The Lightly Manned Autonomous Combat Capability (LMACC)

Dr. Johnathan Mun & Dr. Shelley Gallup

Introduction

What is the need?

The U.S. Navy needs three tiers of surface ships to be successful in matching and defeating a near peer threat in the Pacific and Atlantic. Tier one are the CVNs and although we are talking surface ships, the submarine force is in this category. Second tier are the CGs and DDGs that support CVN operations and provide access in non-lethal operations. A third tier was to have been the LCS, however these ships are ineffective for the concept we are discussing here.

What is needed in the third tier are, light, fast, agile, well armed and lightly manned warships that integrate autonomy as part of the vessel, leaving humans to do the work of perception in complex situations. These vessels will work in concert with unmanned surface vessels.

A Different Construct

Distributed Maritime Operations

Distributed Maritime Operations (DMO) is not truly possible in the current construct of ship procurements. Ships are being built that add multiple missions to each platform. This means that there are fewer ships, requiring higher personnel needs.

A different construct: Build ships that have a PRIMARY mission and one secondary mission. The LMACC (Sea Fighter) will all have the same primary mission, deliver long range surface missiles into theaters of operation that the first two tiers cannot go into until the adversary's long-range missiles have been defeated. By distributing the secondary missions among many smaller vessels and mixed with unmanned surface vessels (Sea Hunter), the VARIETY of actions these "packs" may accomplish is greatly increased and risk is decreased.

Background

Scenario of Employment

This is but one scenario, but very real.

The PLA has become aggressive to the point of hostilities. SLOCS are at risk in the South Pacific through the various straits. The PLA is superior in that it operates long range, land-based missiles from China, and from man-made islands that are keeping CVNs and large combatants out of the first and second island chain.

“Packs” are sent forward to build force of missiles in theater that can create a first strike capability and allows larger forces to move in towards the threat.

History

The U.S. Navy employed small ships (destroyer escorts, PT boats, etc.) in WW2. Coastal Patrol vessels (PCs) were built after the war and operated into the 1970's. Currently, the U.S. Navy operates 12 Cyclone Class PC's in the Middle East. These have been proven to be effective long after their initial life-span has passed.

In this new age of autonomy, the ability to merge autonomy with new technology in ship design, construction, manning and concepts will enable human-machine tactics that can provide the third tier needed.

This study is intended to show that such a program is cost-feasible.

