a greater extent than the LSD(X). It would replace the retiring class with 11 LSD(XB) ships.

Option 4 - LPD-17 Flt(X):
This alternative would take advantage of the construction line for LPD-17s but would redesign the LPD utilizing the same hull while investigating the trade-space between cargo and vehicle capacity. It would replace the decommissioning class with 11 LPD-17 Flt(X) ships.

Alternatives

***Option 5 - LHA-8*: (Big Deck)**

This alternative would procure 4 America class ships, in addition to the 6 planned for procurement. It posits the possibility of an ARG composed of two big decks. More LHDs could also be procured in the future.

***Option 6 - All LPD-17*: (Small Deck)**

This alternative supposes a procurement of 19 LPDs. It supposes turning away from the procurement of future big deck ships to analyze the performance of a fleet composed of only small deck ships.

ARG Option Comparison

	ARG Configurations	LCAC	Troops	Vehicles	Cargo	Aviation	JP-5
	Requirement	6	2,578	56,153	209,700	90.06	850,410
Option #1	LHD, LPD-17, LPD-17	7	3,093	59,434	193,000	98.97	1,115,488
	LHA(R), LPD-17, LPD-17	6	2,858	57,760	198,000	114.9	1,221,616
	LHA-1, LPD-17, LPD-17	5	3,291	64,987	173,900	86.23	1,044,586
Option #2	LHA-1, LPD-17, LSD(X)	5	2,793	64,107	145,000	82.23	826,278
	LHA(R), LPD-17, LSD(X)	6	2,360	56,880	169,100	110.9	1,003,308
	LHD, LPD-17, LSD(X)	7	2,595	58,554	164,100	94.97	897,180
Option 3#	LHA-1, LPD-17, LSD(XB)	5	3,123	67,107	205,900	84.23	876,278
	LHA(R), LPD-17, LSD(XB)	6	2,690	59,880	230,000	112.9	1,053,308
	LHD, LPD-17, LSD(XB)	7	2,925	61,554	225,000	96.97	947,180

ARG Option Comparison

	ARG Configurations	LCAC	Troops	Vehicles	Cargo	Aviation	JP-5
	Requirement	6	2,578	56,153	209,700	90.06	850,410
Option #4	LHA-1, LPD-17, LPD-17 Flt(X)	5	2,993	72,107	154,900	86.23	1,044,586
	LHA(R), LPD-17, LPD-17 Flt(X)	6	2,560	64,880	179,000	114.9	1,221,616
	LHD, LPD-17, LPD-17 Flt(X)	7	2,795	66,554	174,000	98.97	1,115,488
Option #5	LHD, LHD	6	3,394	35,348	250,000	162.3	957,744
	LHD, LHA-1	4	3,592	40,901	230,900	149.56	886,842
	LHD, LHA(R)	5	3,159	33,674	255,000	178.23	1,063,872
	LHA(R), LHA-1	3	3,357	39,227	235,900	165.49	992,970
Option #6	LPD-17 x 5	10	3,490	104,400	170,000	44.55	1,591,540

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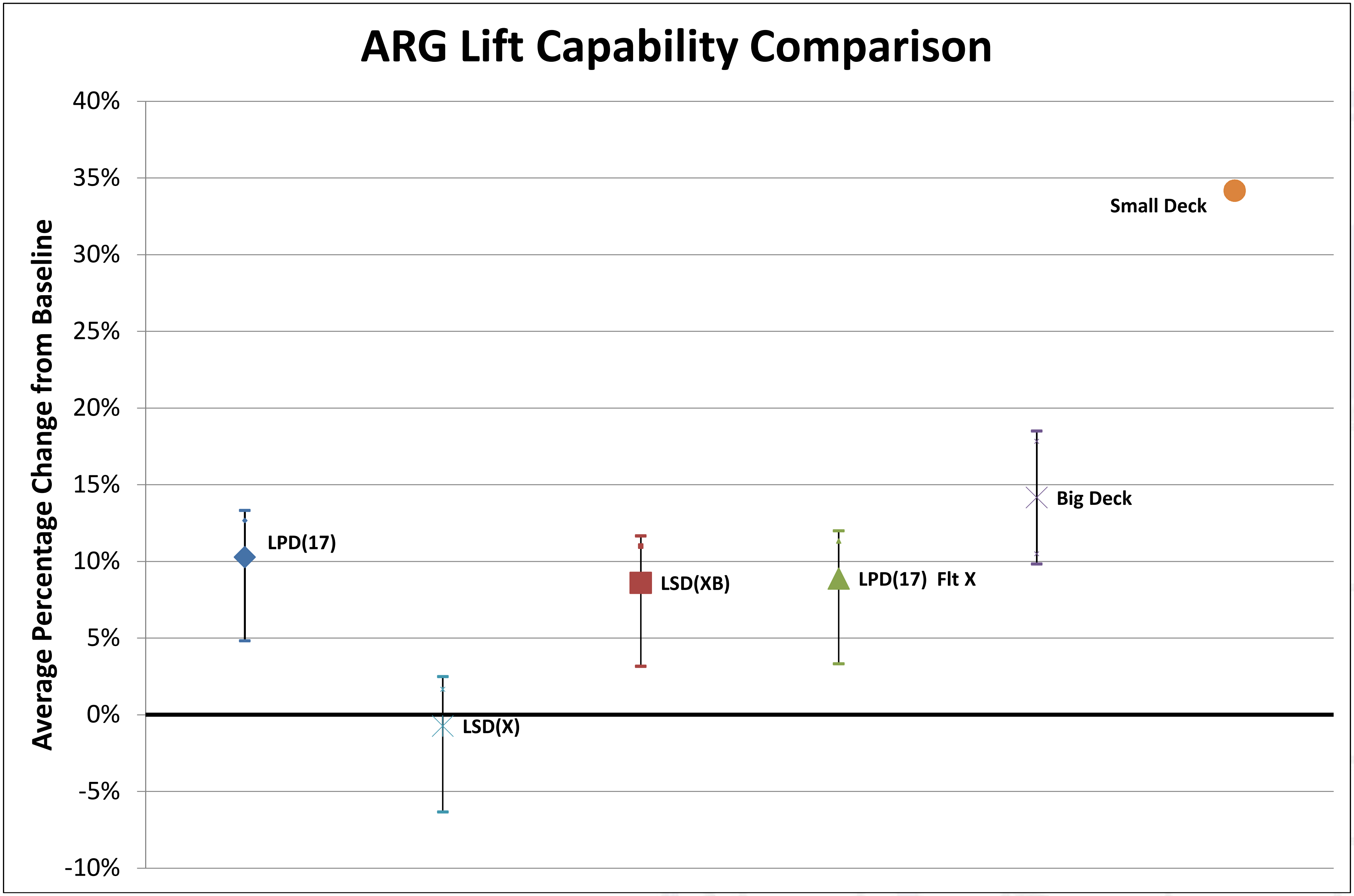
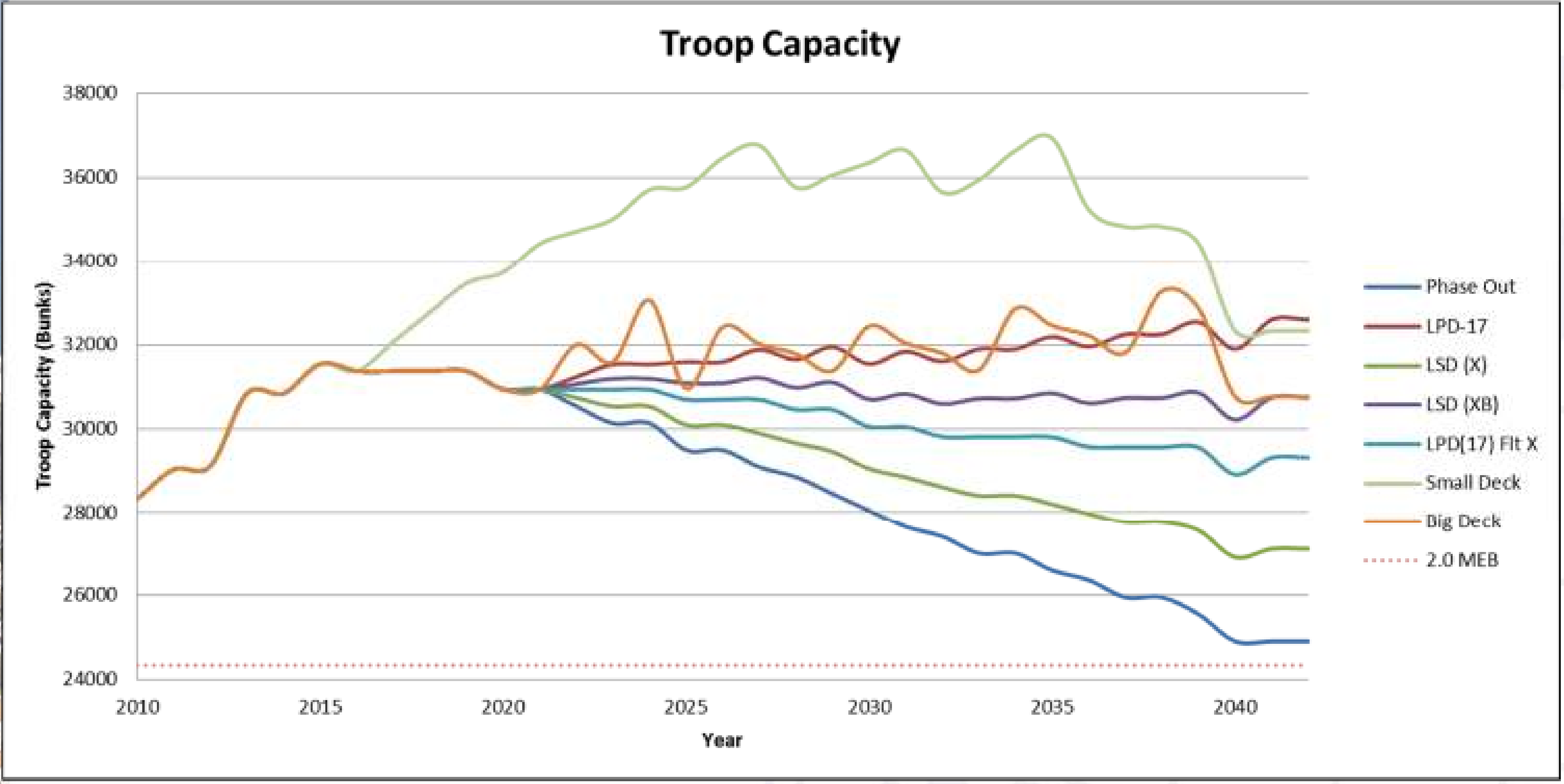
ARG Lift Capability Comparison

	ARG Configurations	LCAC	Troops	Vehicles	Cargo	Aviation	JP-5
	Requirement	6	2,578	56,153	209,700	90.06	850,410
LPD(17)	LHD, LPD(17), LPD(17)	17%	20%	6%	-8%	10%	31%
	LHA(R), LPD(17), LPD(17)	0%	11%	3%	-6%	28%	44%
	LHA(1), LPD(17), LPD(17)	-17%	28%	16%	-17%	-4%	23%
		0%	20%	8%	-10%	11%	33%
LSD(X)	LHA(1), LPD(17), LSD(X)	-17%	8%	14%	-31%	-9%	-3%
	LHA(R), LPD(17), LSD(X)	0%	-8%	1%	-19%	23%	18%
	LHD, LPD(17), LSD(X)	17%	1%	4%	-22%	5%	5%
		0%	0%	6%	-24%	6%	7%
LSD(XB)	LHA(1), LPD(17), LSD(XB)	-17%	21%	20%	-2%	-6%	3%
	LHA(R), LPD(17), LSD(XB)	0%	4%	7%	10%	25%	24%
	LHD, LPD(17), LSD(XB)	17%	13%	10%	7%	8%	11%
		0%	13%	12%	5%	9%	13%
LPD(17) Flt X	LHA(1), LPD(17), LPD(17 FLX)	-17%	16%	28%	-26%	-4%	23%
	LHA(R), LPD(17), LPD(17 FLX)	0%	-1%	16%	-15%	28%	44%
	LHD, LPD(17), LPD(17 FLX)	17%	8%	19%	-17%	10%	31%
		0%	8%	21%	-19%	11%	33%
Big Deck	LHD, LHD	0%	32%	-37%	19%	80%	13%
	LHD, LHA(1)	-33%	39%	-27%	10%	66%	4%
	LHD, LHA(R)	-17%	23%	-40%	22%	98%	25%
	LHA(R), LHA(1)	-50%	30%	-30%	12%	84%	17%
		-25%	31%	-34%	16%	82%	15%
Small Deck	LPD(17) x 5	67%	35%	86%	-19%	-51%	87%

