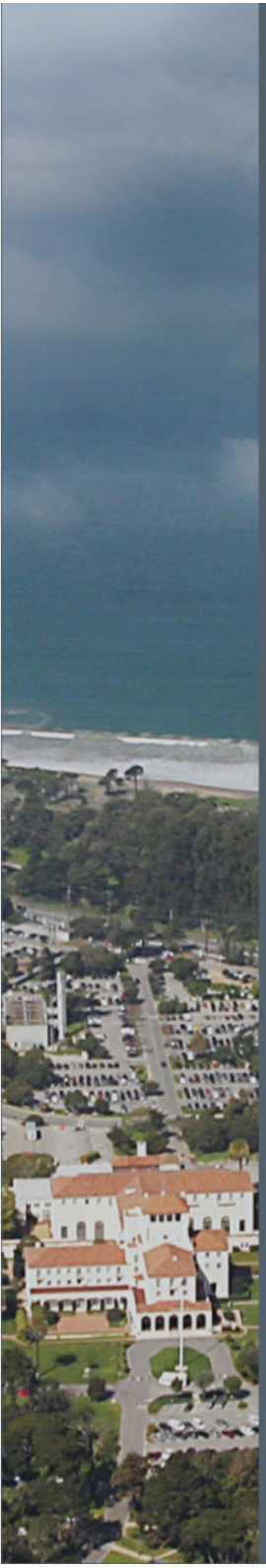


NAVAL
POSTGRADUATE
SCHOOL

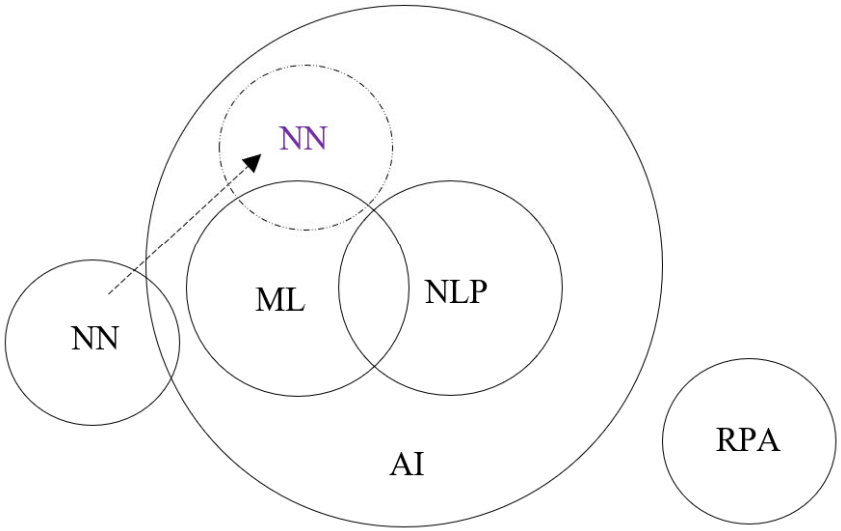
# Cybersecurity, Artificial Intelligence, and Risk Management: Understanding Their Implementation in Military Systems Acquisitions

Johnathan Mun, Ph.D.
Professor of Research
Dept. Information Sciences

*Quantitative Data Science Risk-Based Stochastic Decision Analytics*

MAY 2022

# From AI to Autonomy




**Artificial Intelligence (AI):**
algorithms exhibiting "smart" behavior

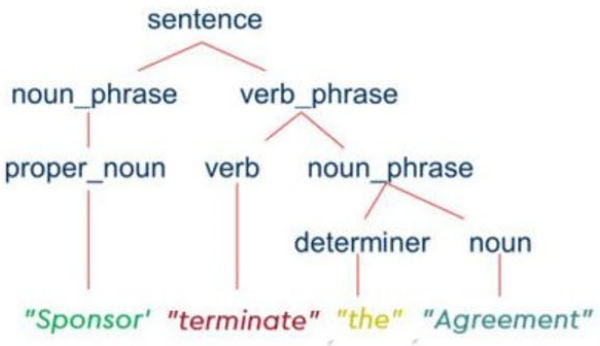
**Machine Learning (ML):**
algorithms that detect patterns and use them for prediction and decision making

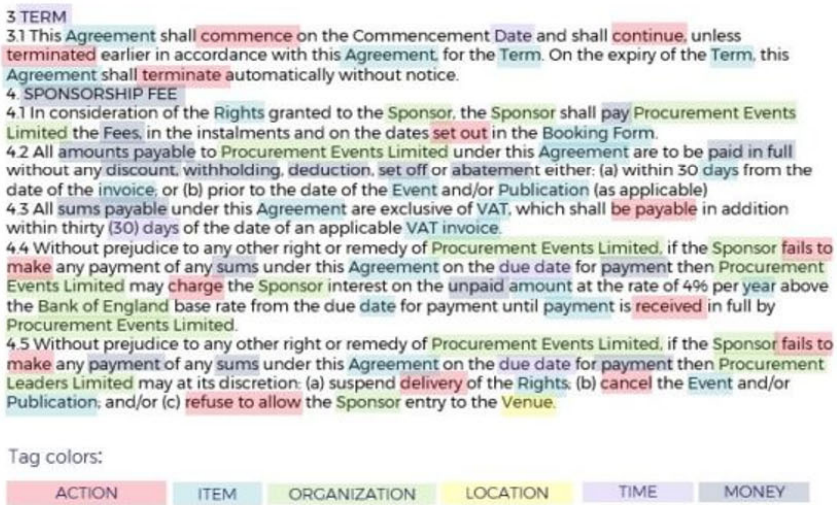
**Natural Language Processing (NLP):**
Algorithms that can interpret, predict, transform, and generate human language

**Robotic Process Automation (RPA):**
Algorithms that mimic human actions to reduce simple but repetitive tasks

## NATURAL LANGUAGE PROCESSING IN PROCUREMENT

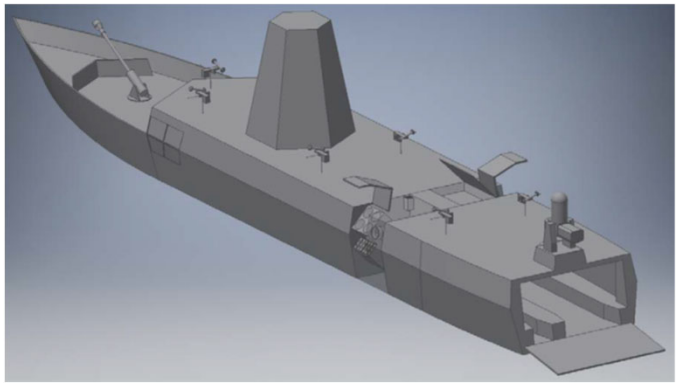
Identifying parts of a text and their grammatical roles through text parsing.