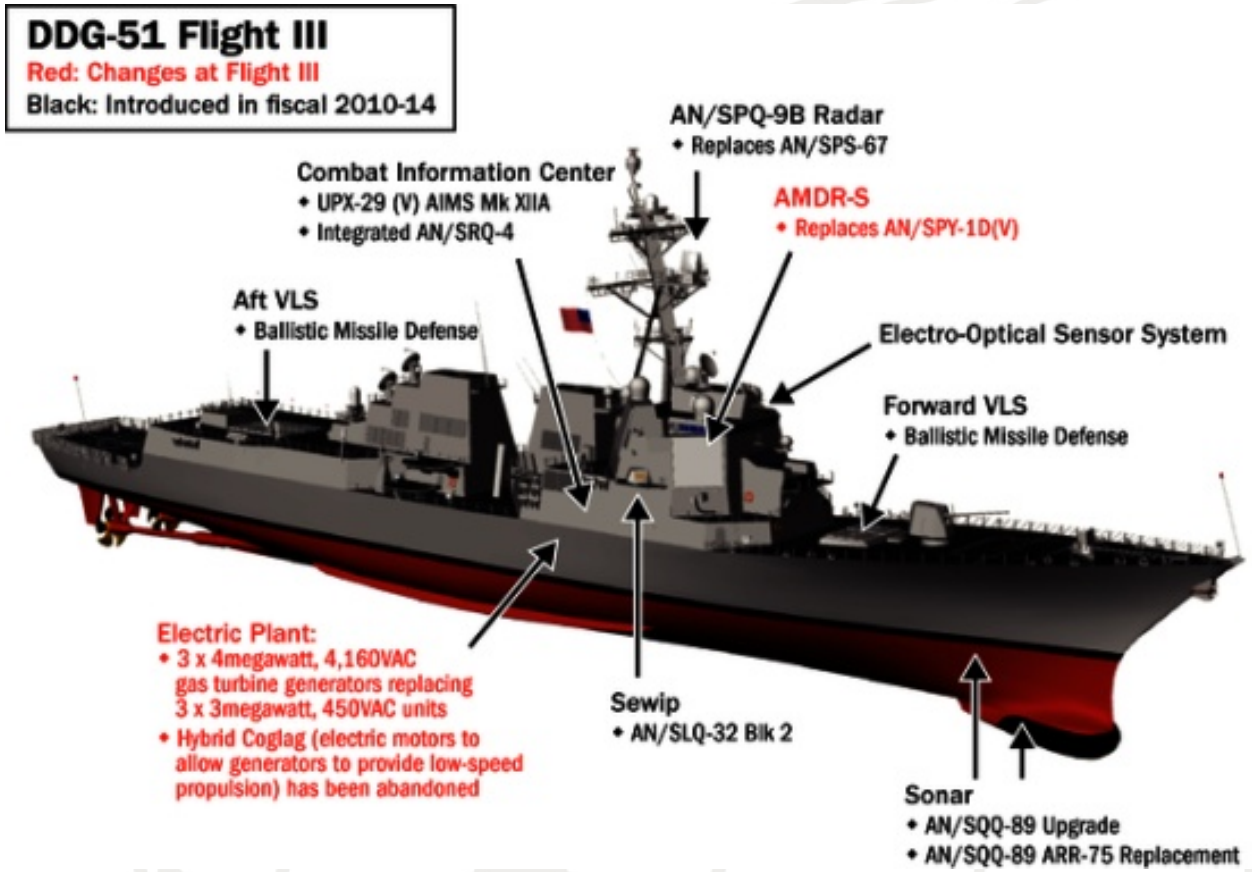
Cost Analysis of DDG 51 FLT III

Overview of U.S. Navy Ships (DDG 51 Destroyer Class)

The Navy Ship Models Reviewed: **Arleigh Burke Class Guided Missile Destroyer DDG 51 Flight I, Flight II, Flight IIA, Flight III**, and also the Joint High Speed Vessel (JHSV), CG 47 Ticonderoga, DDG 1000 Zumwalt, LPD 17 San Antonio Class, LHA 6 America Class, and Nimitz Class Aircraft Carrier (CVN 68), among others warship models.

In the cost analysis models, we will consider the full build of the ship, with its accoutrements such as weapons systems, electrical systems, radar and electronic warfare systems, communication and navigation systems, aircraft, and other extra add-ons.

Cost-Schedule estimation follows a ***bottom-up*** approach, and the Multivariate Analysis (parametric) follows a ***top-down*** approach.



Department of Defense (DoD) Budget Data (DDG 51 Destroyer)

Information and data were obtained via publicly available sources and were collected, collated, and used in an integrated cost modelling methodology. Due to lack of proprietary data, we used publicly sourced information and applied subject matter expert opinions. The objective of this study is to develop a comprehensive cost modeling strategy and approach, and Notional Data were used to perform Rough Order Magnitude (ROM) estimates.

DoD Spending, Procurement and RDT&E: FY 2012/13/14 + Budget for FYs 2015 + 2016 Go to Top