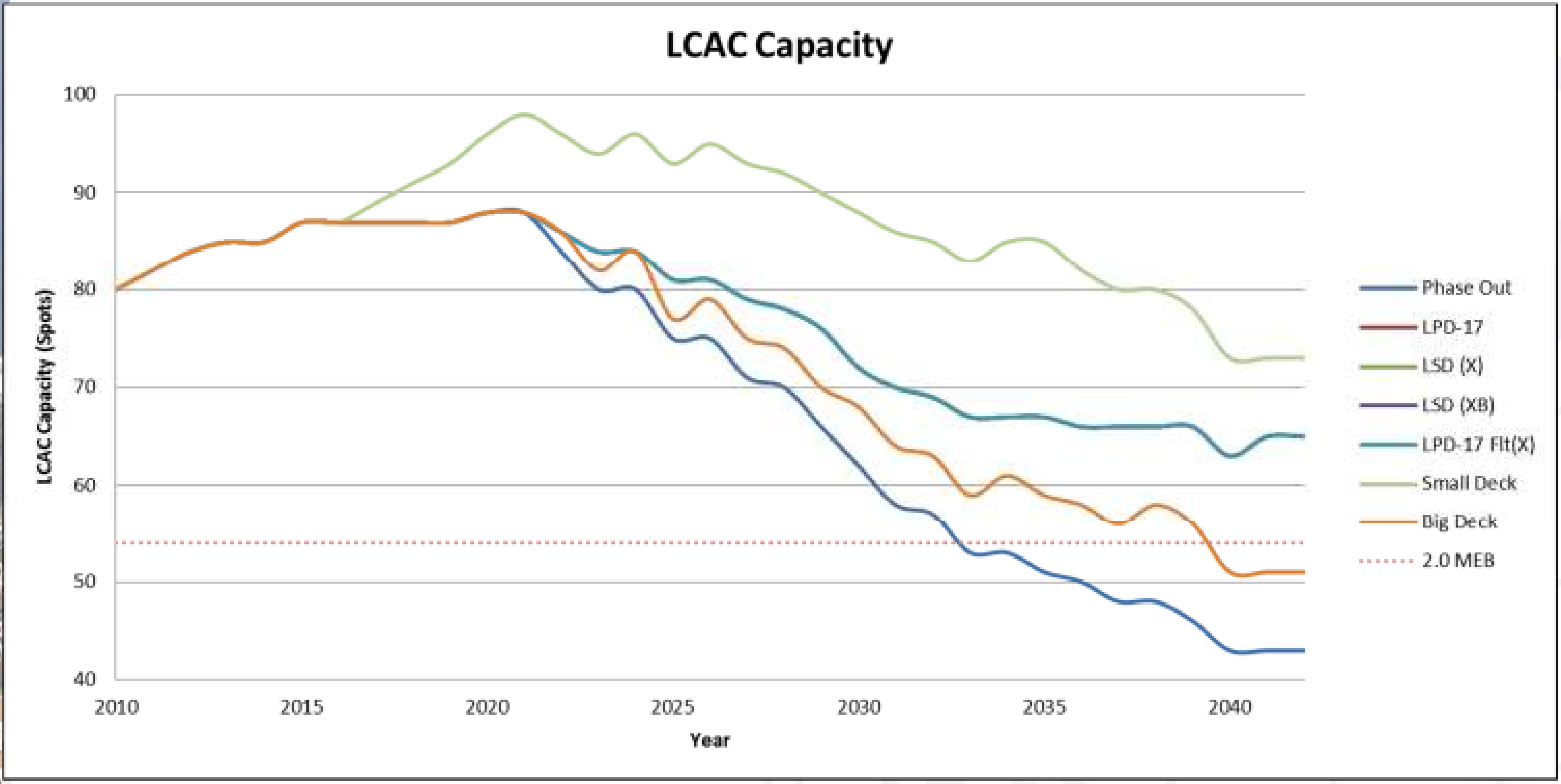
ARG Lift Capability Comparison



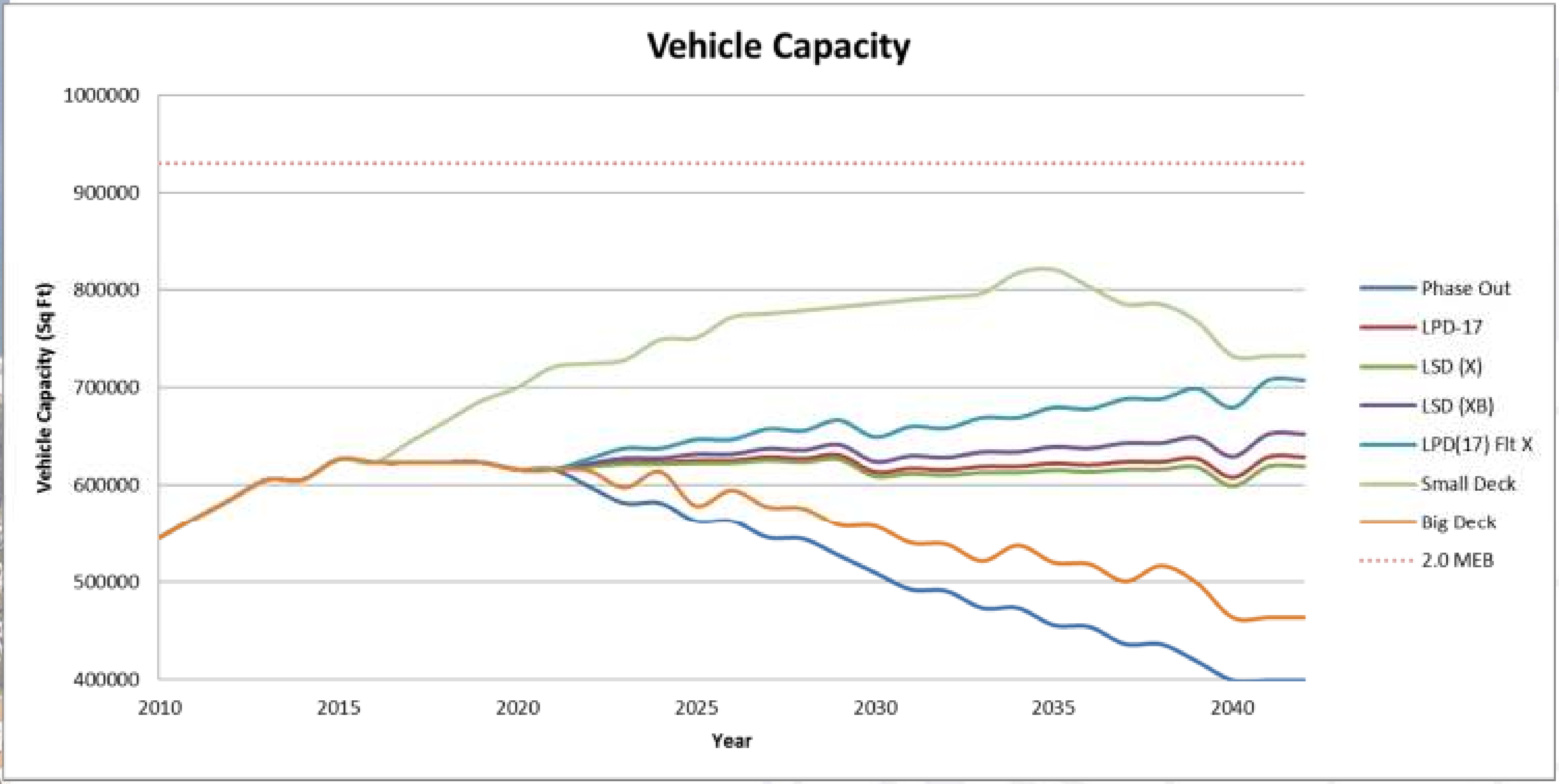
30 Year MEB Lift Analysis



30 Year MEB Lift Analysis cont.



30 Year MEB Lift Analysis cont.

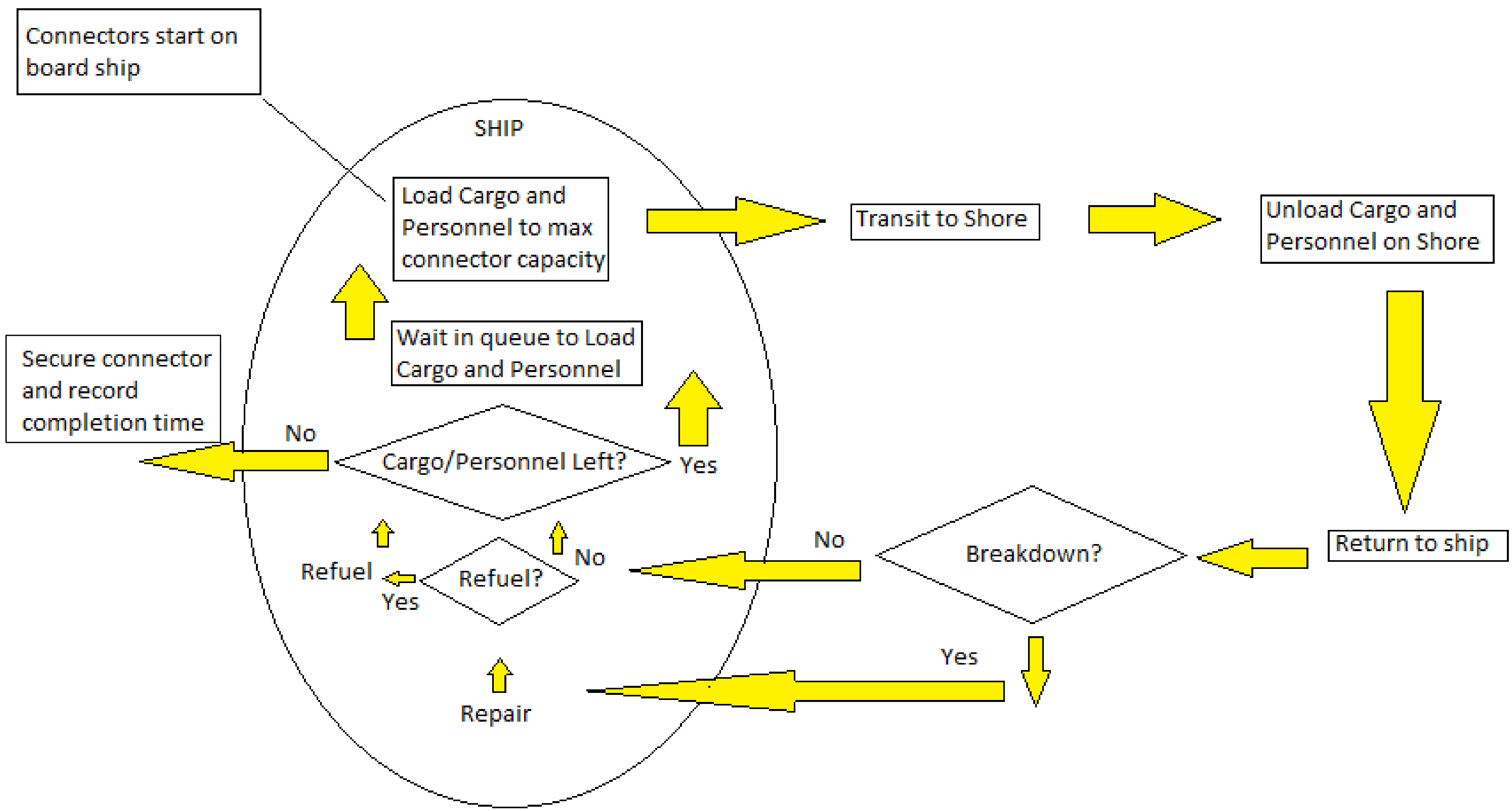


Simulation Implementation

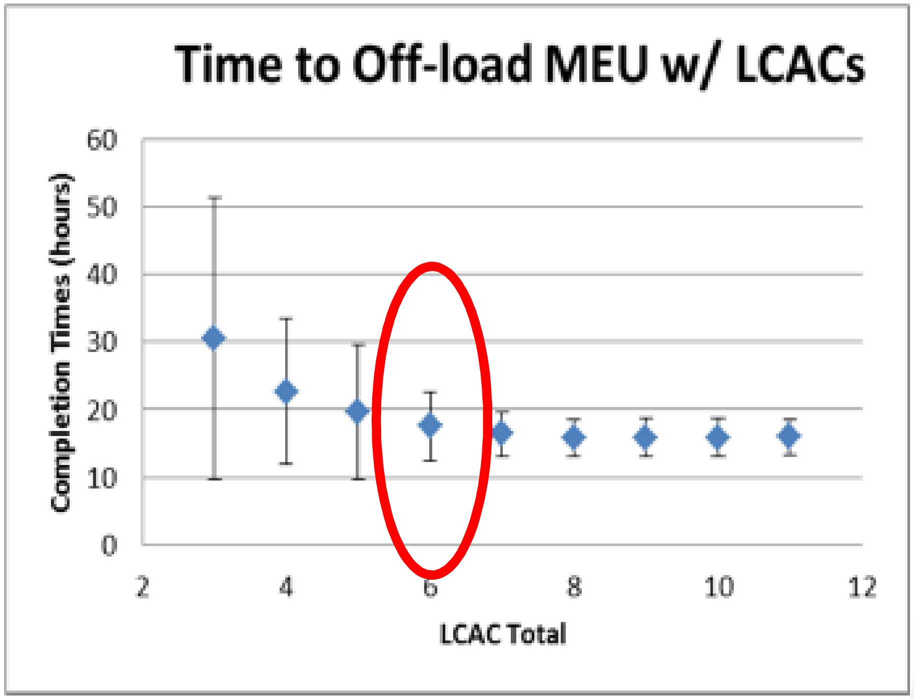
The purpose is to investigate points of inflection in design trade space for both the LSD(X) and various ARG architectures based on throughput and survivability:

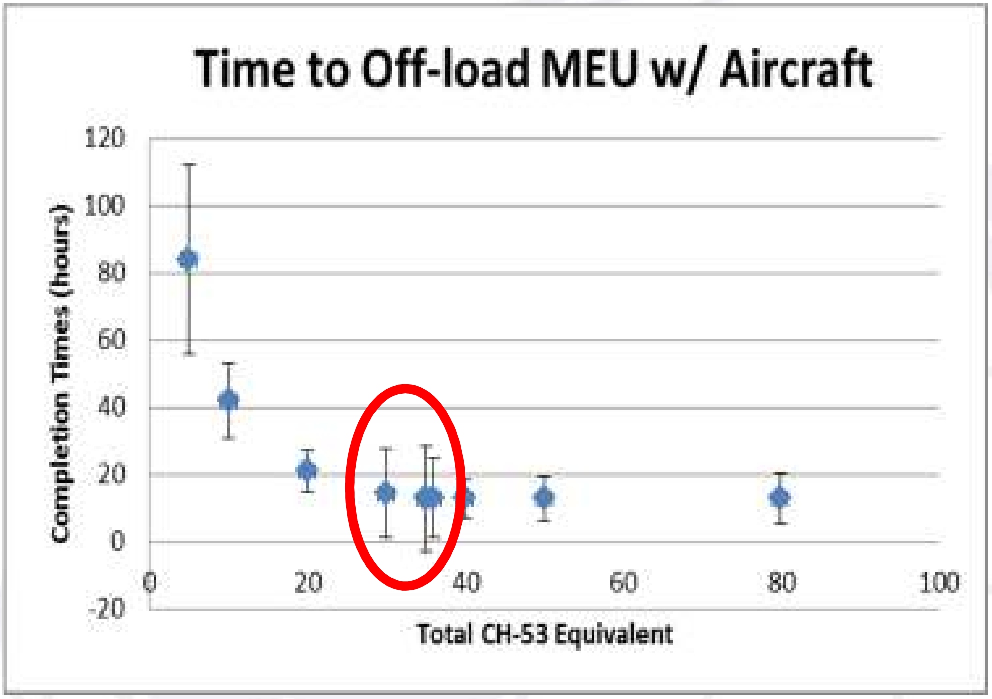
- Aircraft (total in ARG)
- Aircraft spots (total in ARG)
- LCACs (total in ARG)
- LCAC spots (ships in ARG)

Simulation Process



Off-loading the ARG





Simulation Data Analysis

- Multiple tools were used to analyze the simulation output
  - Nearly Orthogonal Latin Hypercube (NOLH) Experimental Design
  - Principal Component Analysis (Multivariate Regression)
  - Partition Trees

Performance Results

- Top derived Architectures:
  - HA/DR:

Ranking	Option
1	Small Deck Option
2	LSD(X) Option
3	LPD-17 Flt(X) option

  - Assault: Variations of the Big Deck Architecture (Option 5) took 1st through 3rd places.

Ranking	Option
1	LHD, LHD
2	LHA(R), LHA-1
3	LHD, LHA-1

NOLH Setup

Factor Name	Number Levels	Low Level	High Level
LCAC Spots	4	2	5
A/C Spots	7	12	18
LCAC Total	8	3	10
A/C Total	26	25	50
LCAC Transit Time (min)	300	10	30
A/C Transit Time (min)	300	3.3	10
JP-5 (Gal)	300	778,438	1,591,540
Troop Total	300	2,360	3,592
Cargo total (Sq Ft)	300	48,174	129,900

- 14.1 Q Total Levels

NOLH Results

- Best Derived ARG Composition Significant Factors:
  - LCACs: 6
  - Ships: 4
  - CH-53 equiv: 40
  - A/C spots: Insignificant factor

Cost Analysis Assumptions

- Design and Procurement costs are based on Lead Ships at the 1-digit Ship Work Breakdown Structure (SWBS) level (i.e. 100, 200, …, 900).
- There is a 30 year life cycle for Amphibious Ships.
- The class of ships to be constructed is similar to the class of ships used in developing the costs estimates.
- Monte Carlo simulation was used to develop an estimate of the 80th percentile of LCCE CDF.
- All estimates are made in FY 2012 Dollars.

Cost Considerations

- ***Option 1- LPD-17*:** Procurement of 11 LPD-17s every other year as a continuation of the current line of LPD-17s utilizing the learning curve from the original 11.

- ***Option 2 - LSD(X) clean sheet design*:** Procurement of 11 LSD(X)s cost was modeled using historical data and regression of current amphibious ships at the 1-digit SWBS level.

- ***Option 3 - LSD(XB) clean sheet design*:** Procurement of 11 LSD(XB)s cost was modeled using historical data and regression of current amphibious ships at the 1-digit SWBS level.