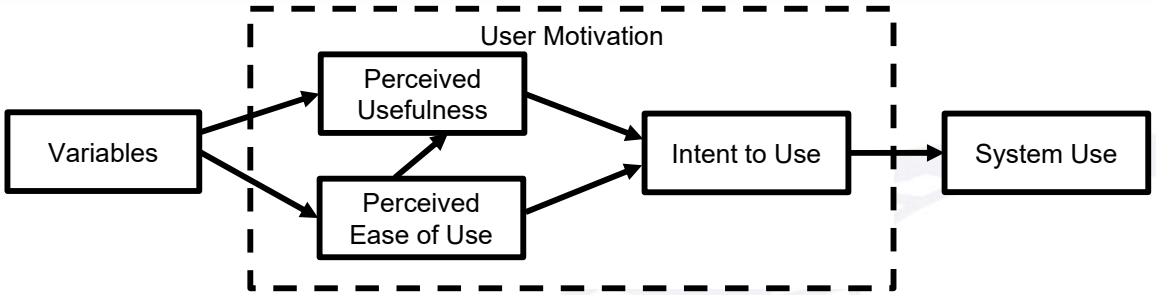



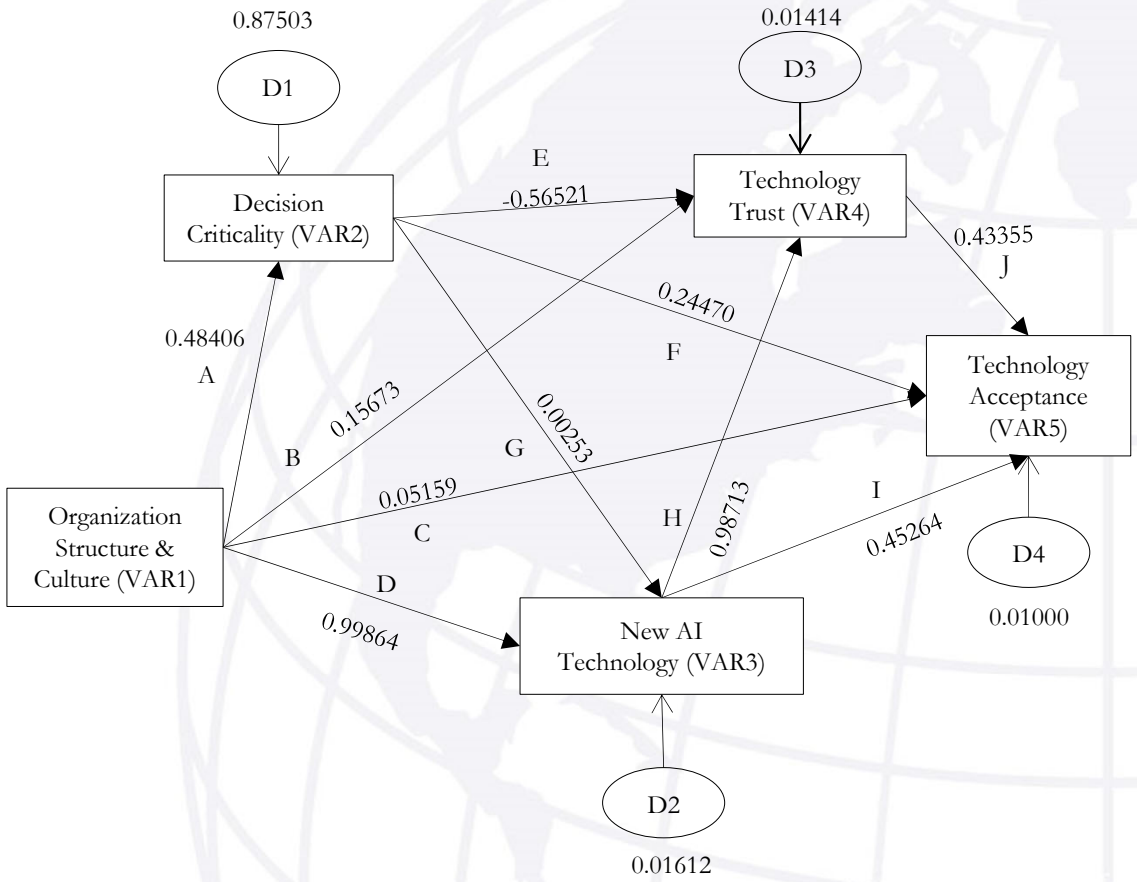
# AI/Autonomy: Technology Trust & Technology Use

Sea Ox & Sea Otter (EOD)



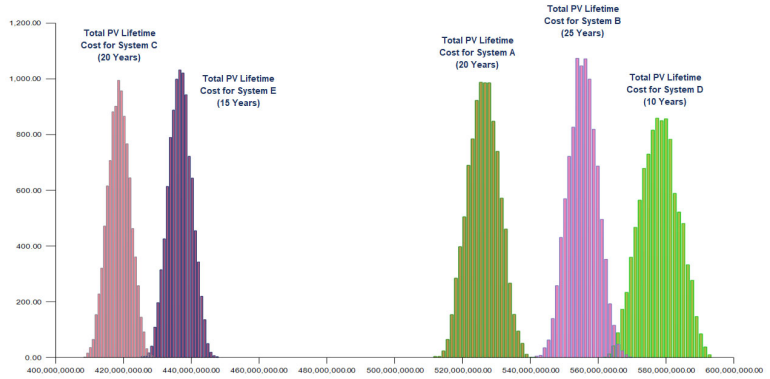
LMACC Lightly Manned Autonomous Combat Capability (Sea Hunter/Sea Strike)