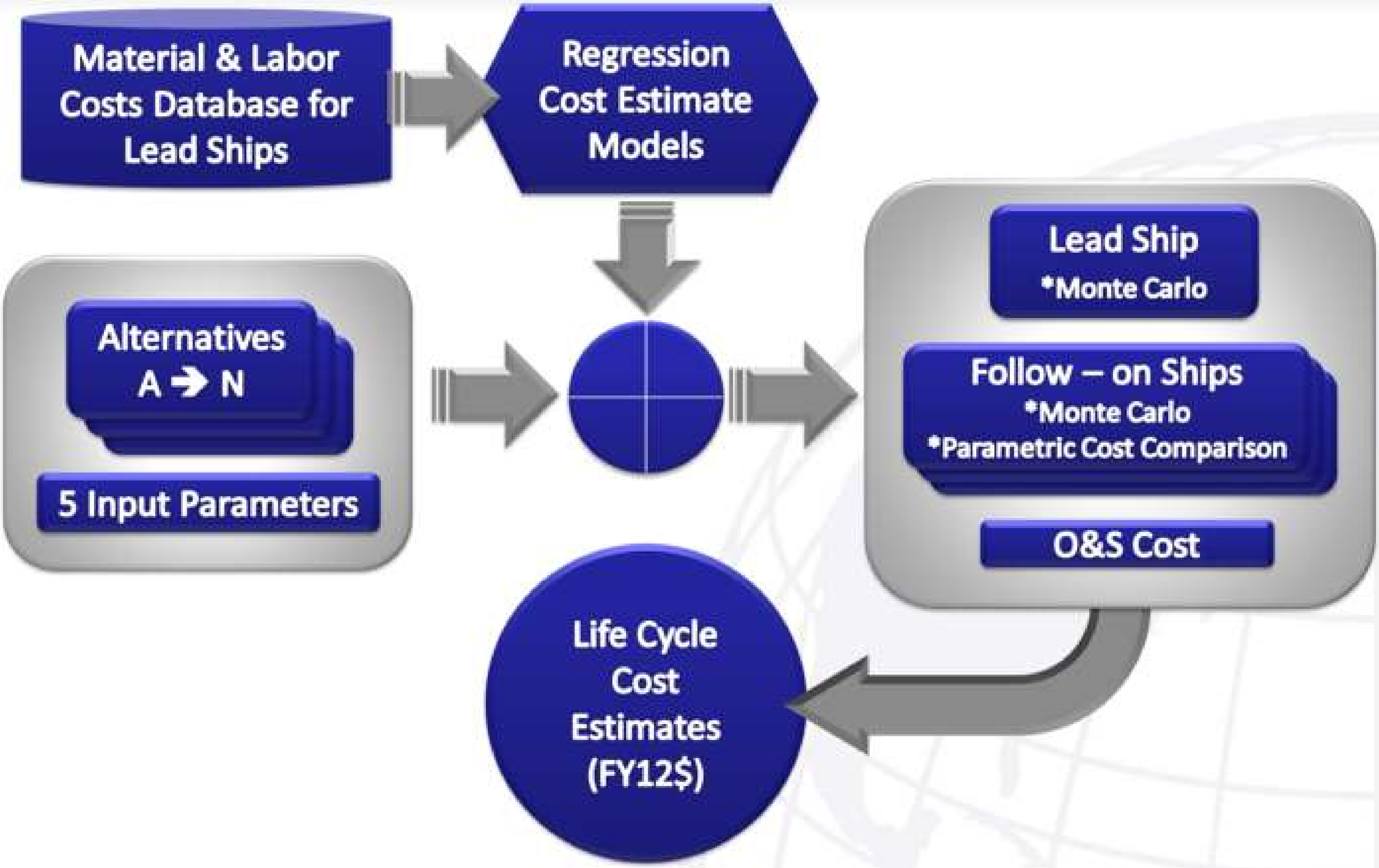
- ***Option 4 - LPD-17 Flt(X)*:** Procurement of 11 LPD-17 Flt(X)s utilizing the current LPD hull results in a ship which is 70% Legacy and 30% New and provides a continuation of the current line of LPD-17s.

Cost Considerations

- ***Option 5- LHA-8*:** This alternative would procure 4 America Class ships, in addition to the 6 currently planned for procurement. The LCCE for this option is the difference between the SEA-18 plan for 10 LHAs and the original Navy ship building plan of 6 LHAs.

- ***Option 6 – All LPD-17*:** Procurement of 19 LPD-17s at a rate of one per year as a continuation of the current line of LPD-17s utilizing the learning curve from the original 11.

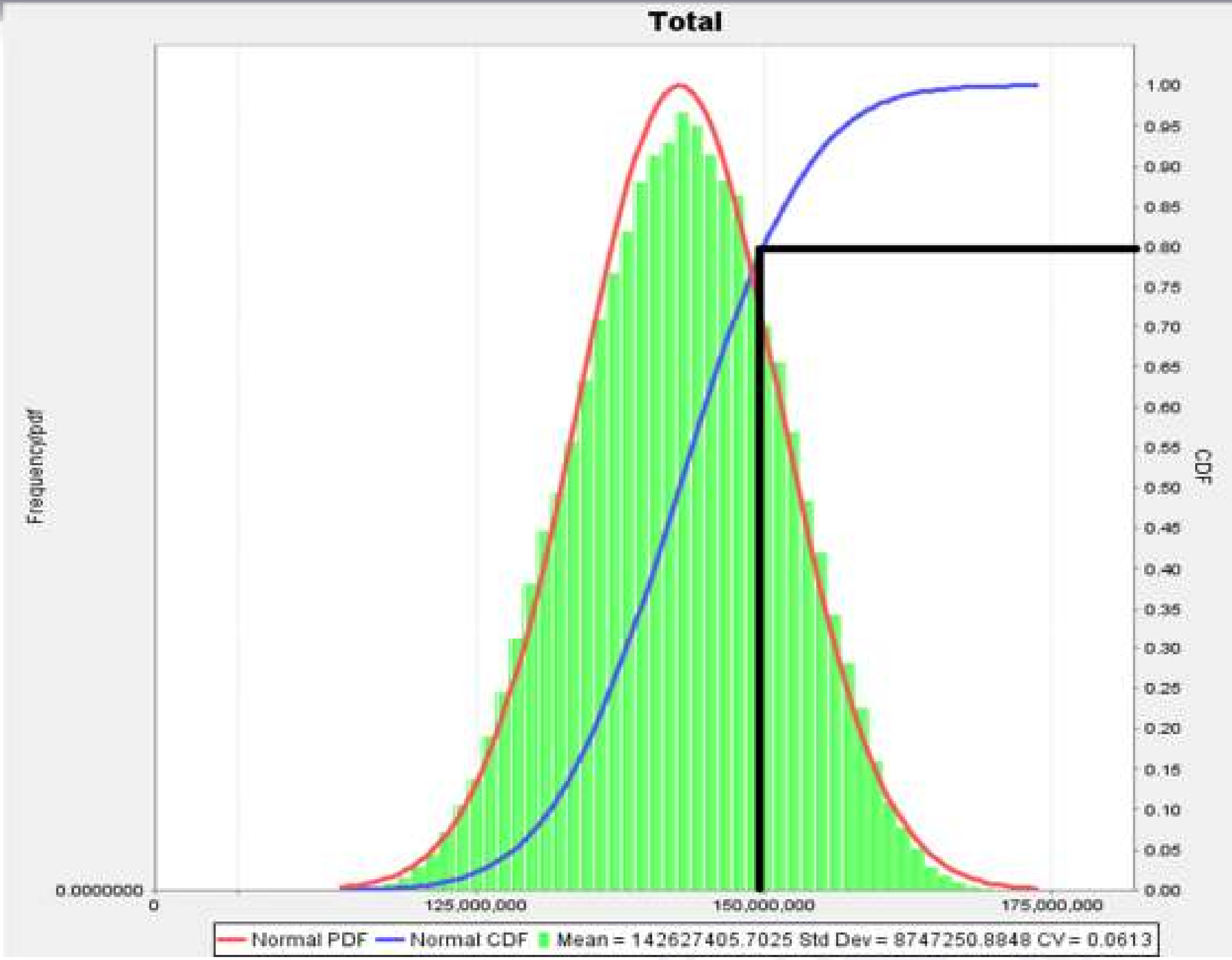
New Construction Cost Model



Cost Model Validation

Input Parameters	Whidbey Island LSD-41	Harpers Ferry LSD-49	San Antonio LPD-17	America LHA-6	Wasp LHD-1
LCACs (#)	4	2	2	0	3
Cargo (Cu Ft)	5,000	50,700	34,000	160,000	125,000
Crew (#)	434	434	388	1,124	1,188
Troops (#)	402	402	720	1,687	1,687
Beam (Ft)	84	84	105	194	140
Model Output Cost	1.0025	1.1149	0.6834	0.9839	1.1850
Total Historical Cost	1.0000	1.0000	1.0000	1.0000	1.0000
Cost Difference	0.25 %	11.49 %	-31.65 %	-1.60 %	18.50 %
		(Cargo & Learning)	(Overly Expensive)		

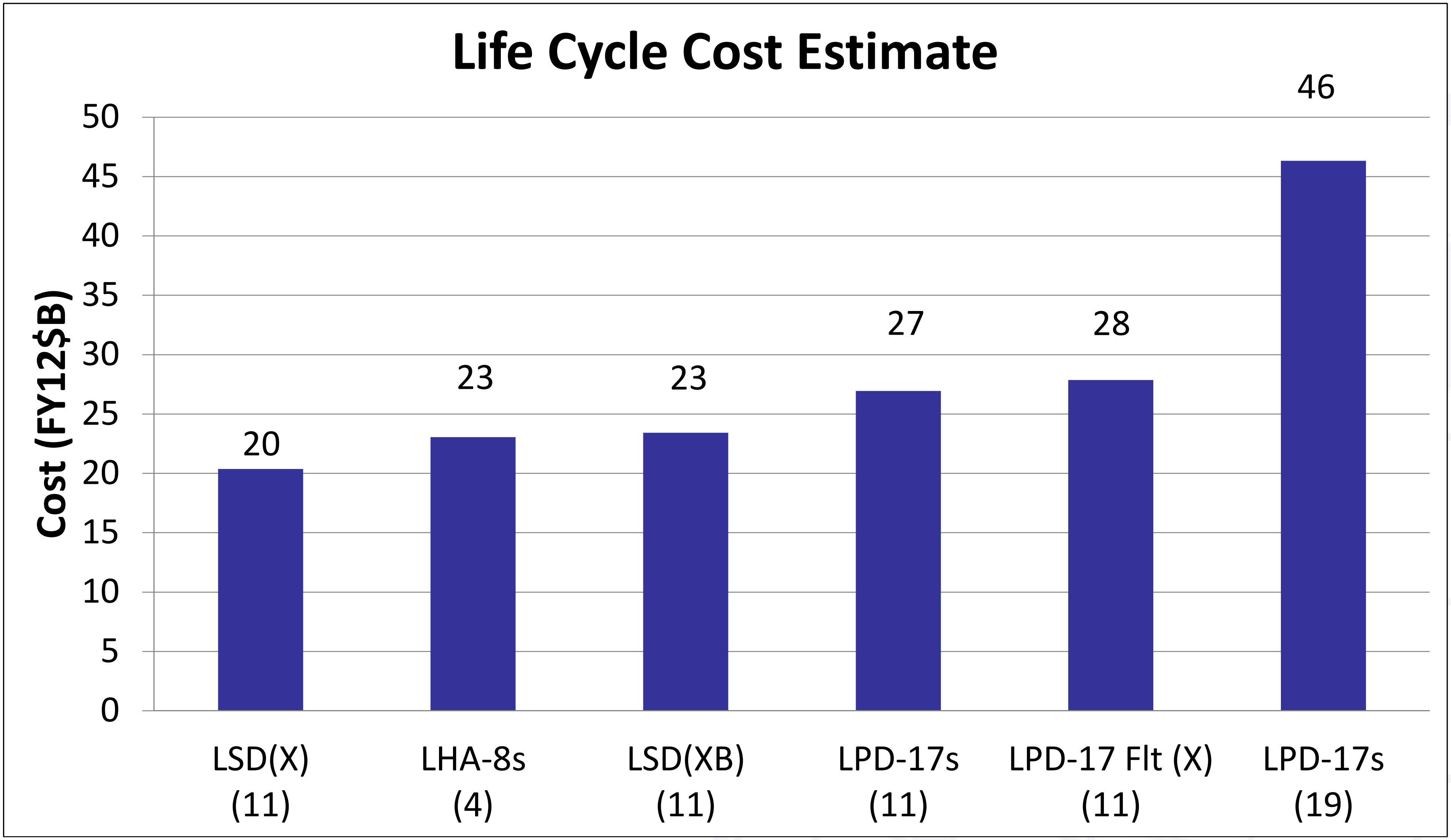
Monte Carlo 80th Percentile



Results of Monte Carlo Simulation for Material Costs – LSD(X)

80% of the time the actual cost will be below the estimate.

LCCE Summary



Synthesizing Results

- Performance Results, lift capability and throughput, were compared to LCCEs of each option.
- The charts on the following slides show how each option compares with the ARG option currently in use (baseline) with respect to Assault and HA/DR operations.

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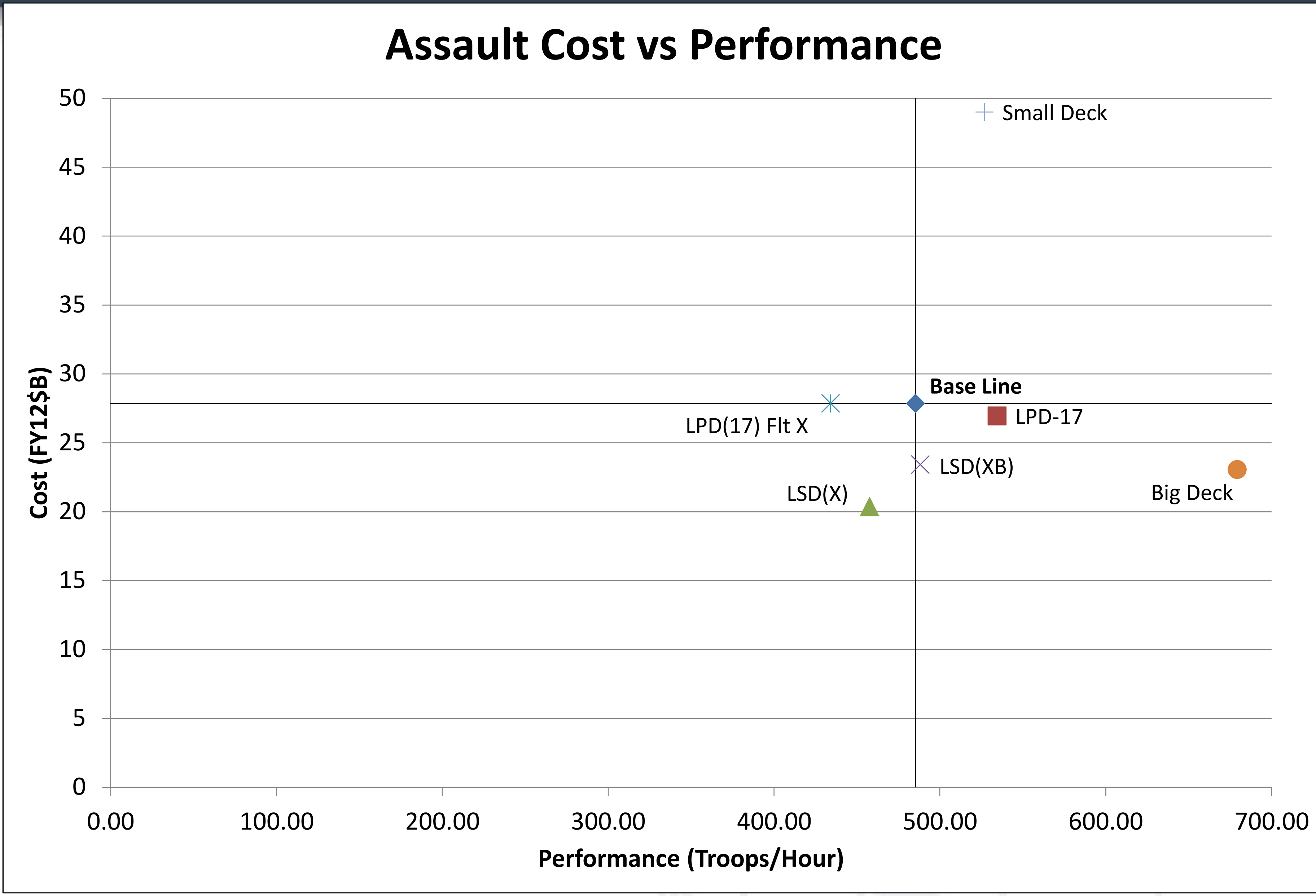
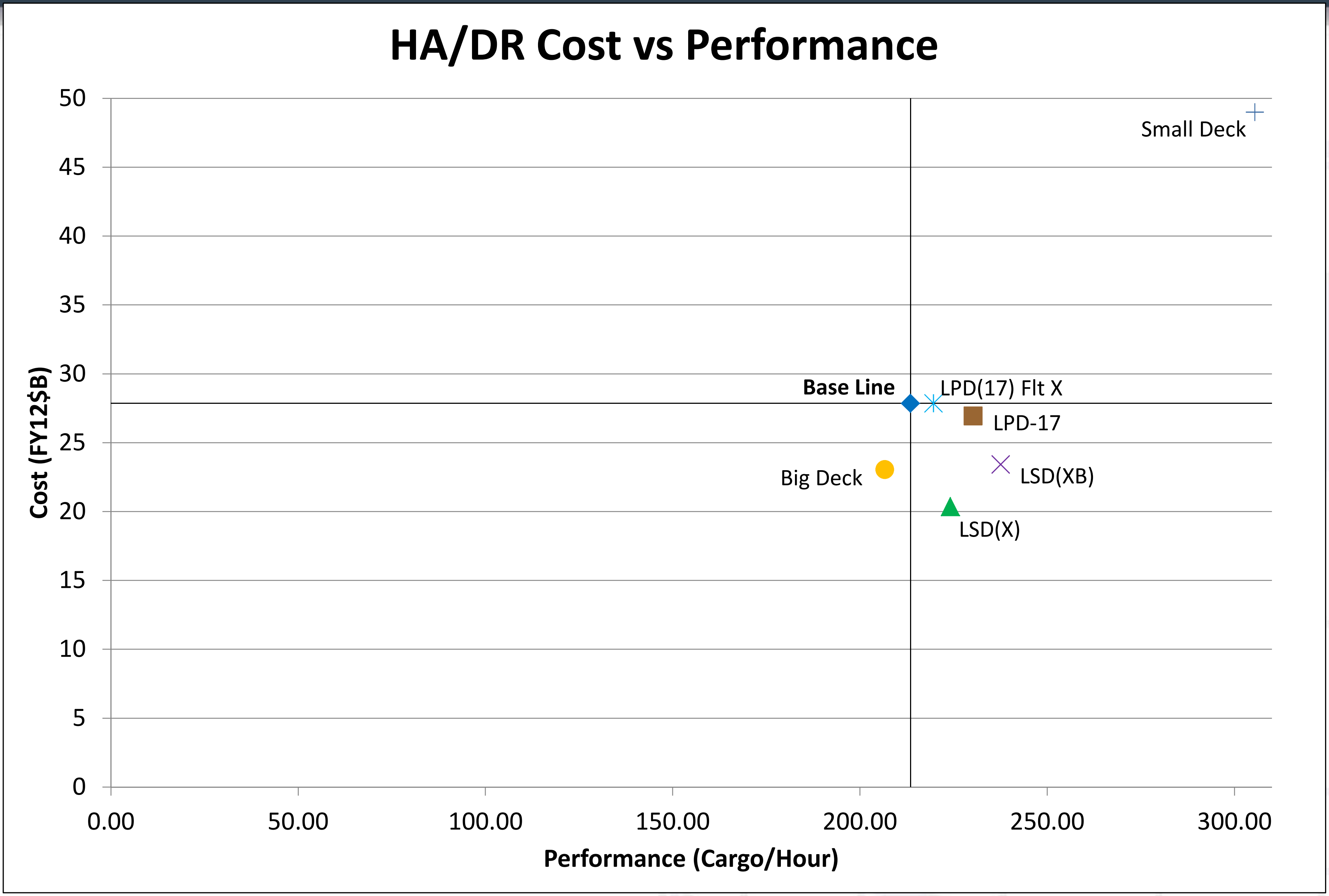
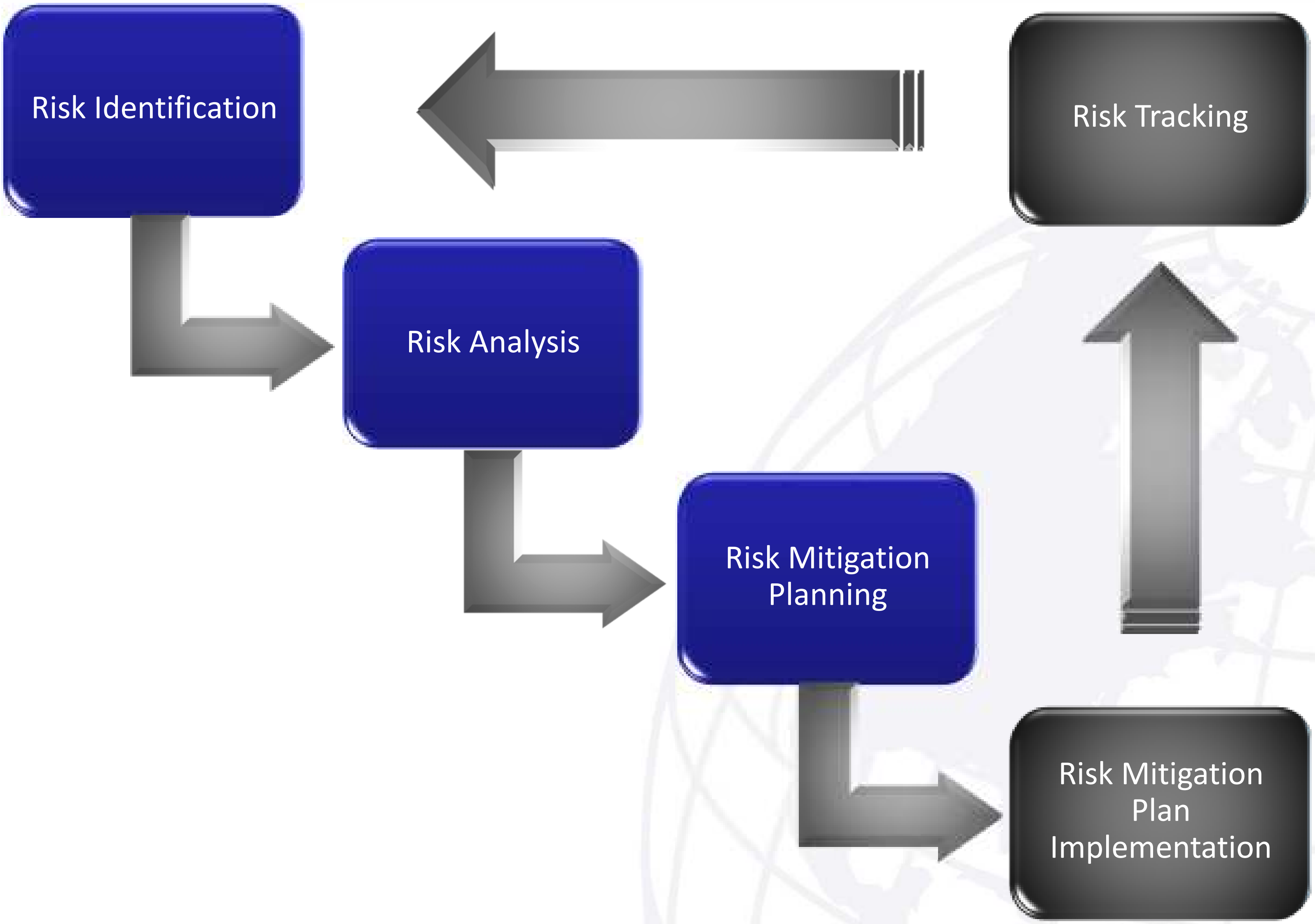
Assault Cost vs Performance



HA/DR Cost vs Performance



Risk Management Process



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Risk Identification

Performance	Schedule	Cost
• Risk of Not Meeting Lift Requirements • Number of Ships Due to Failure or Maintenance • Risk of Failing to Conduct a Diverse Mission Set • Mission Accomplishment (Split-Ops Impacts) • Risk of Mission / Force Projection Delays Due to Enemy Actions	• Number of Ships Being Built or Timeline Required • Risk of Delay • Risk of Insufficient Testing of Systems • Ship Design / Building Issues • Construction Availability • Risk of Exceeding Approved Annual Ship Construction Budget	• Cost Overrun • Production Process Not Proven • Sufficient Facilities are Not Available for Construction • Sensitivity to Fuel, Maintenance, Personnel Cost Flux • Infrastructure Changes Required for Port Facilities

Alternatives with High Inherent Risk

Alternatives That Add LPD-17s (Options 1, 4 & 6)

The LPD-17 hull design has had significant challenges due to budget overruns of around 30%. This risk to the cost of the project may be unacceptable to decision makers without significant mitigating measures in place.

Alternatives That Utilize A New Hull Design (Options 2 & 3)

One risk identified was the development of new ship designs has historically been problematic. Cost overruns and delays associated with the acquisition of recent systems such as the LPD-17 and LCS have been significant.

Alternatives That Reduce Or Increase The Number Of Ships (Options 5 & 6)

The risk associated with the loss of one of these ships due to construction delays, enemy action, or maintenance delays pose a significant threat to the amphibious fleet’s ability to meet mission requirements. Significant risk would be in the limited ability to support fixed wing aircraft operations.

Risk Analysis

Probability / Likelihood Level Criteria	
Likelihood Level	**Description**
0.1	Remote
0.3	Unlikely
0.5	Likely
0.7	Highly Likely
0.9	Near Certain

Consequence Level Criteria			
Level	**Performance**	**Schedule**	**Cost**
0.1	Minimal or no impact	Minimal or no impact on total ship design or production schedule	Minimal or no impact on total objective cost
0.3	Acceptable with some reduction in margin	Additional resources required; able to meet need dates	< 5% increase
0.5	Acceptable with significant reduction in margin	Minor slip in key milestones; not able to meet need date	5 - 7% increase
0.7	Acceptable; no remaining margin	Major slip in key milestone or critical path impacted	7-10% increase
0.9	Unacceptable	Can't achieve key team or major program milestone	>10% increase

$$R_i = \sum_i PL_i CF_i$$

- Each alternative's risk was analyzed for its overall risk based on three factors.
- Each factor was given a probability and consequence of it occurring.
- Overall risk was then calculated by summing individual risks factors per alternative.

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Risk Analysis Results

Overall Risk Assessment for Alternative Architecture	
Alternative	**Overall Weighted Risk**
Option 1: LPD(17)	1.7
Option 2: LSD(X)	**2.6**
Option 3: LSD(XB)	2.1
Option 4: LPD(17) FltX	1.9
Option 5: Big Deck	**2.4**
Option 6: Small Deck	**1.5**

$$Overall.Risk = w_p R_p + w_s R_s + w_c R_c$$

- A weight was assigned to the factors of performance, cost and schedule risk at 0.9, 0.5, and 0.3 respectively.
- The results of the analysis show options that focused on the production of the LPD-17 to replace the LSD demonstrate the lowest risk and that new LSD(X) Option would be the riskiest.

Risk Mitigation

- After identifying major risk factors mitigating strategies were determined in the three major risk consideration areas of performance, schedule and cost.
- The strategy will first deal with considerations that need to be addressed within each of the alternatives of this analysis and then any that were found to be specific to a particular alternative.

Risk Mitigation Analysis

- Based on the analysis of factors that would most likely impact decisions being made for the adoption of an overall strategy.
- The primary factors that were chosen represent a combination of the probability that decision makers would adopt the strategy, the probability that the strategy would be successful and the anticipated range of cost savings that could be expected for that strategy on the overall cost of the program.

Risk Mitigation Strategy Table				
Strategy	**Mitigation Strategy Category**	**Assessed Implementation**	**Assessed $P_{SUCCESS}$**	**Possible Reduction Range ***
Improve Maintenance Schedule	Performance	0.8	0.8	5-7%
Using Mature Technology	Schedule	0.9	0.8	5-8%
Open Ship to Foreign Military Sales	Cost	0.9	0.5	5-9%
Expand Life Cycle	Cost	0.9	0.9	4-6%
Pre-Warehouse Spares	Cost	0.9	0.9	3-5%

Conclusion

- Best 1 for 1 replacement:
  - LPD-17
  - LSD(XB) is approximately 30% larger than existing LSD classes.

Recommendation

- Investigate the feasibility of Options 5 and 6.
- Determine annual COCOM demand.
- 11/11/11 is not the best amphibious fleet architecture.

Questions & Discussion

Back-up Slides

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SWBS Definitions

100	Hull Structure	Shell plating, decks, bulkheads, framing, superstructure, pressure hulls & foundations
200	Propulsion Plant	Boilers, reactors, turbines, gears, shafting, propellers, steam piping, & lube oil piping
300	Electric Plant	Ship service power generation equipment, power cable, lighting systems, & emergency electrical power systems.
400	Command & Surveillance	Navigation systems, interior communication systems, fire control systems, radars, sonars, radios, telephones, and command & control systems.
500	Auxiliary Systems	Air conditioning, ventilation, refrigeration, replenishment at sea systems, anchor handling, elevators, fire extinguishing systems, distilling plants, steering systems, and aircraft launch & recovery systems.
600	Outfit and Furnishing	Hull fittings, painting, insulation, berthing, sanitary spaces, offices, medical spaces, ladders, storerooms, laundry & workshops.
700	Armament	Guns, missile launchers, ammunition handling and stowage torpedo tubes, depth charges, mine handling and stowage, small arms.
800	Integration / Engineering	Recurring engineering
900	Ship Assembly & Support Services	Staging, scaffolding, launching, trials, temporary utilities and services, material handling and removal services, and cleaning services.

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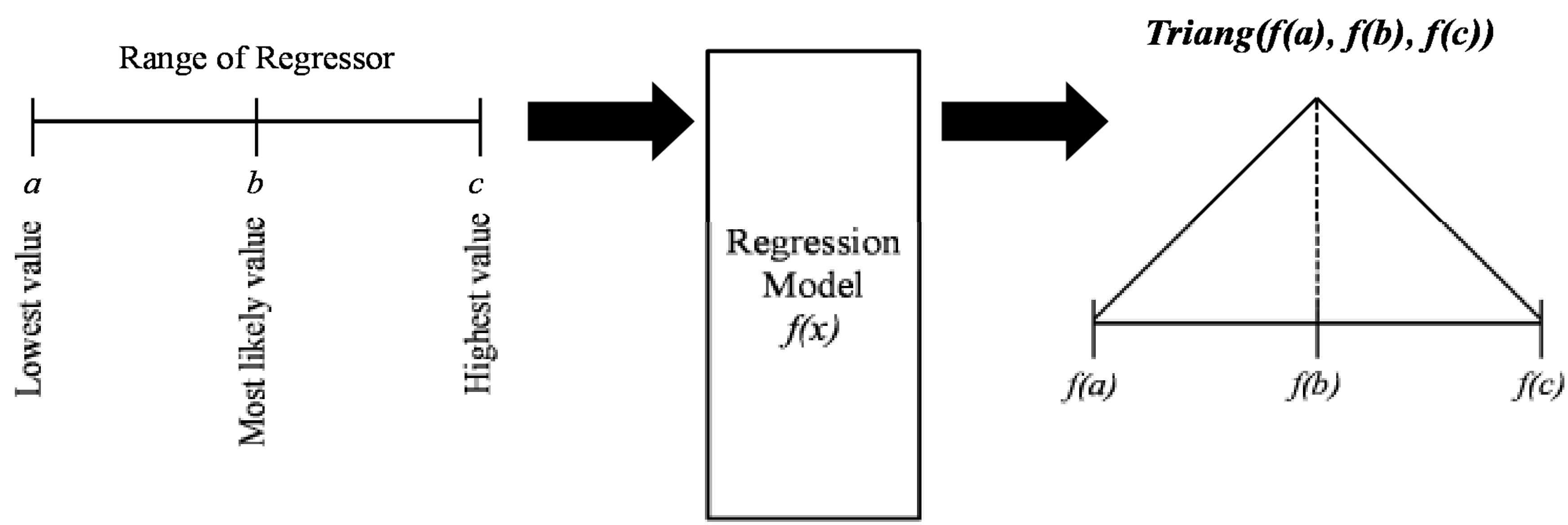
SWBS Regression Data

SWBS Level	Material Variables	Regression Method	Labor Variables	Regression Method
100	Beam	Standard linear regression	Troops	Power model
200	Cargo	Standard linear regression	Mean	-
300	Crew	Power model	Beam	Logarithmic model
400	Troops	Exponential model	Mean	-
500	Crew	Logarithmic model	Mean	-
600	Cargo	Standard linear regression	Troops	Power model
700	LCAC	Standard linear regression	Mean	-
800	Beam	Standard linear regression	Crew	Logarithmic model
900	Beam	Standard linear regression	Troops	Logarithmic model

Regression Equations: Material Cost(100)=44.3M+619K(Beam in feet) y=mx+b
Material Cost(400)=10^(6.93+.000647(# of troops)) Log(y)=b0+b1(log(x))