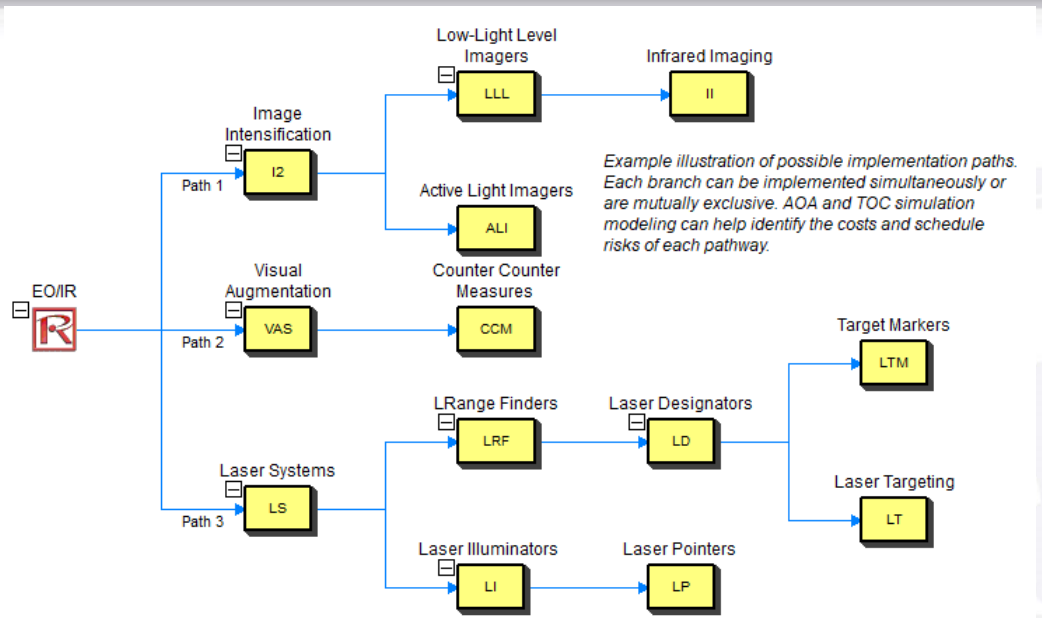


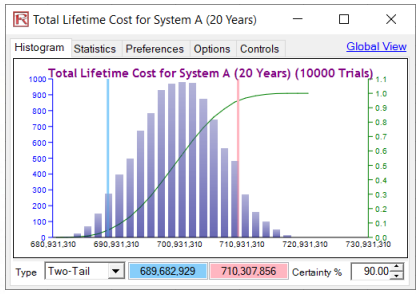



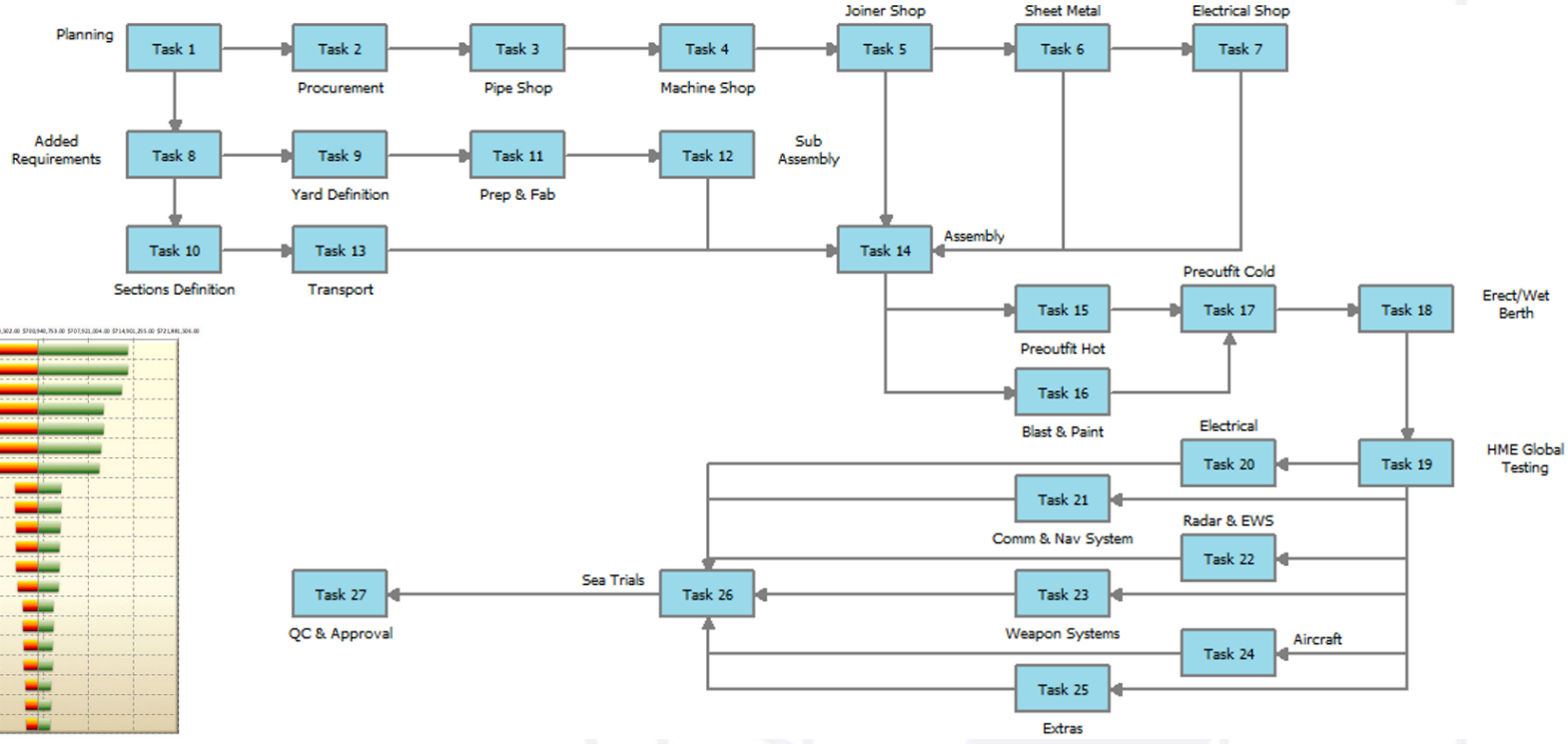
NAVAL POSTGRADUATE SCHOOL

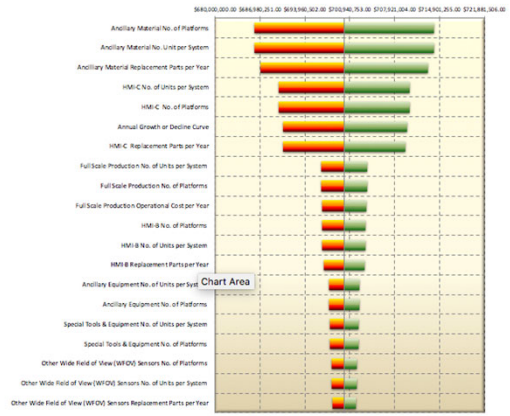
# Decision Analytics (AOA & Options)



NAVAL POSTGRADUATE SCHOOL

# Lifecycle and TOC: Cost & Schedule Risk

Project Management | Applied Analytics | Risk Simulation | Options Strategies | Options Valuation | Forecast Prediction | Dashboard | Knowledge Center

Ship Building | ICT Navigation | Weapon Systems | Aircraft | Electrical Systems | Radar Systems | Extra Systems | Support Processes | Portfolio Analysis

Select the Project Schedule & Cost Risk Model to use: ○ Sequential Path ◉ Complex Network Path Project Name/Notes:

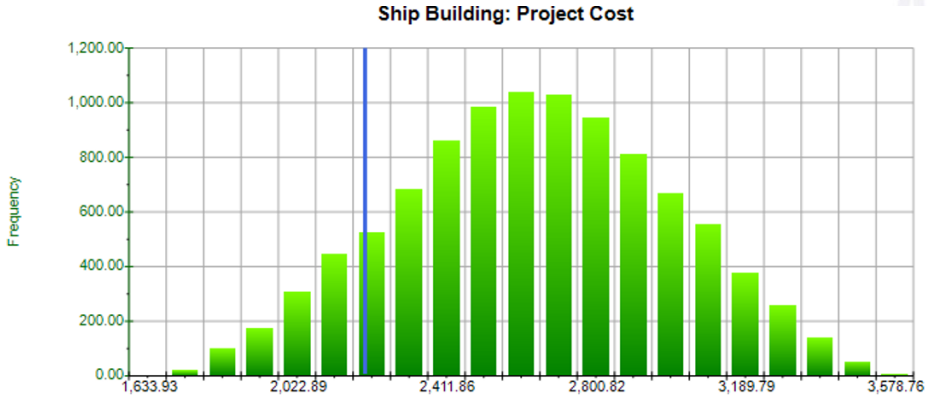
Network Diagram | Schedule & Cost

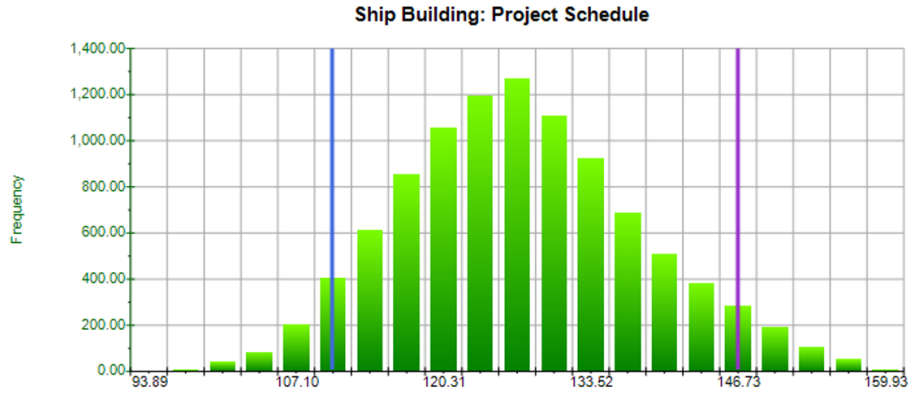
☑ Include Schedule-Based Cost Analysis ☐ Include Probabilities of Success of Each Task and Model Their Impacts

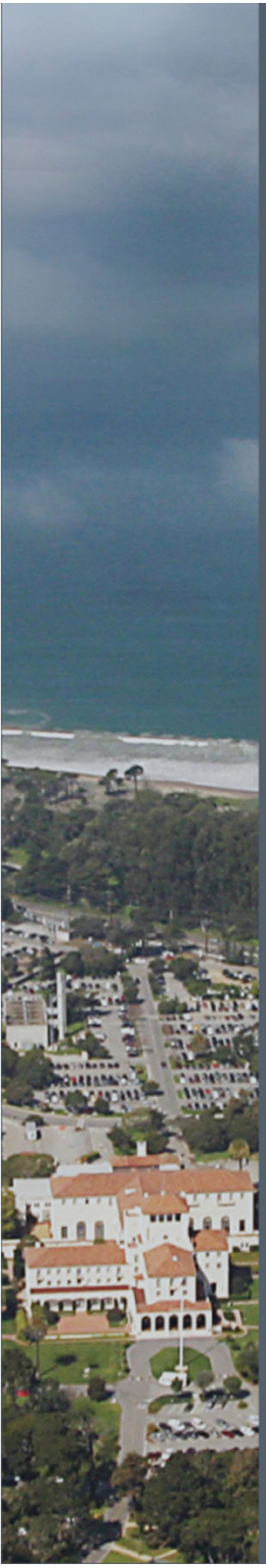
☑ Include Budget Overrun & Buffers ☑ Perform Risk Simulation Run Run All Projects

Show 27 Tasks with Weekly Simulation Trials: 1,000,000 ☑ Apply Seed Value: 123 Triangular

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Task 6 | Sheet Metal | 19.70 | 24.62 | 29.55 | 27 | 1.27 | 2.00 | 2.73 | 0.04 | 10.00% |
| Task 7 | Electrical Shop | 19.70 | 24.62 | 29.55 | 29 | 3.17 | 5.00 | 6.84 | 0.40 | 10.00% |
| Task 8 | Added Requirements | 2.36 | 3.07 | 4.76 | 4 | 2.53 | 4.00 | 5.47 | 0.16 | 10.00% |
| Task 9 | Yard Definition | 2.63 | 3.41 | 5.29 | 4 | 2.53 | 4.00 | 5.47 | 0.16 | 10.00% |
| Task 10 | Sections Definition | 2.89 | 3.75 | 5.82 | 4 | 1.27 | 2.00 | 2.73 | 0.16 | 10.00% |
| Task 11 | Prep & Fab | 1.84 | 2.38 | 3.70 | 4 | 3.80 | 6.00 | 8.20 | 0.16 | 10.00% |
| Task 12 | Sub Assembly | 21.01 | 27.25 | 42.33 | 31 | 2.53 | 4.00 | 5.47 | 0.24 | 10.00% |
| Task 13 | Transport | 13.13 | 17.03 | 26.45 | 20 | 1.90 | 3.00 | 4.10 | 0.24 | 10.00% |
| Task 14 | Assembly | 31.51 | 40.88 | 63.49 | 47 | 3.17 | 5.00 | 6.84 | 0.40 | 10.00% |
| Task 15 | Preoutfit Hot | 13.13 | 17.03 | 26.45 | 20 | 1.90 | 3.00 | 4.10 | 0.24 | 10.00% |
| Task 16 | Blast & Paint | 3.15 | 4.09 | 6.35 | 5 | 1.90 | 3.00 | 4.10 | 0.24 | 10.00% |
| Task 17 | Preoutfit Cold | 2.63 | 3.41 | 5.29 | 4 | 1.27 | 2.00 | 2.73 | 0.16 | 10.00% |
| Task 18 | Erect/Wet Berth | 39.39 | 51.10 | 79.36 | 57 | 1.90 | 3.00 | 4.10 | 0.24 | 10.00% |
| Task 19 | HME Global Testing | 55.14 | 71.54 | 111.10 | 87 | 6.33 | 10.00 | 13.67 | 0.79 | 10.00% |
| Task 20 | Electrical | 4.40 | 11.05 | 17.70 | 20 | 17.07 | 44.00 | 70.93 | 0.16 | 10.00% |
| Task 21 | Comm & Nav System | 19.64 | 47.07 | 74.50 | 61 | 19.40 | 50.00 | 80.60 | 0.16 | 10.00% |
| Task 22 | Radar & EWS | 158.16 | 385.70 | 613.24 | 435 | 23.28 | 60.00 | 96.72 | 0.16 | 10.00% |
| Task 23 | Weapon Systems | 514.54 | 1,262.38 | 2,010.21 | 1,397 | 18.62 | 48.00 | 77.38 | 0.16 | 10.00% |
| Task 24 | Aircraft | 24.56 | 61.54 | 98.52 | 71 | 13.97 | 36.00 | 58.03 | 0.08 | 10.00% |
| Task 25 | Extras | 18.03 | 45.24 | 72.44 | 52 | 9.31 | 24.00 | 38.69 | 0.08 | 10.00% |
| Task 26 | Sea Trials | 42.01 | 54.50 | 84.65 | 74 | 5.06 | 8.00 | 10.94 | 1.59 | 10.00% |
| Task 27 | QC & Approval | 26.26 | 34.07 | 52.91 | 38 | 1.90 | 3.00 | 4.10 | 0.24 | 10.00% |





NAVAL
POSTGRADUATE
SCHOOL

# BACKUP

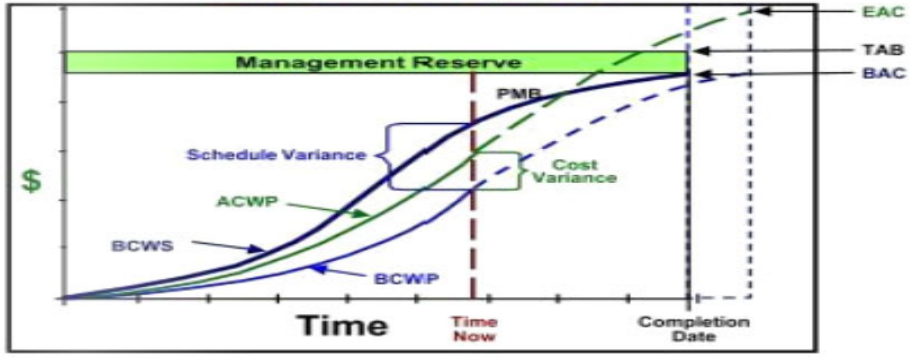
Johnathan Mun, Ph.D. (Research Professor, Dept. Information Sciences)

*Excellence Through Knowledge*

NAVAL POSTGRADUATE SCHOOL

# EVM to IRM

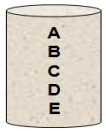
## Earned Value Management 'Gold Card'




## Integrated Risk Management Process

**1 List of projects and strategies to evaluate**

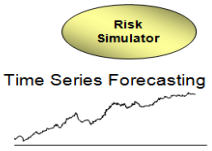
RISK IDENTIFICATION




Start with a list of projects or strategies to be evaluated… these projects have already been through qualitative screening

**2 Base case projections for each project**

RISK PREDICTION




…with the assistance of time-series forecasting, future outcomes can be predicted…

**3 Develop static financial models**

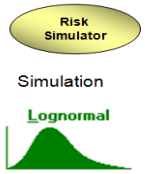
RISK MODELING

Traditional analysis stops here!