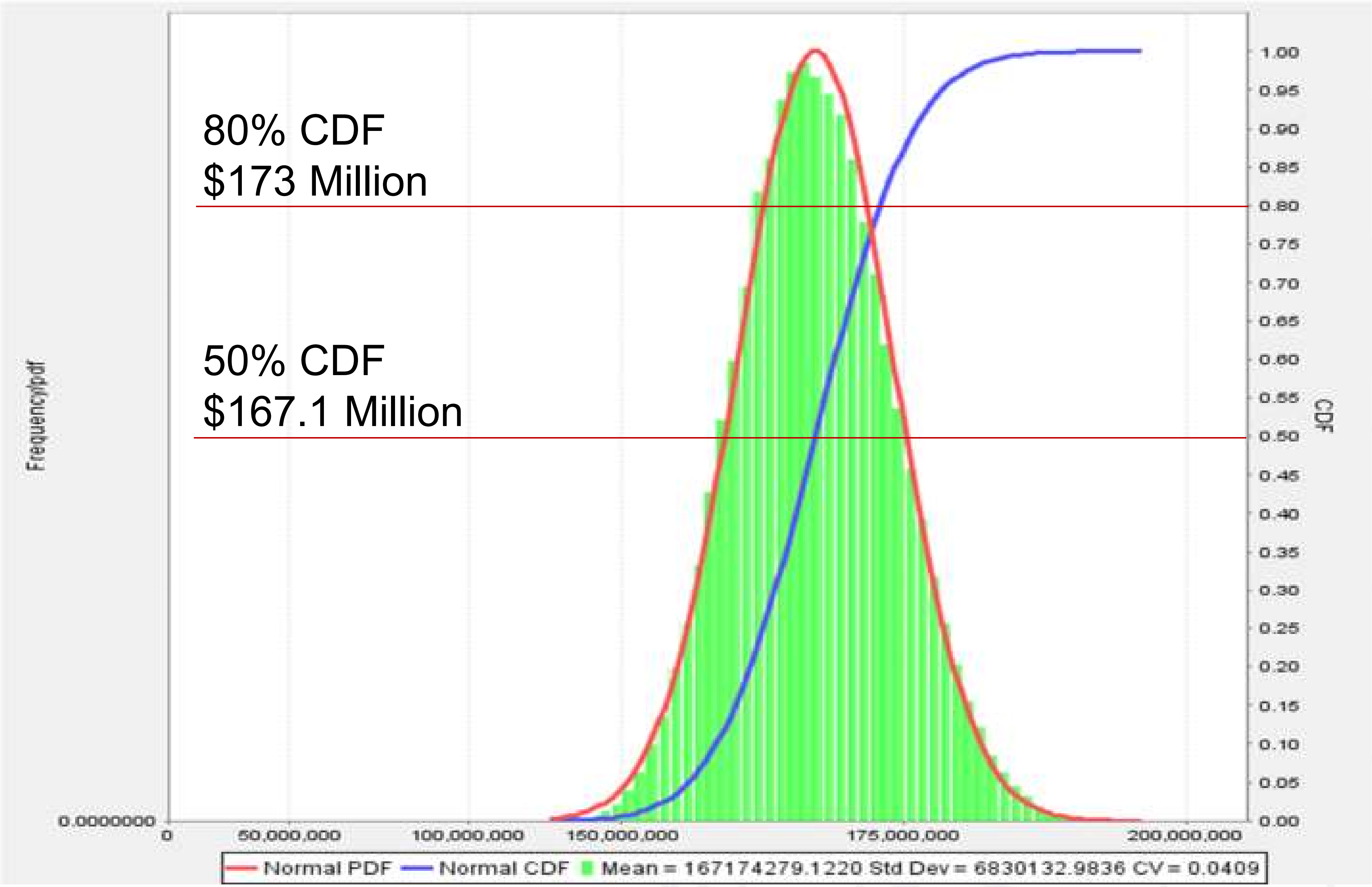
Monte Carlo Simulation

For each SWBS Level



Regressor	Lowest Value f(a)	Most Likely Value f(b)	Highest Value f(c)
Beam (Ft)	84	90	96
Cargo (Ft)	5,100	5,500	34,000
Troops (#)	400	500	600
Crew (#)	388	420	450
LCAC (#)	1	2	4

Material Cost



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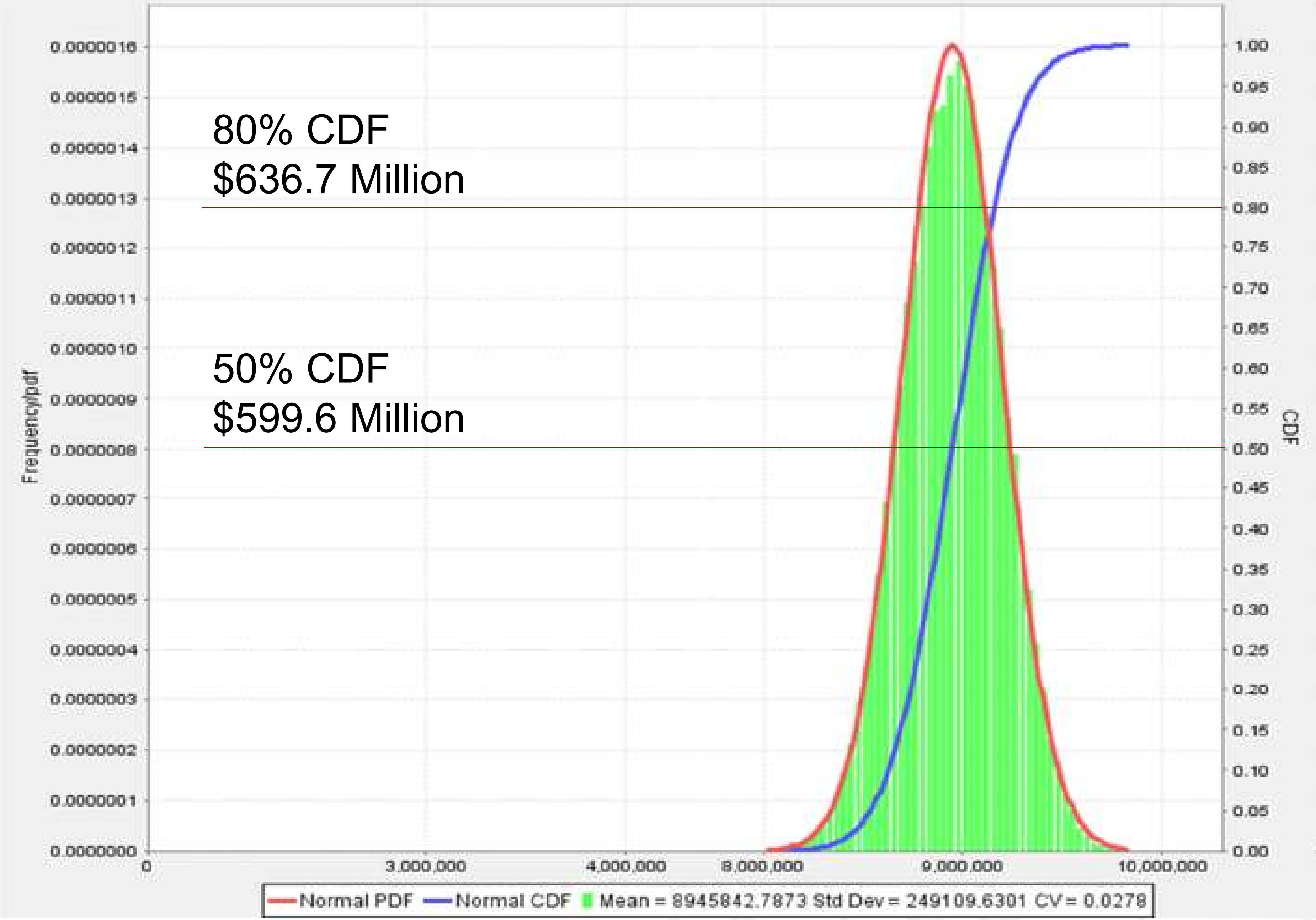
Labor Cost



Lead Ship Cost

Preliminary results show a clean sheet LSD(X) Lead Ship cost approximately:

Design Costs		$ 350 M
Material Costs		$ 167 M
Labor Costs	+	$ 600 M
Total Cost (50%)		**$1117 M**
Total Cost (80%)		**$1160 M**

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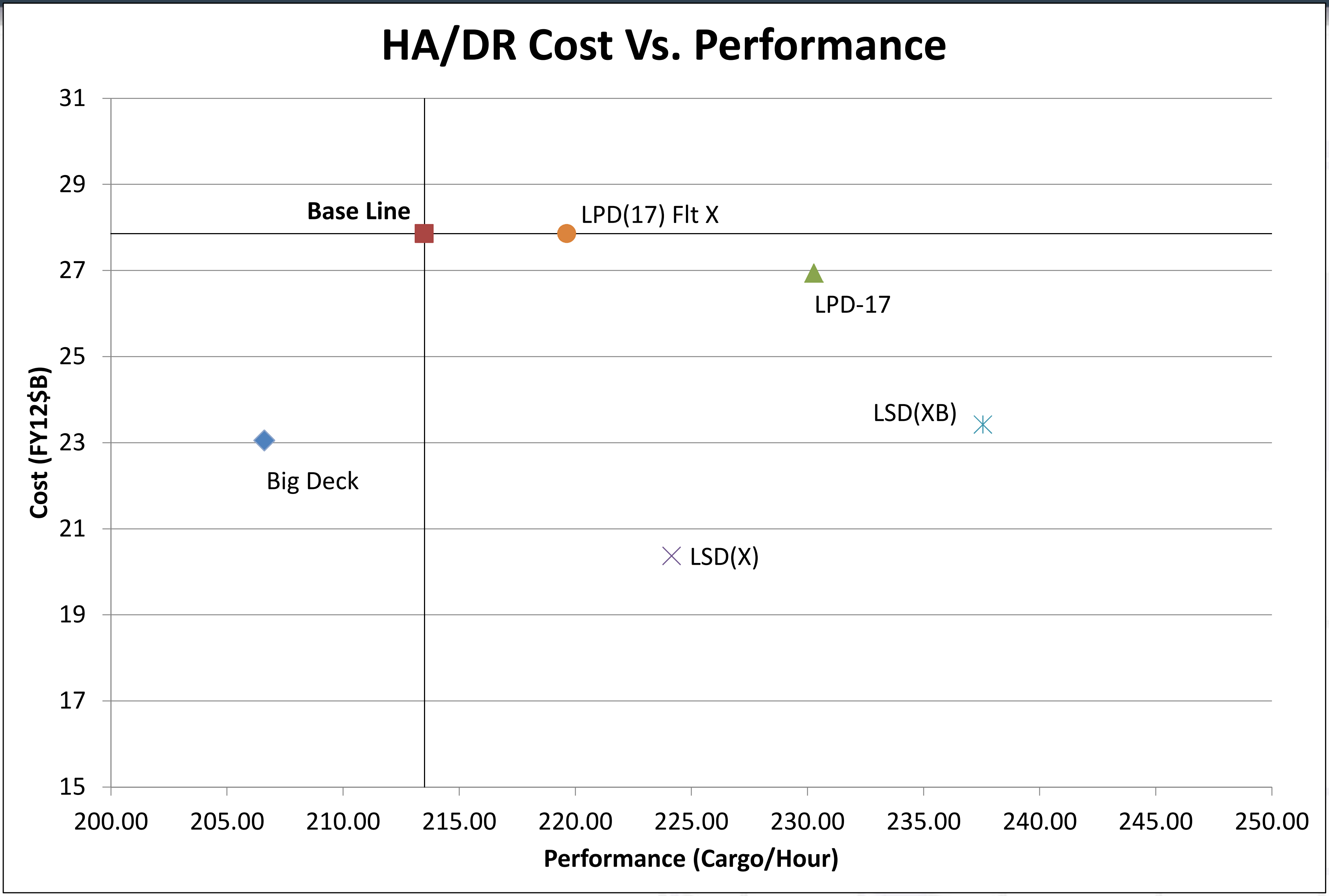
Risk Mitigation Options

Strategy	Likelihood of Implementation	Likelihood of Success	Possible Reduction Range
Add Additional Ship	0.1	0.9	2-5%
Optimize Maintenance Schedule	0.8	0.8	5-7%
Preposition Equipment	0.3	0.6	3-5%
Follow-on Shipping	0.5	0.8	2-4%
Fixed Wing CVN Only	0.7	0.8	4-6%
Using EVM	0.9	0.9	2-5%
Mature Technology	0.9	0.8	5-8%
Using Known Facilities	0.7	0.6	3-5%
Open Ship to Foreign Military Sales	0.9	0.7	5-9%
Incentivize Lower Cost	0.8	0.7	3-5%
Increase Automation	0.8	0.8	2-4%
Optimize Internal Sensors	0.8	0.8	1-3%
Increased Specialized Training	0.8	0.9	2-5%
Expand Life-cycle	0.9	0.9	4-6%
Optimize Maintenance Programs	0.9	0.9	5-7%
Reduce Building Standards	0.7	0.8	4-6%
Minimize Class Upgrades (Use Standard Technology)	0.7	0.7	3-5%
Pre-Warehouse Spares	0.9	0.9	3-5%
Continue Research for New Fuel Technology	0.7	0.7	1-2%
Out-Source Labor	0.5	0.9	5-7%

HA/DR Cost vs Performance



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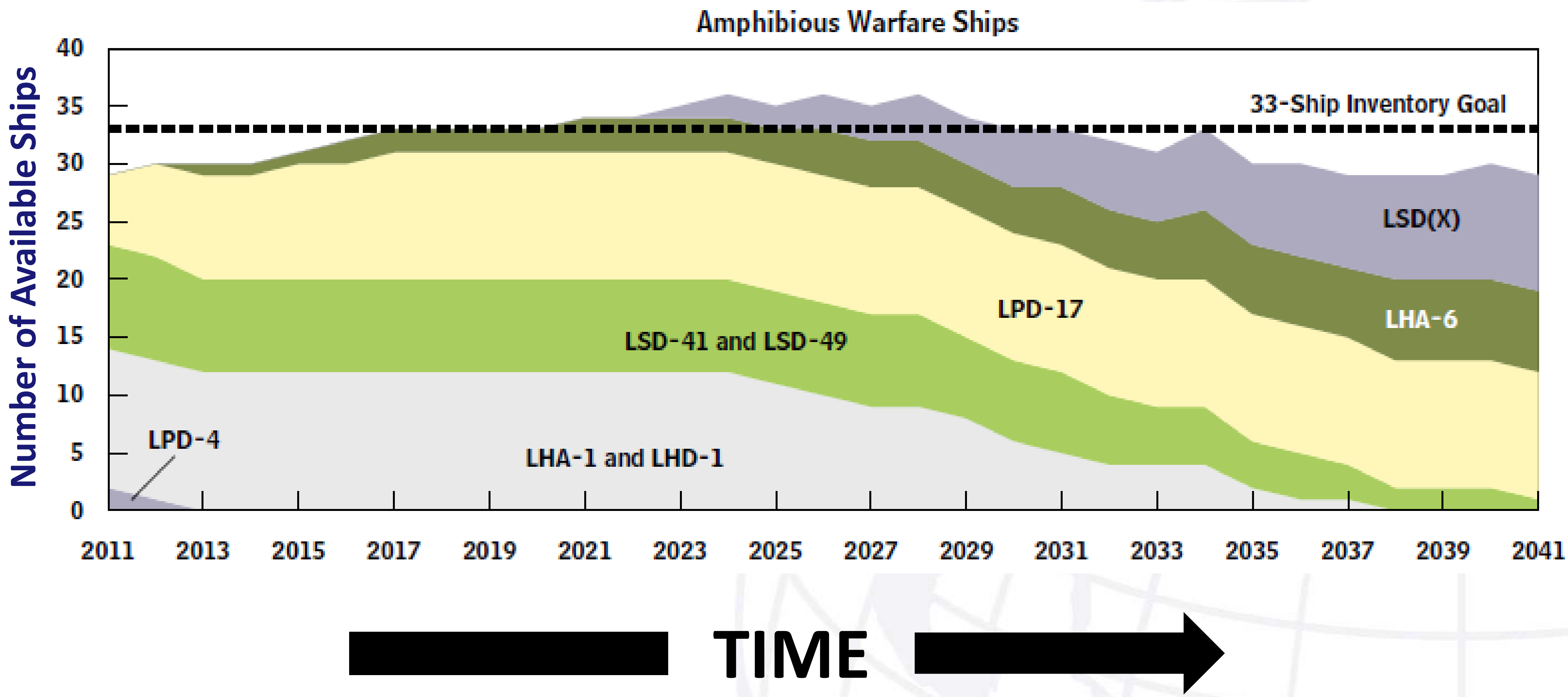
A Visual Representation



ARG Architecture Alternatives

Configurations	MEU Lift Requirements						
	LCAC (#)	Troops (#)	Vehicles (Sq Ft)	Cargo (Cu Ft)	Aviation (MH 60 eq)	JP-5 (gal)	O&S Costs (FY12$M)
	6	2578	88640	227048	104.22	1592344	Avg O&S Cost
Current ARG Architecture	66%	12%	-39%	-21%	-22%	-50%	$283
LSD Phase Out	-89%	8%	5%	8%	19%	33%	$257
LSD (X) Option	-89%	-8%	4%	-4%	14%	15%	$257
All Big Deck Option	-56%	-12%	-25%	38%	85%	41%	$315
LPD-17 Option	1%	-25%	54%	-36%	-47%	4%	$249

This chart lists each architecture's average lift risk and a comparison between each derived option and the current architecture's risk.

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ARG Architecture Alternatives

Lift Capability Analysis

LSD Phase Out ARG Configurations	MEU Lift Requirements						
	LCAC (#)	Troops (#)	Vehicles (Sq Ft)	Cargo (Cu Ft)	Aviation (MH 60 eq)	JP-5 (gal)	O&S Costs (FY12$M)
	6	2578	88640	227048	104.22	1592344	
LHD, LPD(17), LPD(17)	1	20%	33%	15%	5%	30%	$257
LHA(6), LPD(17), LPD(17)	2	20%	41%	0%	1%	22%	$257
LHA(R), LPD(17), LPD(17)	0	11%	35%	13%	10%	23%	$257
LHA(1), LPD(17), LPD(17)	1	28%	27%	23%	17%	34%	$257
Most Risk Accepted	2	0%	41%	23%	17%	34%	Average Cost
Avg Risk Accepted	23%	20%	34%	13%	3%	17%	$257

ARG Architecture Alternatives

Lift Capability Analysis

	MEU Lift Requirements						
LSD(X) ARG Configurations	LCAC (#)	Troops (#)	Vehicles (Sq Ft)	Cargo (Cu Ft)	Aviation (MH 60 eq)	JP-5 (gal)	O&S Costs (FY12$M)
	6	2578	88640	227048	104.22	1592344	
LHA(1), LPD(17), LSD(X)	1	8%	28%	36%	22%	53%	$257
LHA(6), LPD(17), LSD(X)	2	0%	42%	12%	4%	3%	$257
LHA(R), LPD(17), LSD(X)	0	8%	36%	26%	6%	42%	$257
LHD, LPD(17), LSD(X)	1	1%	34%	28%	10%	48%	$257
Most Risk Accepted	2	8%	42%	36%	22%	53%	Average Cost
Avg Risk Accepted	23%	4%	35%	25%	8%	35%	$257

ARG Architecture Alternatives

Lift Capability Analysis

	MEU Lift Requirements						
All Big Deck ARG Configurations	LCAC (#)	Troops (#)	Vehicles (Sq Ft)	Cargo (Cu Ft)	Aviation (MH 60 eq)	JP-5 (gal)	O&S Costs (FY12$M)
	6	2578	88640	227048	104.22	1592344	
LHD, LHD	0	32%	60%	10%	56%	40%	$315
LHD, LHA(1)	2	39%	54%	2%	44%	44%	$316
LHD, LHA(6)	3	31%	68%	26%	61%	12%	$316
LHD, LHA(R)	1	23%	62%	12%	71%	33%	$316
LHA(1), LHA(6)	5	39%	62%	17%	49%	7%	$316
LHA(6), LHA(6)	6	31%	77%	41%	67%	63%	$316
LHA(R), LHA(1)	3	30%	56%	4%	59%	38%	$316
LHA(R), LHA(6)	4	22%	70%	28%	77%	18%	$316
LHA(R), LHA(R)	2	13%	64%	15%	86%	27%	$316
Most Risk Accepted	6	0%	68%	0%	0%	44%	Average Cost
Avg Risk Accepted	56.0%	0%	64%	17%	63%	9%	$315

ARG Architecture Alternatives

Lift Capability Analysis

	MEU Lift Requirements						
Small Boy ARG Configurations	LCAC (#)	Troops (#)	Vehicles (Sq Ft)	Cargo (Cu Ft)	Aviation (MH 60 eq)	JP-5 (gal)	O&S Costs (FY12$M)
	6	2578	88640	227048	104.22	1592344	
LPD(17) x 5	4	35%	18%	25%	57%	0%	$248
LSD(X) x 5	4	61%	13%	89%	81%	92%	$250
Most Risk Accepted	0%	61%	0%	89%	81%	92%	Average Cost
Avg Risk Accepted	67%	13%	15%	57%	69%	46%	$249

Survivability Analysis

Overall Intent

- The performance and effectiveness group is working on building the models necessary to analyse the MOPS and MOE to determine the optimal fleet architecture.

- The team will be looking at the capabilities and limitations of each vessel individually to determine the performance when combined.

- The analysis will focus on aircraft spots, LCAC spots, troop capacity, square footage, cubic footage, JP-5 capacity, and operating rooms.

- The “ilities” will also be analysed.

Scenarios

The scenarios with MOEs and MOPs that will be used to analyse the Performance/Effectiveness (P/E) of alternatives were mainly for Assault and HADR operations. The core MOEs and MOPs for these operations are as follows:

A. Natuna Basar (Assault). The mission of this operation is to establish and secure forcible entry point on beach with the following key MOEs.

i. MOE: ability to rapidly secure beach

- MOP – Hostiles Eliminated in landing area / unit time
- MOP –Total casualties sustained en route to beach

ii. MOE: ability to rapidly off load troops and gear on the beach

- MOP – vehicles offloaded / unit time
- MOP – Equipment offloaded / unit time
- MOP – Personnel Offloaded / unit time

Survivability Analysis

iii. MOE – Ability to defend

- MOP – P_s against missile threat
- MOP – P_s against small boat threat
- MOP – P_s against mine threat

iv. MOE – Ability to defend off loaded vehicles (LCACs)

- MOP – P_s against missile threat
- MOP – P_s against small boat threat
- MOP – P_s against mine threat

Survivability Analysis

Scenarios

B. Haiti (HADR). The mission of this operation is to provide disaster relief to impoverished nation with the following key MOEs.

i. MOE – ability to provide massive amounts of food, water, medical supplies and infrastructure restoration equipment and personnel to the location of disaster.

- MOP – Cubic ft. cargo / unit time off loaded
- MOP – Cubic ft. cargo / mission stored
- MOP – # of OR / mission

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Survivability Analysis

ii. MOE – Ability to defend

- MOP – P_s against missile threat
- MOP – P_s against small boat threat
- MOP – Ps against mine threat

iii. MOE – Ability to defend off loaded vehicles (LCACs)

- MOP – P_s against missile threat
- MOP – P_s against small boat threat
- MOP – P_s against mine threat

Ps (vs Anti-Ship Missiles)

Objective

The Ps values obtained from this model are intended to be:

1. Used in a higher level simulation that studies the amphibious group operations performance in terms of Probability of Survival when faced with a possibly hostile landing zone with anti-ship missile threats.

2. As a Measure of Effectiveness (MOE) relating to the survivability of amphibious group operations during amphibious landing operations in “hot” landing zone against anti-ship missile threats.

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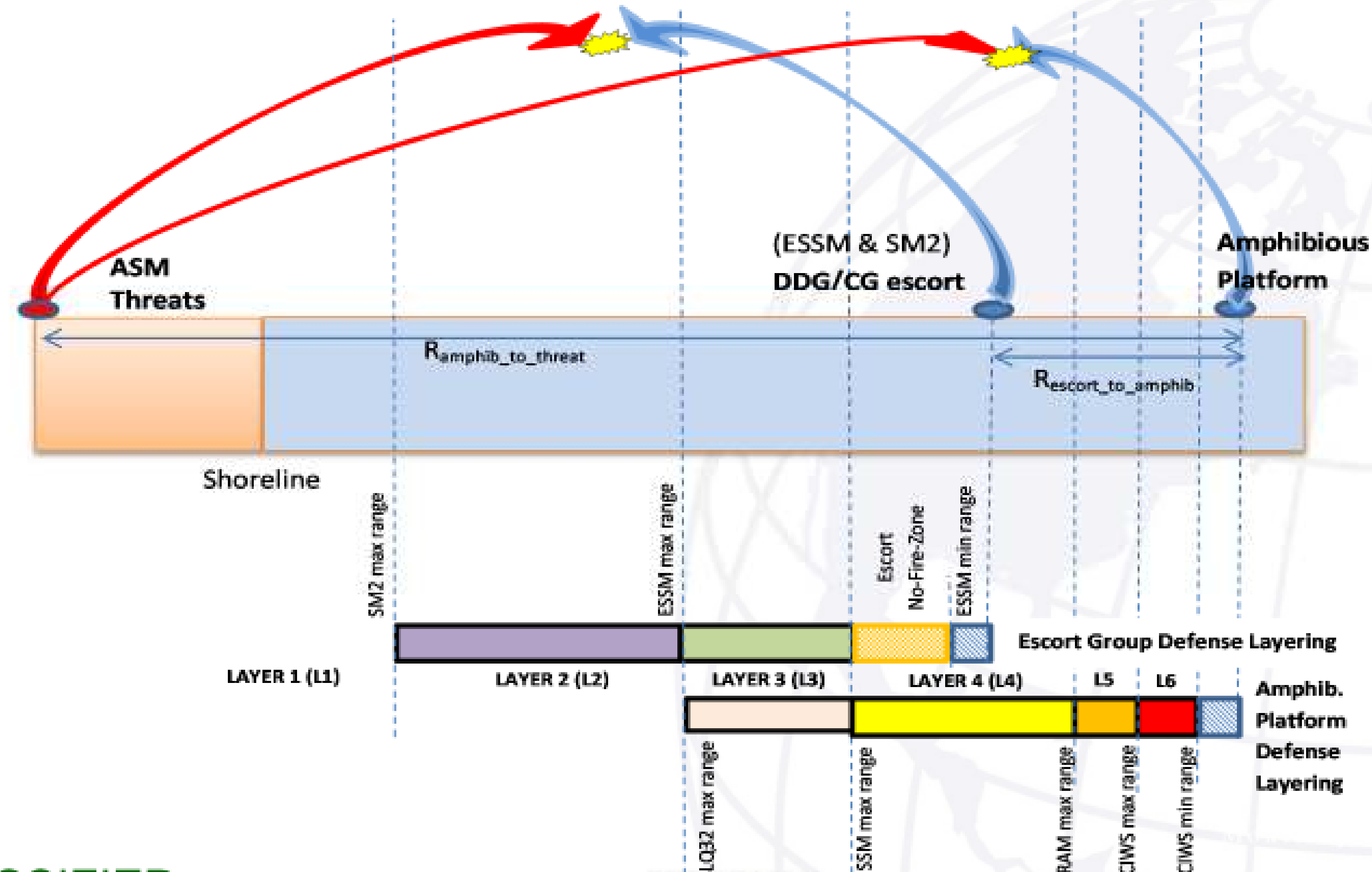
Ps (vs Anti-Ship Missiles)

Description & Assumptions: The schematic diagram below illustrates the geometrical layout assumed in the computations.



Ps (vs Anti-Ship Missiles)

Summary of Defense Layering

	Amphibious. Platform Self Defense Systems	Escort Group Outer Layer defense	Assumed Layer Ranges (w.r.t amphibious. Platform)
Layer 1	SLQ32 (Jammer)		40nm to 80nm
Layer 2	SLQ32 (Jammer)	SM-2	15nm to 40nm
Layer 3	SLQ32 (Jammer)	ESSM	10nm to 15nm
Layer 4	NSSM (or SLQ32 *)	Escort No Fire Zone (***)	3.5nm to 10nm
Layer 5	RAM (or SLQ32 **)		1.1nm to 3.5nm
Layer 6	CIWS		0.3nm to 1.5nm

(* if NSSM is not available on evaluated platform)
(** if NSSM & RAM are both not available on evaluated platform)
(*** SAG assumed to leave the leakers in this zone for the self-defense systems of the amphibious platforms)

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Ps (vs Anti-Ship Missiles)

Computation Methodology

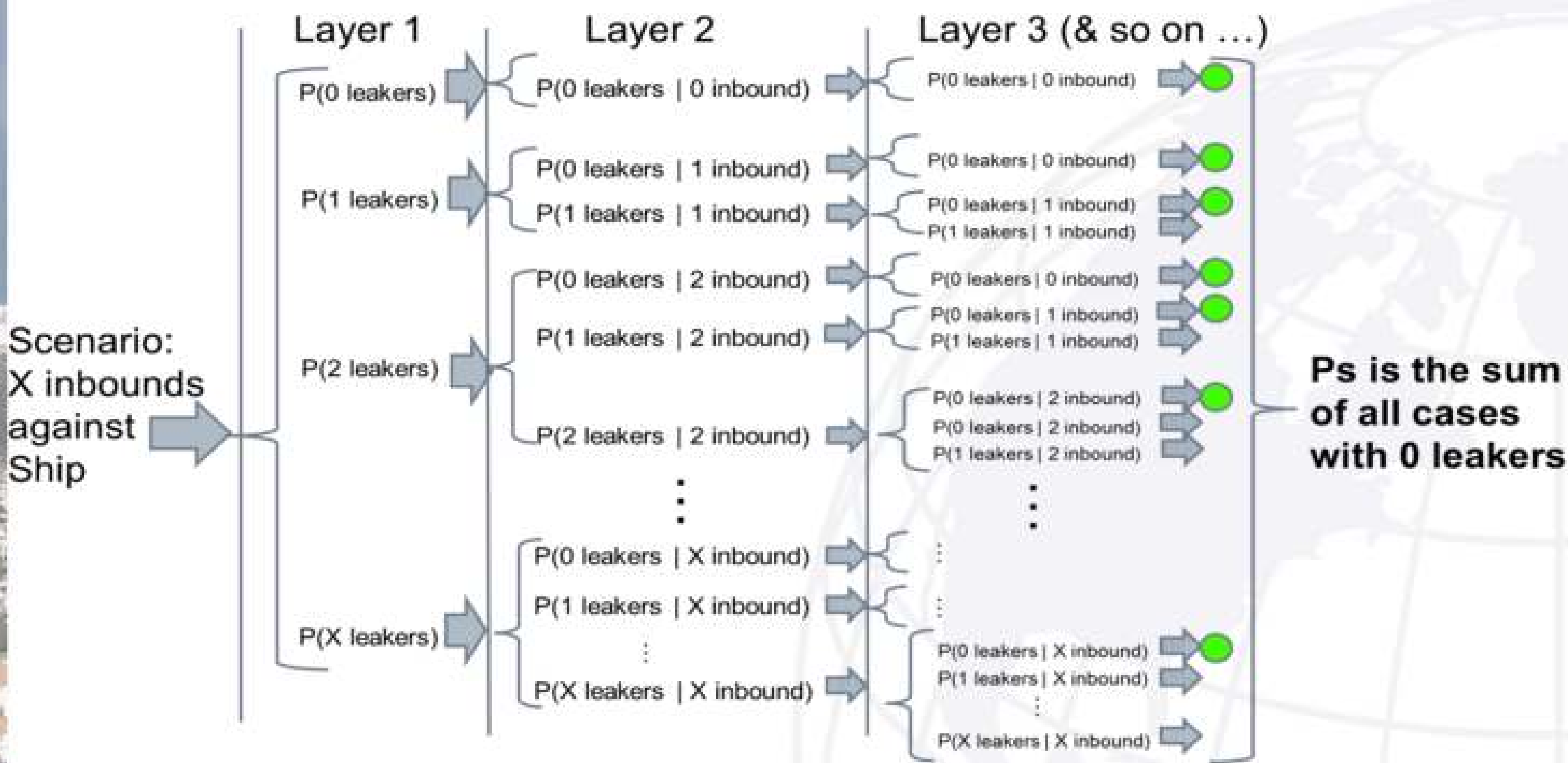

Illustration of Bayesian analysis for layered defense

Ps (vs Anti-Ship Missiles)

Threat Parameters

Threat Type	Subsonic	Supersonic
Threat Speed	300 m/s	1000 m/s
Threat Detected (w.r.t amphib)	12 Nm from Amphib	20 Nm from Amphib
Threat Pk per round	100%	100%

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Ps (vs Anti-Ship Missiles)

Escort Group Weapon Parameters

Escort Range from Amphib	4 Nm (ahead)