…the user generates a traditional series of static base case financial (discounted cash flow) models for each project…

**4 Dynamic Monte Carlo simulation**

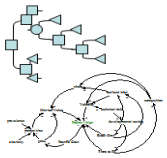
RISK ANALYSIS




…Monte Carlo simulation is added to the analysis and the financial model outputs become inputs into the real options analysis…

**5 Framing Real Options**

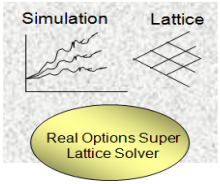
RISK MITIGATION



…the relevant projects are chosen for real options analysis and the project or portfolio real options are framed…

**6 Options analytics, simulation, optimization**

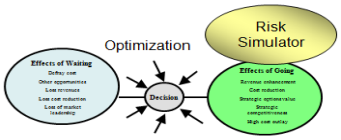
RISK HEDGING




…real options analytics are calculated through binomial lattices and closed-form partial-differential models with simulation…

**7 Portfolio optimization and asset allocation**

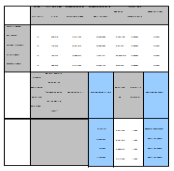
RISK DIVERSIFICATION




…stochastic optimization is the next optional step if multiple projects exist that require efficient asset allocation given some budgetary constraints… useful for strategic portfolio management…

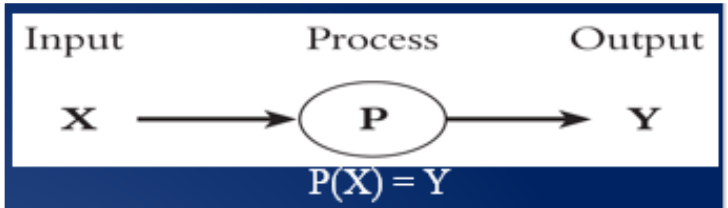
**8 Reports presentation and update analysis**

RISK MANAGEMENT



…create reports, make decisions, and do it all again iteratively over time…

WWW.NPS.EDU




$P(X) = Y$

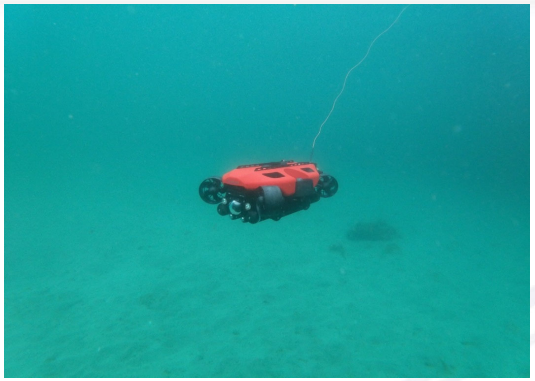
Fundamental assumptions:
1. If X = Y no value has been added.
2. "value" ∝ "change"
3. "change" can be measured by the amount of knowledge required to make the change.

So "value" ∝ "change" ∝ "amount of knowledge required to make the change"

| Steps | Learning Time | Process Description | Binary Query Method |
|---|---|---|---|
| One | Identify core process and its subprocesses. | | |
| Two | Establish common units and level of complexity to measure learning time. | Describe the products in terms of the instructions required to reproduce them and select unit of process description. | Create a set of binary yes or no questions such that all possible outputs are represented as a sequence of yes or no answers. |
| Three | Calculate learning time to execute each subprocess. | Calculate number of process description words, pages in manual, and lines of computer code pertaining to each subprocess. | Calculate length of sequence of yes or no answers for each subprocess. |
| Four | Designate sampling time period long enough to capture a representative sample of the core processes final product or service output. | | |
| Five | Multiply the learning time for each subprocess by the number of times the subprocess executes during the sample period. | Multiply the number of process words used to describe each sub process by the number of times the subprocess executes during sample period. | Multiply the length of the yes or no string for each sub process by the number of times the subprocess executes during sample period. |
| Six | Calculate cost to execute knowledge (learning time and process instructions) to determine process costs. | | |
| Seven | Calculate ROK and ROP and interpret the results. | | |