Weapon Types	SM-2	ESSM
Weapon Speed	1000 m/s	1000 m/s
Weapon min range	15 Nm from SAG (*)	10 Nm from Amphib (**)
Weapon max range	40 Nm from SAG	15 Nm from SAG
Weapon Time Betw. Launches	2 sec	2 sec
Weapon Slew Interval	0 sec (VLS)	0 sec (VLS)
Weapon Pk per round	90%	90%
Weapon Max Round per Threat	3 rounds	3 rounds
Weapon Max Qty Available	Unlimited	Unlimited

(* to deconflict with ESSM coverage, this is set to be the same as max ESSM range)
(** This is set as the limit of the SAG No-Fire zone since it is the max range of the NSSM)

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Ps (vs Anti-Ship Missiles)

Platform Self-Defense Weapons Equipping

	Existing Platforms				Hypothetical Designs		
Platform Type	**LHD-1**	**LHA-1 or LSD-41/49**	**LPD-4**	**LPD-17**	**LSD-X1**	**LSD-X2**	**LSD-X3**
Class Name	Wasp	Tawara Harper Ferry / Whidbey Island	Austin	San Antonio	LSD(X1)	LSD(X2)	LSD(X3)
Assumed no. of sectors	2	2	2	2	2	2	2
NSSM launchers/ sector	1	0	0	0	1	1	1
RAM turrets / sector	1	1	0	1	1	0	0
CIWS turrets / sector	1	1	1	0	0	1	0
SLQ32 Jammer	1	1	1	1	1	1	1

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Ps (vs Anti-Ship Missiles)

Platform Self-Defense Weapons Equipping

<table>
<tr><th>Platform Type</th><th>LHD-1</th><th>LHA-1 or LSD-41/49</th><th>LPD-4</th><th>LPD-17</th><th>LSD-X1</th><th>LSD-X2</th><th>LSD-X3</th></tr>
<tr><td>Layer 0A (If Escorted)</td><td colspan="4">15-40nm, SM-2</td><td colspan="3">15-40nm, SM-2</td></tr>
<tr><td>Layer 1A (If Escorted)</td><td colspan="4">10-15nm, ESSM</td><td colspan="3">10-15nm, ESSM</td></tr>
<tr><td>Layer 1B (Outermost)</td><td>10-15nm SLQ32</td><td>10-15nm SLQ32</td><td>10-15nm SLQ32</td><td>10-15nm SLQ32</td><td>10-15nm SLQ32</td><td>10-15nm SLQ32</td><td>10-15nm SLQ32</td></tr>
<tr><td>Layer 2</td><td>3.5-10nm NSSM+SLQ3 2</td><td>3.5-10nm SLQ32</td><td>3.5-10nm SLQ32</td><td>3.5-10nm SLQ32</td><td>3.5-10nm NSSM+SLQ3 2</td><td>3.5-10nm NSSM+SLQ3 2</td><td>3.5-10nm NSSM+SLQ3 2</td></tr>
<tr><td>Layer 3</td><td>1.1-3.5nm RAM</td><td>1.1-3.5nm RAM</td><td>1.1-3.5nm (NIL)</td><td rowspan="2">0.5-3.5nm RAM</td><td rowspan="2">0.5-3.5nm NSSM</td><td rowspan="2">0.5-3.5nm RAM</td><td>1.1-3.5nm (NSSM)</td></tr>
<tr><td>Layer 4 (Innermost)</td><td>0.3-1.1nm CIWS</td><td>0.3-1.1nm CIWS</td><td>0.3-1.1nm CIWS</td><td>0.3-1.1nm CIWS</td></tr>
</table>

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Ps (vs Anti-Ship Missiles)

Platform Self-Defense Weapons Parameters

Weapon Types	NSSM	RAM	Phalanx CIWS	SLQ32 Jammer
Weapon Speed	385 m/s	600 m/s	1100 m/s	$3x10^8$ m/s
Weapon min range	3.5 Nm	1.1 Nm	0.3 Nm	3.5 Nm (*)
Weapon max range	10 Nm	3.5 Nm	1.1 Nm	15 Nm (*)
Weapon Time Betw. Launches	2 sec	5 sec	0.02 sec	10 sec (*)
Weapon Slew Interval	3 sec	3 sec	3 sec	0 sec
Weapon Pk per round	70%	60%	0.2%	50%
Weapon Max Round per Threat	*Scenario-based*	*Scenario-based*	*Scenario-based*	1
Weapon Max Qty Available	8 rds/launcher	21 rds/launcher	1550 rds/load	Unlimited

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LCAC Ps Modeling

Objective

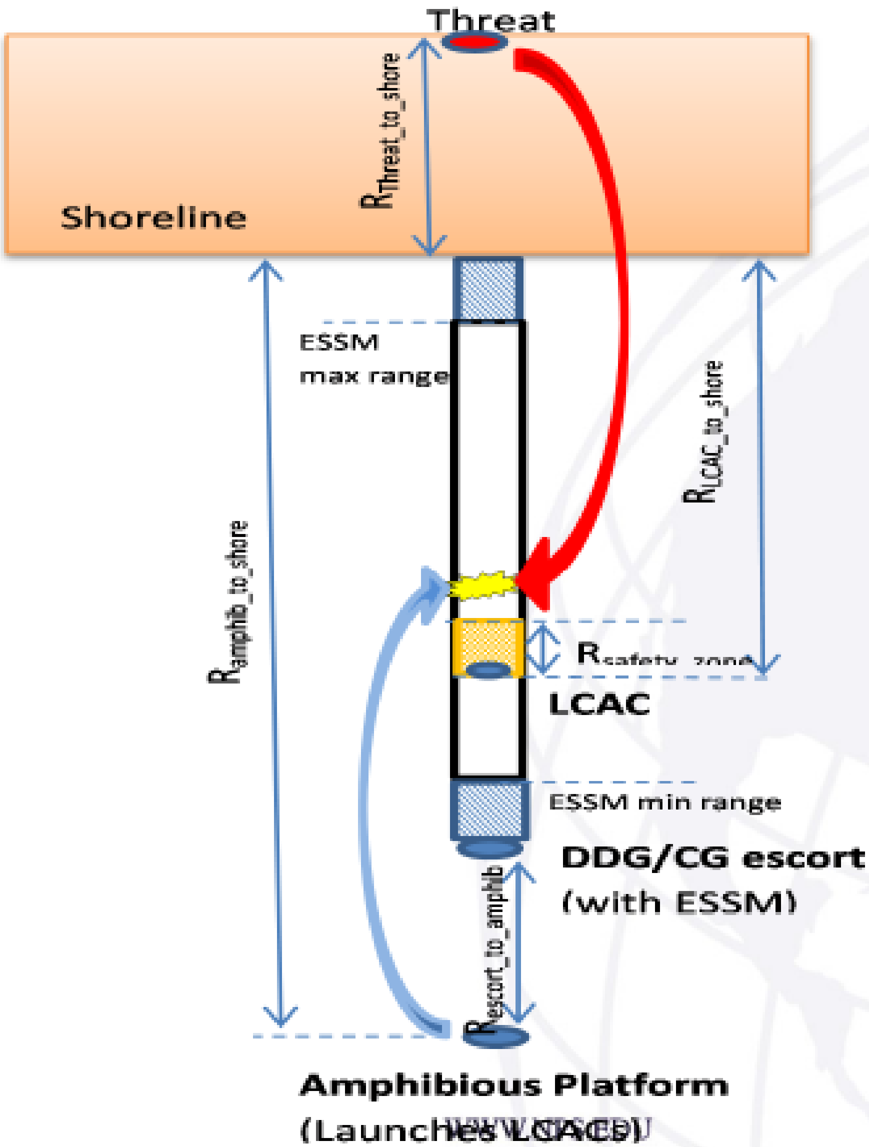
The Ps values obtained from this model are intended to be:

1. Used in a higher level simulation that studies the logistics disembarkation performance of troops & equipment using LCACs when faced with a possibly hostile landing zone.

2. As a Measure of Effectiveness (MOE) relating to the survivability of LCACs during amphibious landing operations in “hot” landing zone.

LCAC Ps Modeling

<u>Description & Assumptions:</u> The schematic diagram below illustrates the geometrical layout assumed in the computations.



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LCAC Ps Modeling

Summary of LCAC Ps for the different cases

Case	Probability of Survival (Ps)
ESSM intercepts with 3 rounds	0.9991
ESSM intercepts with 2 rounds	0.9910
ESSM intercepts with 1 round	0.9100
ESSM cannot intercept	0.1000

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Conclusion

- It is recommended that the optimal range for the amphibious platform be set at the maximum for Zone 1 where possible, to ensure full protection for the LCACs up to shore if facing only subsonic threats. For the parameter chosen as baseline, this is at a range of roughly 12nm from shore (with escorts at ~ 8nm)

- Against supersonic threats (1000 m/s), analysis shows that the platforms may need to be only 5nm from the shore (escort at 1nm) to provide full protection. This seems impractical as it will open up the fleet to other short range threats.

- As such, in this situation, appropriate risks will need to be taken in terms of LCAC Ps versus the distance of the launch platforms.

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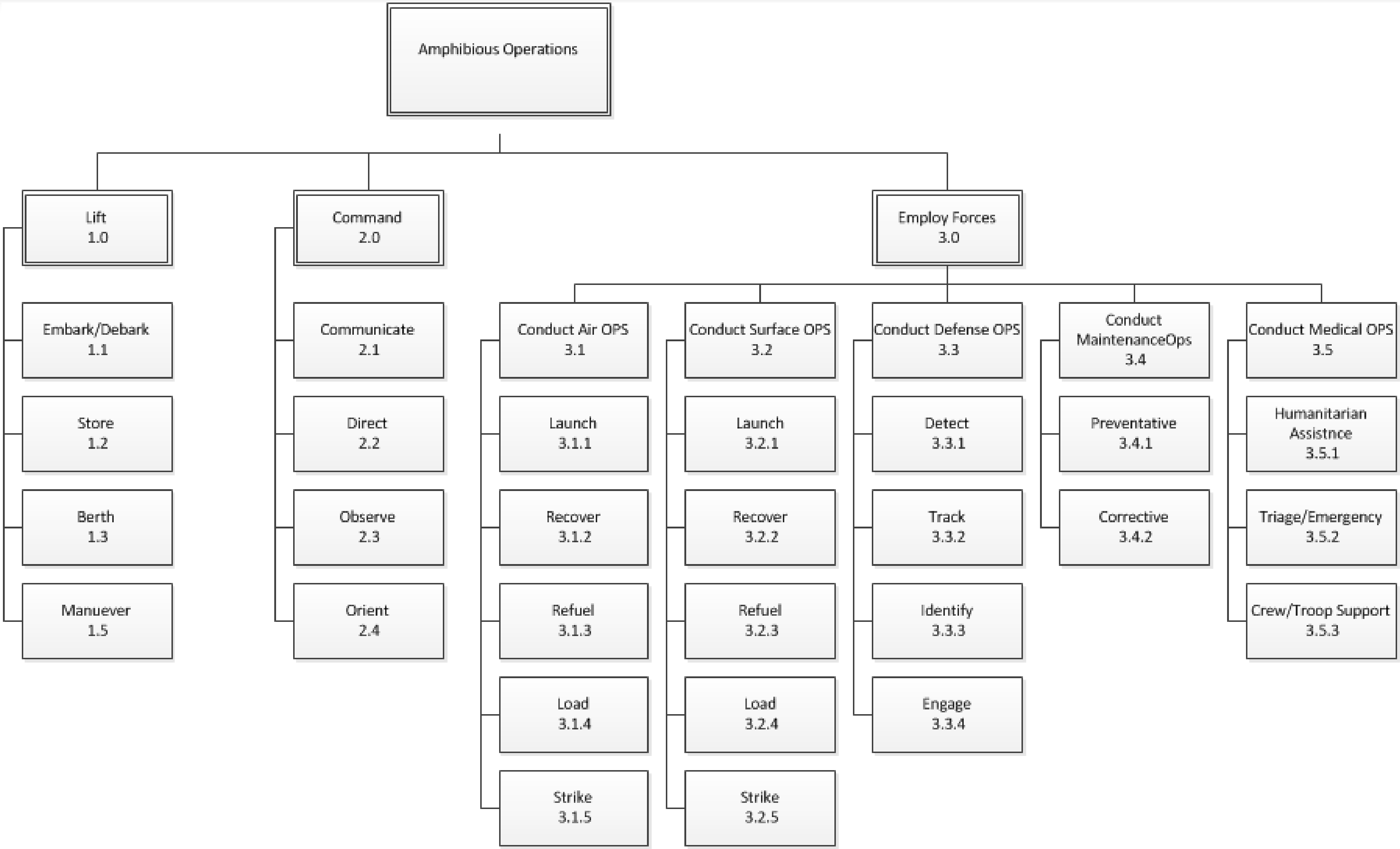
Functional Analysis Snapshot