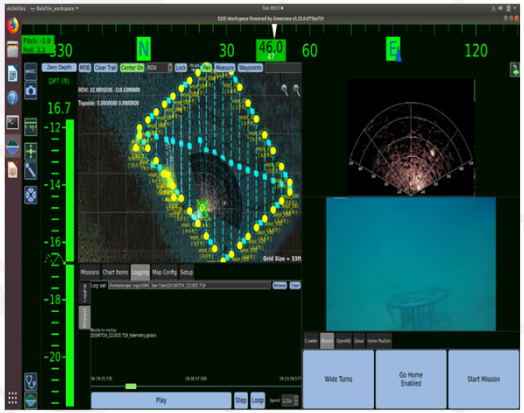
# Levels of Automation

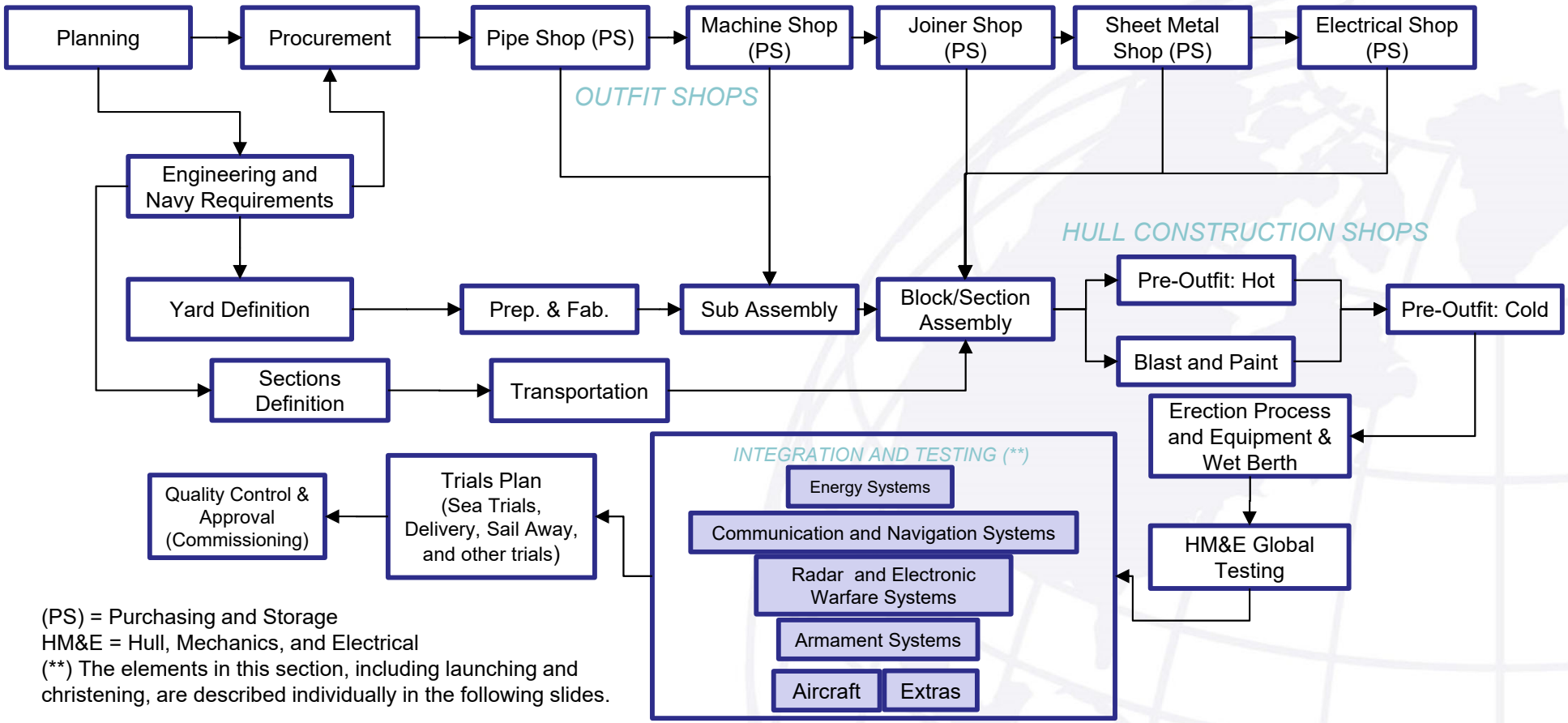
SRS Fusion ROV
Low LOA



Sonar EMILY USV
Medium LOA

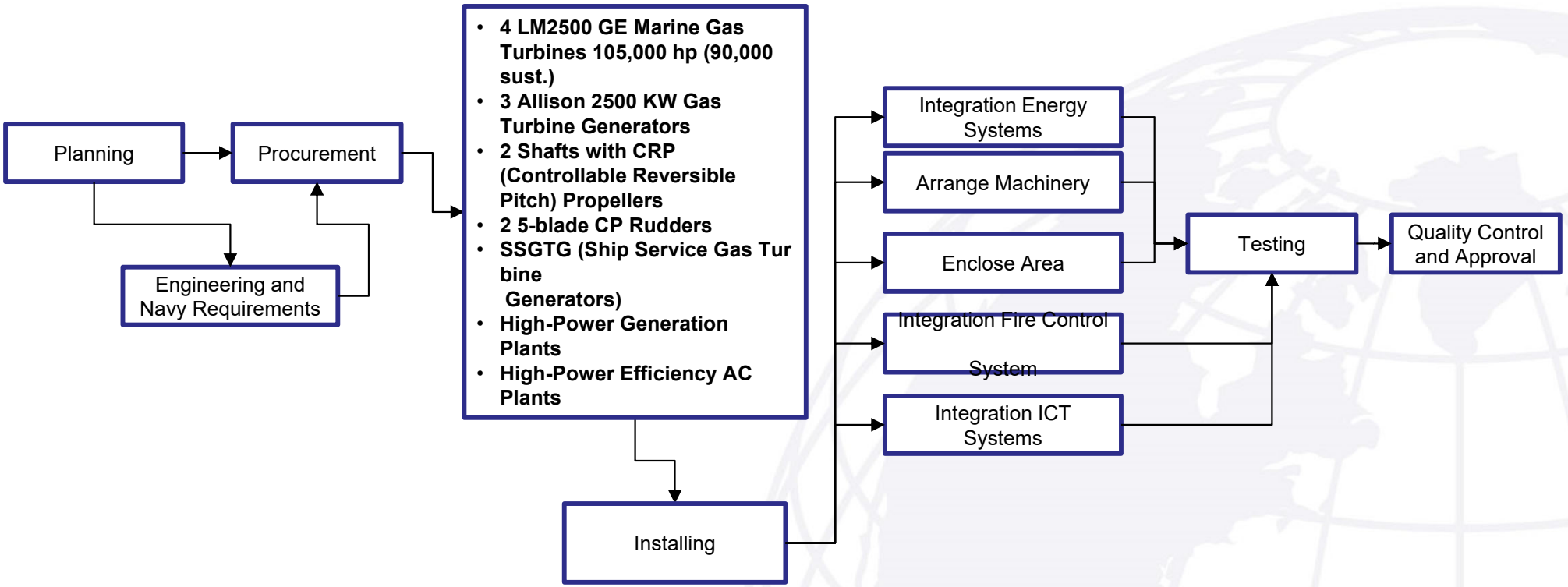
Sea OX
High LOA



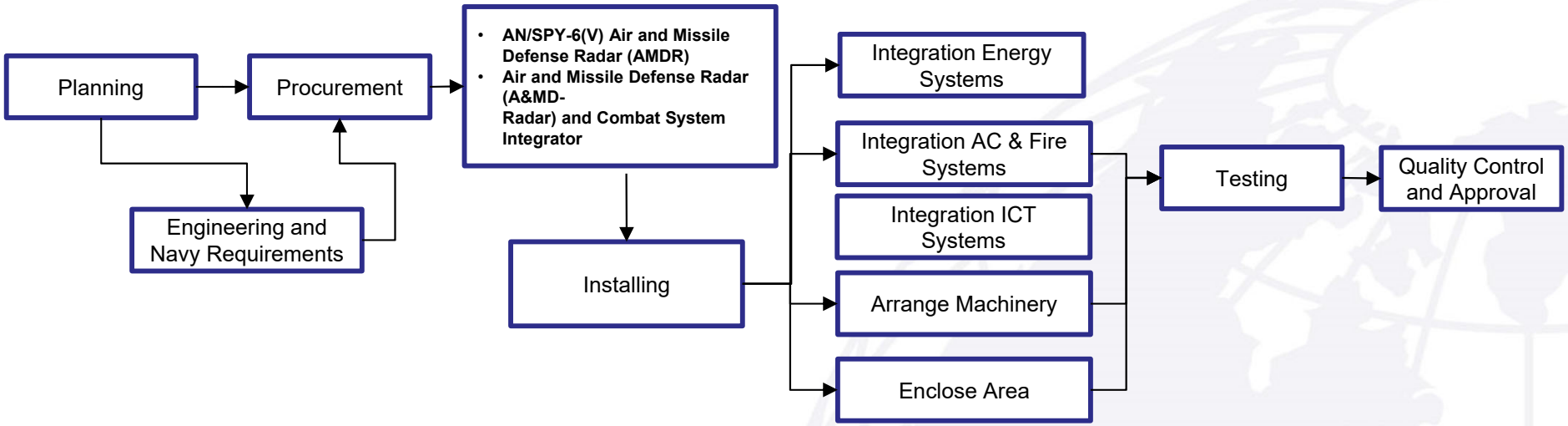



(PS) = Purchasing and Storage
HM&E = Hull, Mechanics, and Electrical
(**) The elements in this section, including launching and christening, are described individually in the following slides.

# Project Tasks (Energy Systems)




Propulsion is supported by 4 General Electric LM2500 gas turbines each generating 26,500 hp (19,800 kW);[4] coupled to two shafts, each driving a five-bladed reversible controllable-pitch propeller




The program completed Technology Development (TD) contracts in September 2012 and released a Request for Proposals for the E&MD Phase in June 2012. The AMDR program achieved Milestone B in September 2013 and received a signed Acquisition Decision Memorandum on October 4, 2013. After a full and open competition, an Engineering and Manufacturing Development (E&MD) phase contract was awarded to Raytheon on October 10, 2013. Raytheon was awarded a $385,742,176 cost-plus-incentive-fee contract for the engineering and modeling development phase design, development, integration, test, and delivery of Air and Missile Defense S-Band Radar (AMDR-S) and Radar Suite Controller (RSC).

http://www.globalsecurity.org/military/systems/ship/systems/amdr.htm

Cost information on Navigation, Weapons, and Aircraft was similarly obtained and is illustrated below:

| *Category* | *Items* | *Quantity* | *Min Unit Cost* | *Aveg Unit Cost* | *Max Unit Cost* | *Total Cost ($M)* |
|---|---|---|---|---|---|---|
| Navigational Equipment | AN/WSN-5 Inertial Navigation System; AN/WRN-6 ; ANISRN-25 (V); MK 4 | 1 | 8 | 14 | 20 | 14.00 |
| | MK 6 MOD 4D Digital Dead Reckoning Tracer | | | | | |
| | AN/URN-25 TACAN; AN/SPS-64 (V) 9 I Band Radar | | | | | |
| | Navy Standard No. 3 Magnetic Compass; | | | | | |
| | Total Navigation system | 1 | 15.84 | 19.8 | 23.76 | 19.80 |
| | Chronometer Size 85; Flux Compass | | | | | |
| ***Total*** | | ***2*** | ***23.84*** | ***33.80*** | ***43.76*** | ***33.80*** |
| Weapons | | | | | | |
| | RIM-66 Standard Missile SM-2MR; RIM-67/RIM-156 Standard Missile SM-2ER | | | | | |
| | RIM-161 Standard Missile SM-3 | 74 | 3 | 3.24 | 10.07 | 239.76 |
| | Vertical Launch ASROC (VLA) missiles; | | | | | |
| | MK 41 Vertical Missile Launch Systems (VLS) | 2 | 38.2 | 110.1 | 182 | 220.20 |
| | BGM-109 Tomahawk | 1 | 0.4552 | 0.569 | 0.6828 | 0.57 |
| | MK-46 torpedoes (from two triple tube mounts); | 6 | | | | |
| | Close In Weapon System (CIWS), | 1 | 3.04 | 3.8 | 4.56 | 3.80 |
| | Mk-45 (Mod.1/2) 5"/54 | | | | | |
| | RIM Evolved Sea Sparrow Missile (ESSM) | 1 | 0.84 | 0.905 | 0.97 | 0.91 |
| | MK 38 self--defense guns | | | | | |
| | Land-Attack Guns | | | | | |
| | Other type of Guided Missiles (Guided shell) | 10 | 0.025 | 0.0375 | 0.05 | 0.38 |
| | Other type of defined Guns and Torpedoes, missiles, being part of the ship's | 1 | 641.40344 | 796.77 | 1296.242 | 796.77 |
| ***Total*** | | ***96*** | ***686.96*** | ***915.42*** | ***1494.57*** | ***1262.38*** |
| Aircraft | MH-60 B/R Seahawk LAMPS III helicopters with Penguin/ Hellfire missiles | 2 | 27.693 | 30.77 | 60 | 61.54 |
| | MK 46/MK 50 torpedoes | | | | | |

*WBS and Global Network Diagram of Warship Building*

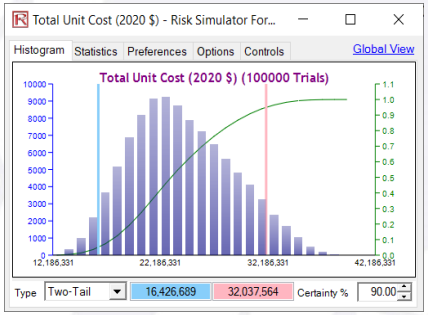
The figures illustrates the analysis of alternatives or strategic options. Based on the pricing policy on PC 14 at the Bollinger Machine Shop and Yard, we were able to extrapolate the data for 1990 to current dollar values (2020) for patrol coastal (PC) boats. The Monte Carlo simulated cost shows a range of $16.4 million to $32 million, with a 90% confidence interval. The range depends on the number of ships, where there is a learning curve (i.e., cost reduces over the course of multiple ships). The figures also show the simulated expected value of PC boats at $23.6 million.

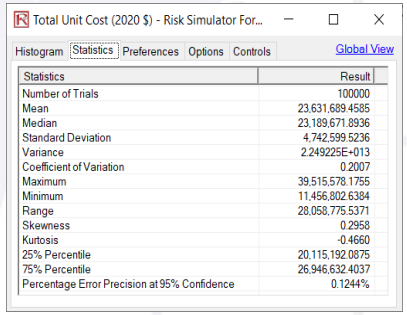
**170 foot Patrol Coastal (PC) by Bollinger Shipyards**

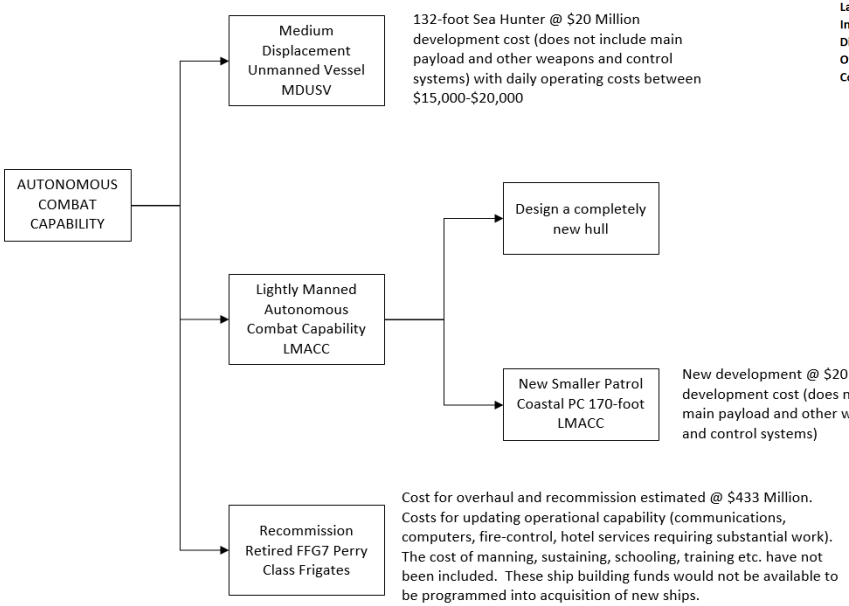
| | 1990 | $11.42 | | | | 2020 | $23.06 | Inflation | 2.37% | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Direct Labor | | Direct Materials & Overhead | | Total | Direct Labor | | Direct Materials & Overhead | | Total |
| ITEMIZATION | Hours | Dollar | Materials | Overhead | | Hours | Dollar | Materials | Overhead | |
| Hull Structure | 41,734 | $476,602 | $122,800 | $738,733 | $1,338,135 | 41,734 | $962,359 | $247,959 | $1,491,656 | $2,701,974 |
| Propulsion Plant | 1,897 | $21,664 | $3,254,200 | $33,578 | $3,309,442 | 1,897 | $43,744 | $6,570,907 | $67,801 | $6,682,452 |
| Electric Plant | 6,640 | $75,829 | $307,000 | $117,534 | $500,363 | 6,640 | $153,114 | $619,897 | $237,326 | $1,010,337 |
| Command and Surveillance | 1,897 | $21,664 | $798,200 | $33,578 | $853,442 | 1,897 | $43,744 | $1,611,732 | $67,801 | $1,723,277 |
| Auxiliary Systems | 11,382 | $129,982 | $798,200 | $201,472 | $1,129,654 | 11,382 | $262,462 | $1,611,732 | $406,814 | $2,281,007 |
| Outfit and Furnishings | 15,176 | $173,310 | $614,000 | $268,630 | $1,055,940 | 15,176 | $349,949 | $1,239,794 | $542,420 | $2,132,163 |
| Armament | 949 | $10,838 | $122,800 | $16,798 | $150,436 | 949 | $21,883 | $247,959 | $33,919 | $303,761 |
| Integration and Engineering | 949 | $10,838 | $61,400 | $16,798 | $89,036 | 949 | $21,883 | $123,979 | $33,919 | $179,781 |
| Ship Assembly and Support Services | 14,227 | $162,472 | $61,400 | $251,832 | $475,704 | 14,227 | $328,065 | $123,979 | $508,501 | $960,546 |
| **SUBTOTAL** | 94,851 | $1,083,198 | $6,140,000 | $1,678,953 | $8,902,151 | 94,851 | $2,187,203 | $12,397,938 | $3,390,156 | $17,975,297 |
| **CONTRACTOR PROFIT @ 10%** | | | | | $890,215 | | | | | $1,797,530 |
| **GRAND TOTAL UNIT PRICE** | | | | | **$9,792,367** | | | | | **$19,772,827** |