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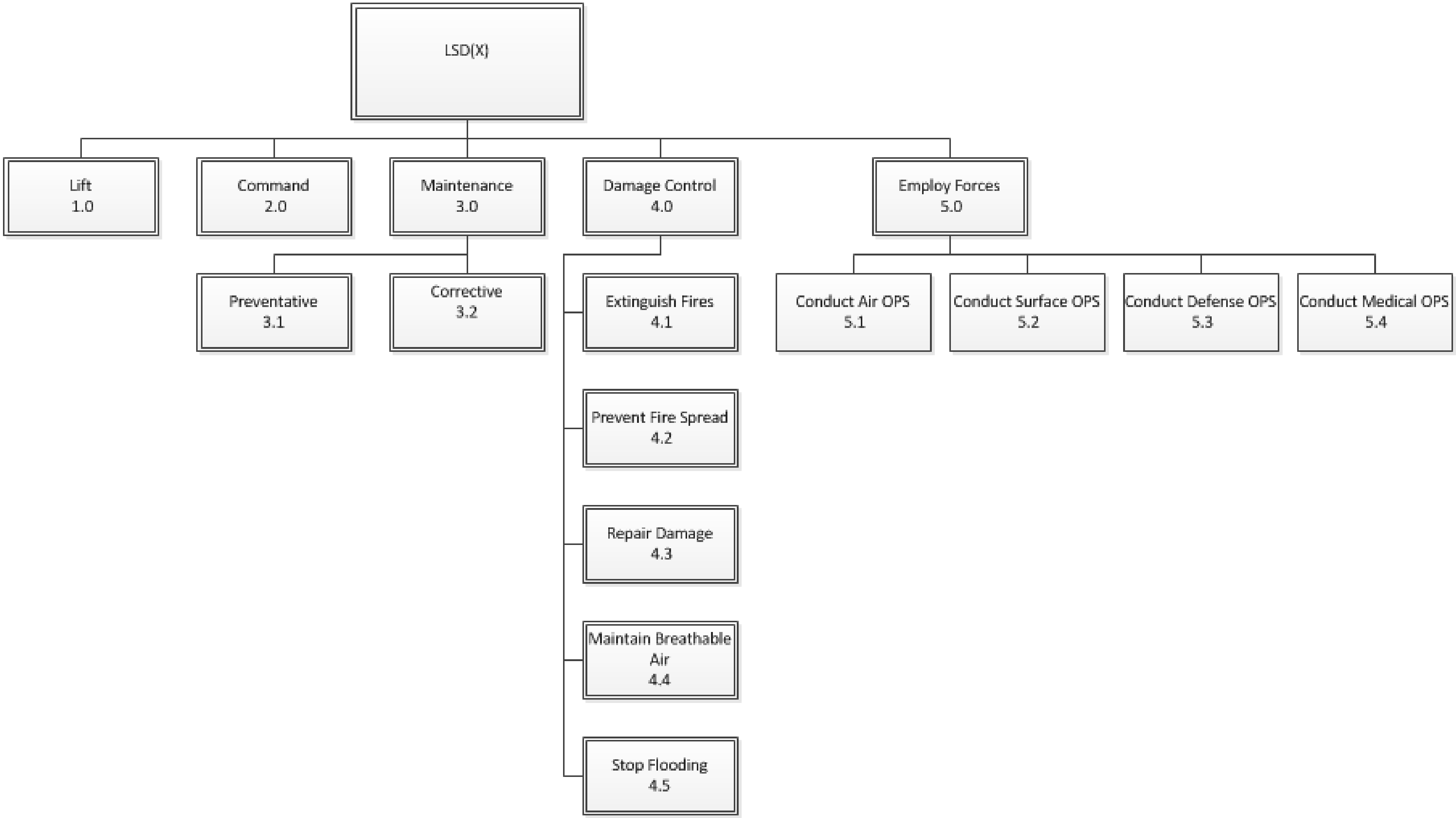
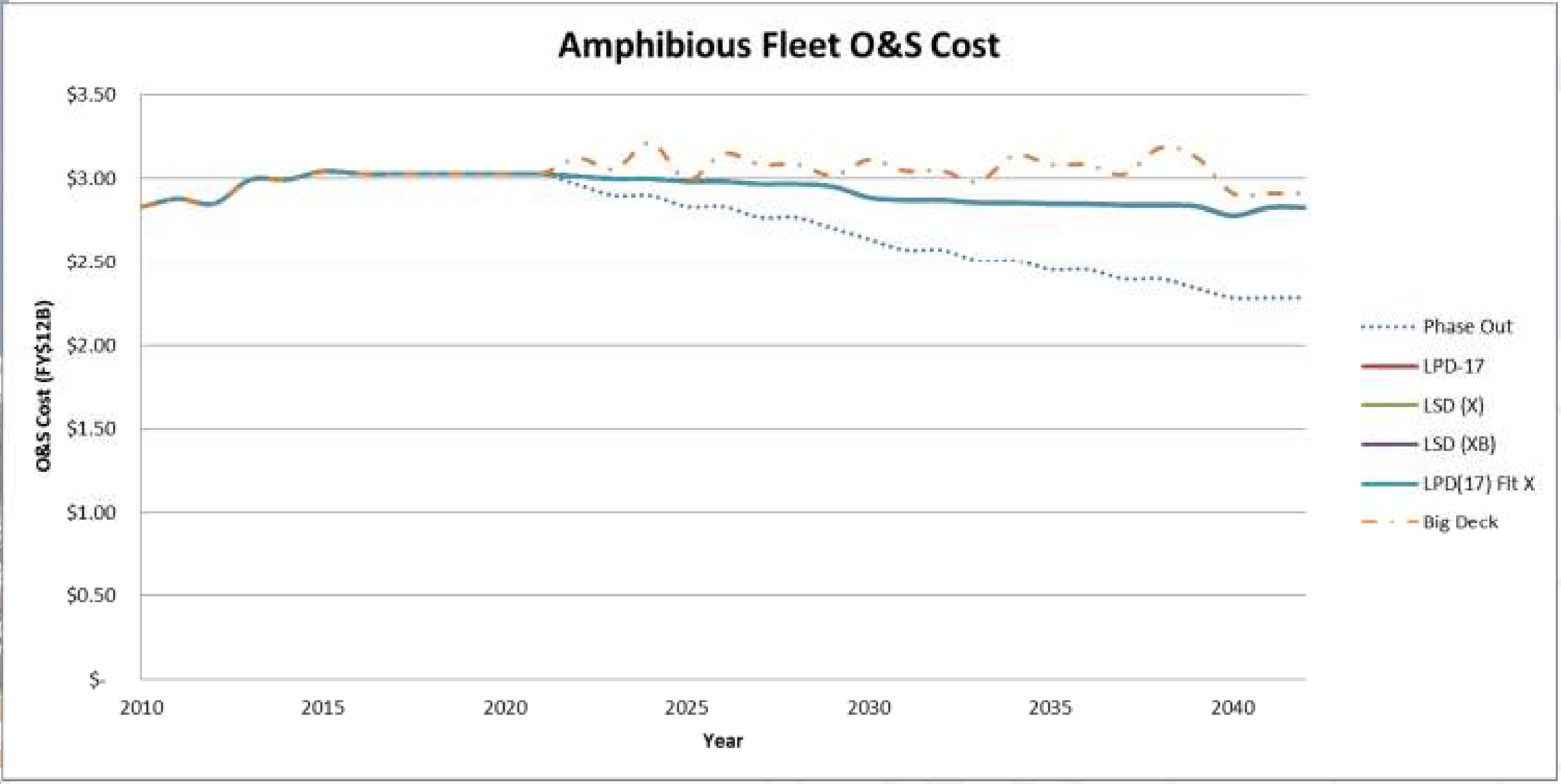
Functional Analysis Snapshot



MEB Lift


Amphibious Fleet O&S Cost
O&S Cost (FY$12B)
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$-
2010
2015
2020
2025
2030
2035
2040
Year
Phase Out
LPD-17
LSD (X)
LSD (XB)
LPD(17) Flt X
Big Deck

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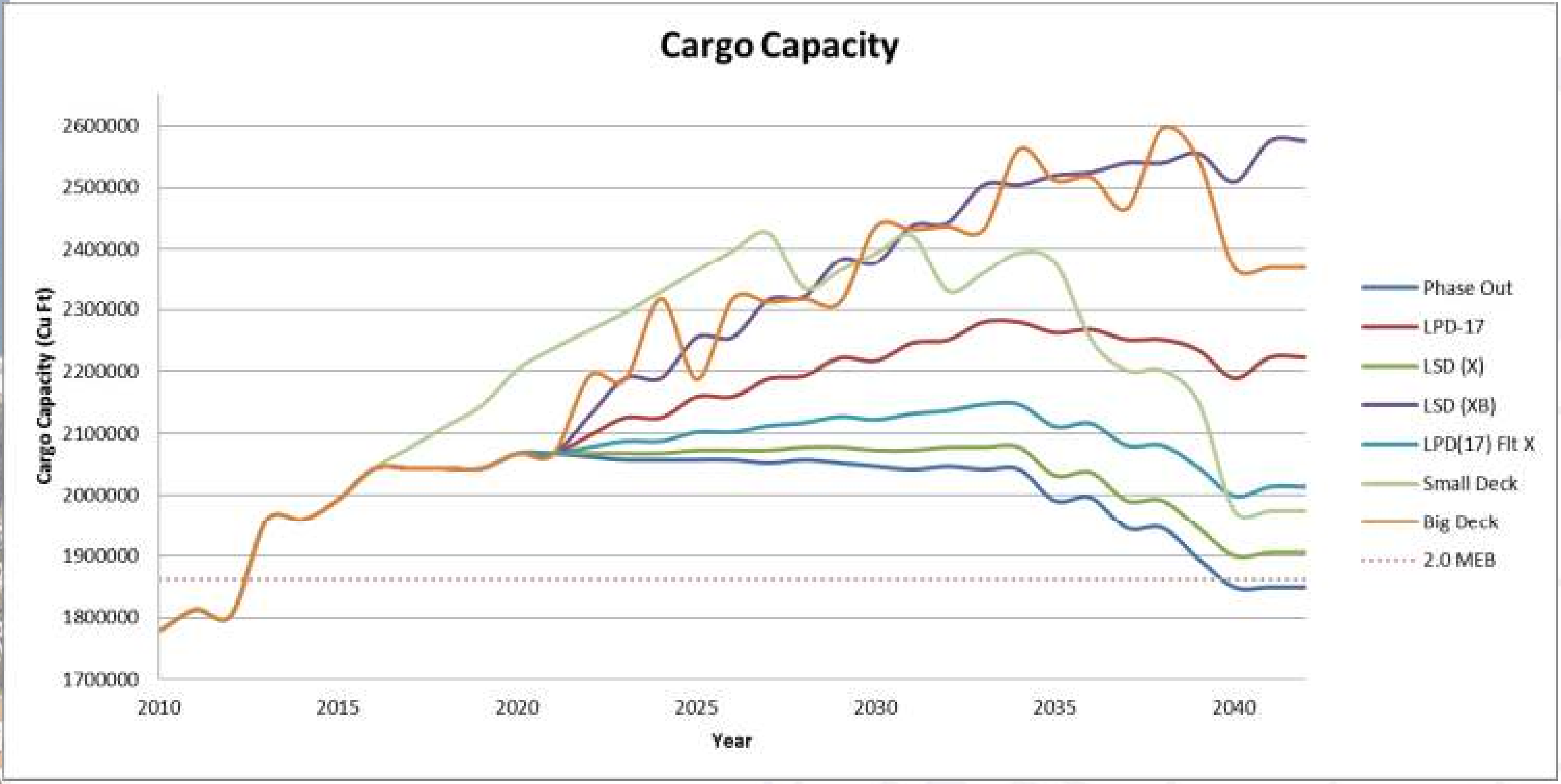
MEB Lift



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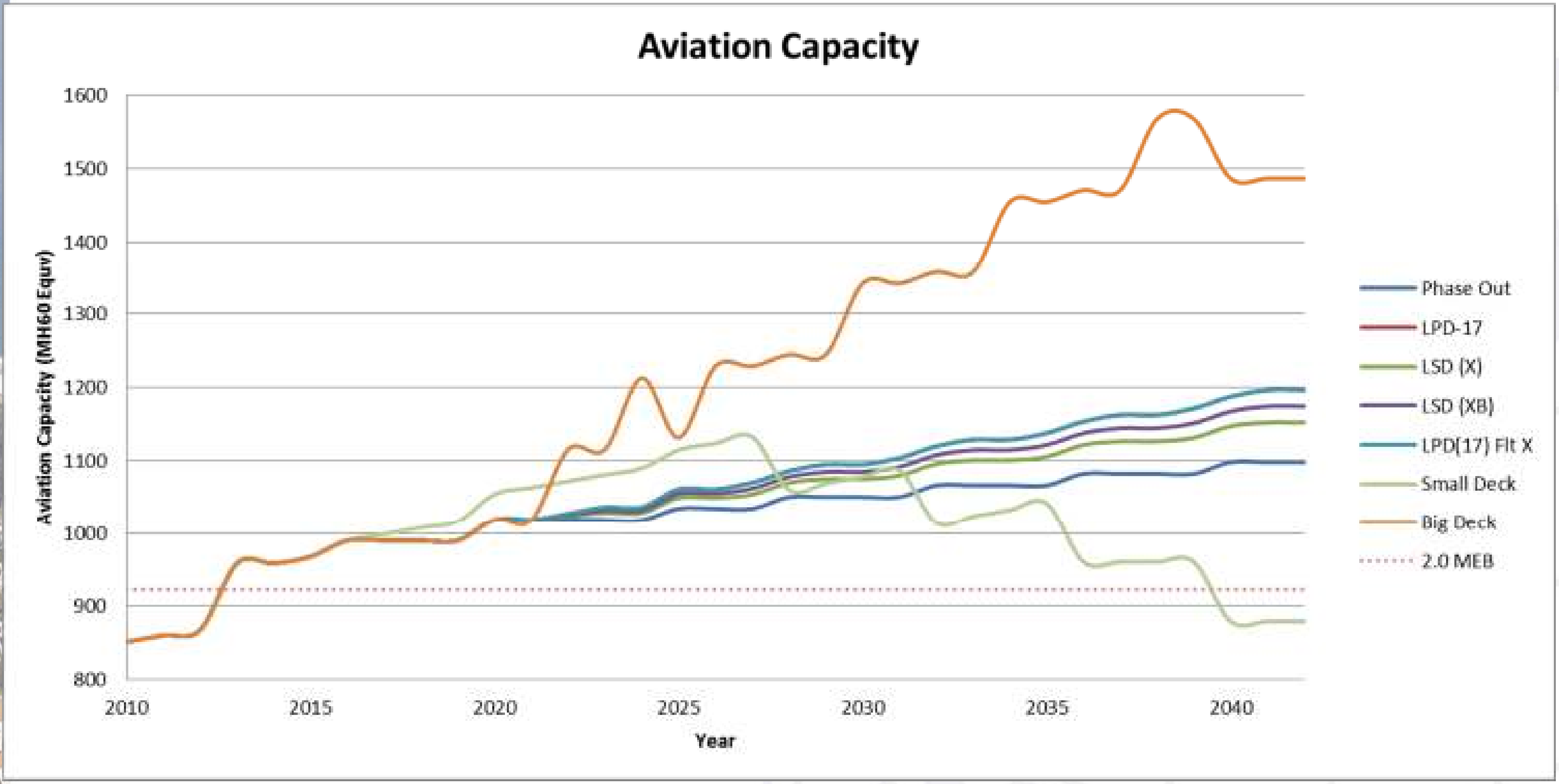
MEB Lift



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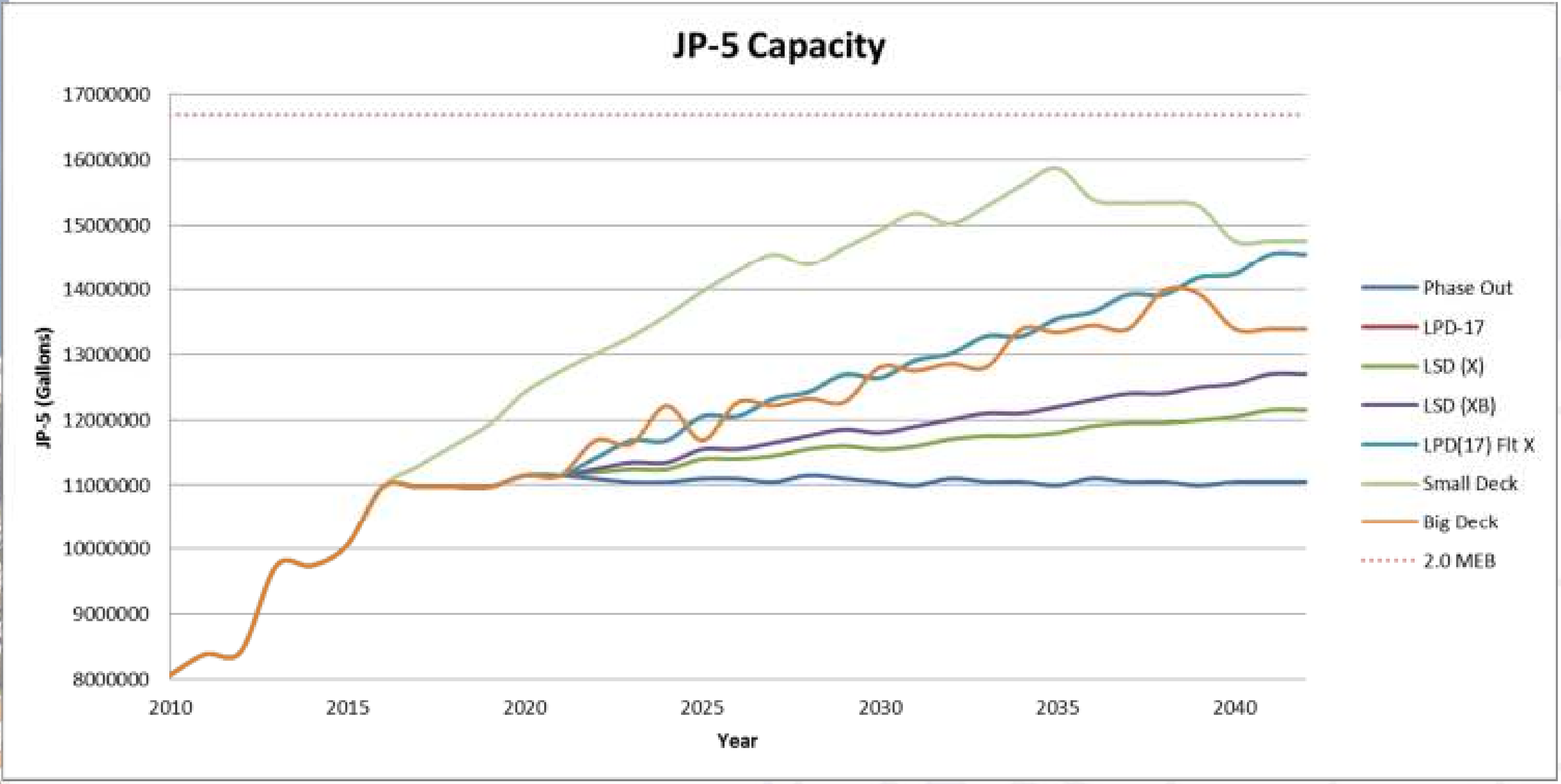
MEB Lift


JP-5 Capacity
17000000
16000000
15000000
14000000
13000000
12000000
11000000
10000000
9000000
8000000
JP-5 (Gallons)
2010
2015
2020
2025
2030
2035
2040
Year
Phase Out
LPD-17
LSD (X)
LSD (XB)
LPD(17) Flt X
Small Deck
Big Deck
2.0 MEB