| | Min | Likely | Max | Simulation |
|---|---|---|---|---|
| **Manhours** | 65,000 | 94,851 | 125,000 | 94,851 |
| **Labor Rate** | $13.11 | $23.06 | $47.97 | $23.06 |
| **Inflation Rate** | 0.46% | 2.37% | 4.90% | 2.37% |
| **Direct Materials** | $6,140,000 | $12,397,938 | $25,788,912 | $12,397,938 |
| **Overhead** | $1,678,953 | $3,390,156 | $7,051,852 | $3,390,156 |
| **Contractor Profit** | 9.00% | 10.00% | 11.00% | 10.00% |
| | **Total Unit Cost for Ship Only (2020 Dollars)** | | | **$19,772,827** |

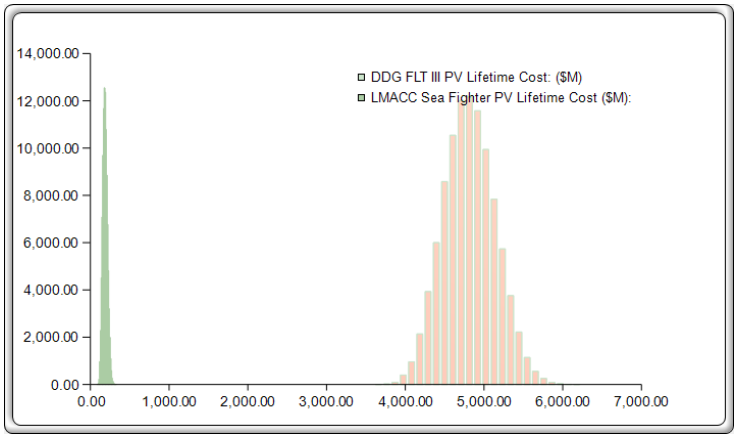
**As a basis of comparison, we use the 32 foot Sea Hunter Cost of Sea Hunter in 2020 is approximately $20 Million**



Using the same approach, we can estimate using notional values to determine the costs of the three alternatives as proposed using a life cycle of 30 years, with a single replacement in Year 15. The figures show the confidence intervals of the costs and simulated values. Sea Fighter has a life-cycle cost of $181.9 million versus $4.76 billion for the DDG 51 FLT III.




**Acquisition Cost ($ Billion) [with LCS Mission Packages]**

| | Option 1 | | | Option 2 | | | Option 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ships | Costs $B | Cost/Unit | Ships | Costs $B | Cost/Unit | Ships | Costs $B | Cost/Unit |
| Littoral Combat Ship | 53 | 33.20 | 0.626 | 28 | 17.10 | 0.611 | 53 | 33.100 | 0.625 |
| Littoral Combat Ship (CG Variant) | 25 | 12.10 | 0.484 | 0 | | | 0 | | |
| National Security Cutter | 5 | 2.90 | 0.580 | 5 | 2.60 | 0.520 | 25 | 12.500 | 0.500 |
| National Security Cutter (CG Variant) | 0 | | | 20 | 10.70 | 0.535 | 0 | | |
| Offshore Patrol Cutter | 0 | | | 25 | 11.10 | 0.444 | 0 | | |

**Acquisition Cost ($ Billion) [without LCS Mission Packages]**

| | Option 1 | | | Option 2 | | | Option 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ships | Costs $B | Cost/Unit | Ships | Costs $B | Cost/Unit | Ships | Costs $B | Cost/Unit |
| Littoral Combat Ship | 53 | 29.80 | 0.562 | 28 | 15.30 | 0.546 | 53 | 29.70 | 0.560 |
| Littoral Combat Ship (CG Variant) | 25 | 12.10 | 0.484 | 0 | | | 0 | | |
| National Security Cutter | 5 | 2.90 | 0.580 | 5 | 2.60 | 0.520 | 25 | 12.500 | 0.500 |
| National Security Cutter (CG Variant) | 0 | | | 20 | 10.70 | 0.535 | 0 | | |
| Offshore Patrol Cutter | 0 | | | 25 | 11.10 | 0.444 | 0 | | |

**Total Lifecycle Cost ($ Billion) [Discounted to NPV from 2009-2055]**

| | Option 1 | | | Option 2 | | | Option 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ships | Costs $B | Cost/Unit | Ships | Costs $B | Cost/Unit | Ships | Costs $B | Cost/Unit |
| Littoral Combat Ship | 108 | 65.10 | 0.603 | 58 | 35.30 | 0.609 | 108 | 65.900 | 0.610 |
| Littoral Combat Ship (CG Variant) | 50 | 23.30 | 0.466 | 0 | | | 0 | | |
| National Security Cutter | 13 | 10.40 | 0.800 | 13 | 9.90 | 0.762 | 53 | 31.200 | 0.589 |
| National Security Cutter (CG Variant) | 0 | | | 40 | 25.00 | 0.625 | 0 | | |
| Offshore Patrol Cutter | 0 | | | 50 | 21.60 | 0.432 | 0 | | |

Total Lifecycle Costs include acquisition costs, cost of replacing the ship one time, cost of operating the ships (fuel, maintenance of structures and systems, and personnel costs)

Option 1 explores the feasibility of having the Coast Guard buy a variant of the Navy's LCS—specifically, the semiplaning monohull—to use as its offshore patrol cutter. (The rationale for this option is that, according to some analysts, the NSC's longer mission range and higher endurance might make it better suited than the LCS to act as a "patrol frigate," which would allow the Navy to carry out certain activities—maritime security, engagement, and humanitarian operations—outlined in the sea services' new maritime strategy.)

| **Alternative 3 ($ Millions)** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ... | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ship Cost (Platform Only, including Contract, Design, and Acquisition): | $20.00 | | | | | | | | | | | | | |
| Additional Cost (Weapons, Systems, Electrical, Sensors): | $7.00 | | | | | | | | | | | | | |
| Ship Operations and Maintenance Cost Annually (O&M): | $3.00 | $3.12 | $3.24 | $3.37 | $3.51 | $3.65 | $3.80 | $3.95 | $4.11 | $4.27 | | $8.65 | $9.00 | $9.36 |
| Any Typical Ship Alterations and Modifications Cost: | | | | | | | | | | | | | | |
| Personnel Cost Pear Year: | $1.00 | $1.04 | $1.08 | $1.12 | $1.17 | $1.22 | $1.27 | $1.32 | $1.37 | $1.42 | | $2.88 | $3.00 | $3.12 |
| Any Nonrecurring Costs: | $3.00 | | | | | | | | | | | | | |
| Decommissioning Costs at End of Life: | | | | | | | | | | | | | | $0.00 |
| Net Costs Per Year: | $34.00 | $4.16 | $4.33 | $4.50 | $4.68 | $4.87 | $5.06 | $5.26 | $5.47 | $5.69 | | $11.53 | $11.99 | $12.47 |
| Total Lifetime Cost: | $308.37 | | | | | | | | | | | | | |
| PC Sea Hunter Total Present Value of Lifetime Cost ($M): | $162.10 | | | | | | | | | | | | | |