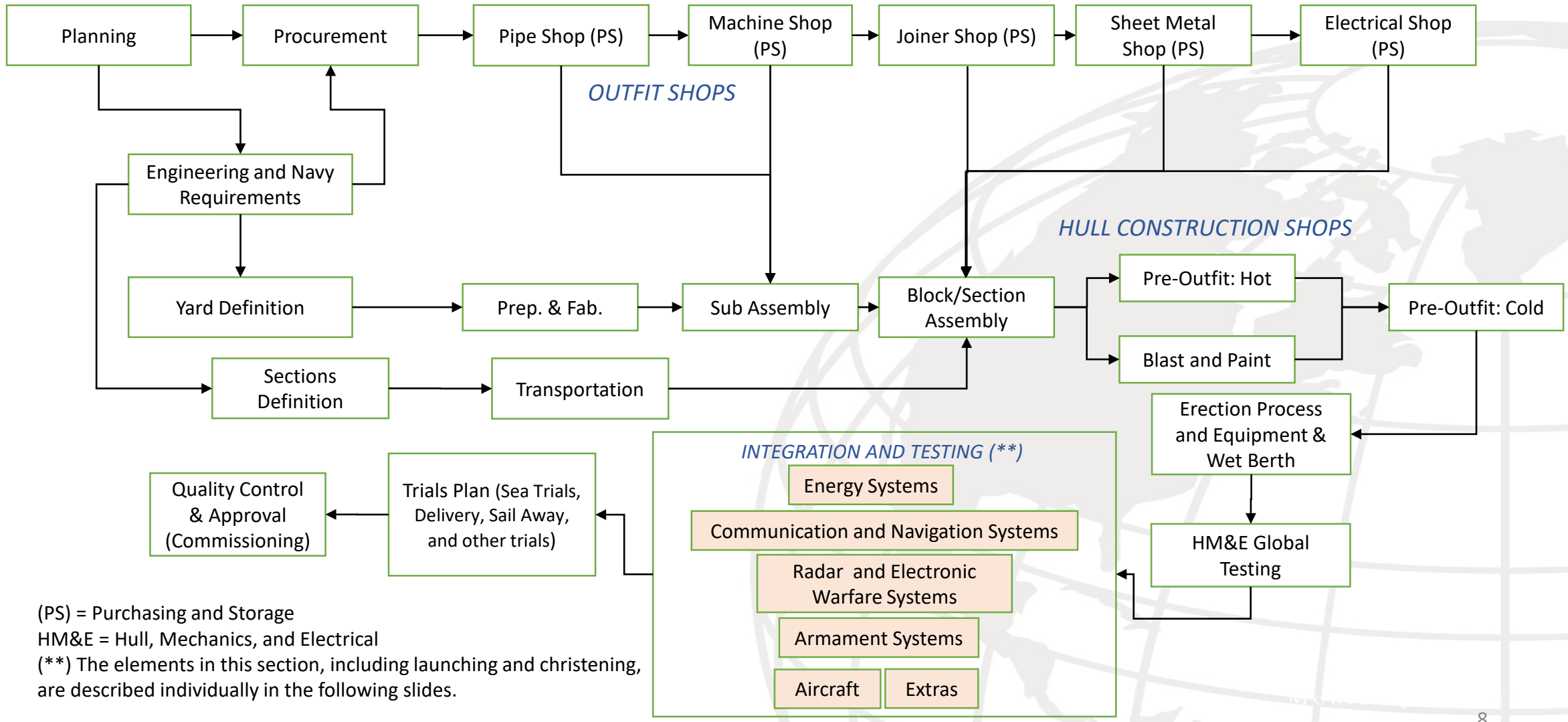
DDG 51 AEGIS Destroyer		ACTUAL FY2012 Total QTY	ACTUAL FY2012 Total Million $	ACTUAL FY2013 Total QTY	ACTUAL FY2013 Total Million $	ACTUAL FY2014 Total QTY	ACTUAL FY2014 Total Million $	PRELIMINARY FY2015 Total QTY	PRELIMINARY FY2015 Total Million $	REQUESTED FY2016 Total QTY	REQUESTED FY2016 Total Million $
Procurement											
Shipbuilding & Conversion	NAVY	1	2,081.43	3	4,497.01	1	1,985.12	2	2,795.95	2	3,149.70
Ship Modifications	NAVY		126.37		407.71		285.99		324.22		364.16
Completion Costs	NAVY		-		-		100.00		129.14		-
Outfitting & Post Delivery	NAVY		49.10		7.30		1.30		6.50		62.10
Total Procurement		**1**	**2,256.91**	**3**	**4,912.02**	**1**	**2,372.41**	**2**	**3,255.81**	**2**	**3,575.96**
RDT&E (Hybrid Electric Drive)	NAVY		-		-		-		7.95		4.22
Total RDT&E			-		-		-		**7.95**		**4.22**
Total Program Spending		**1**	**2,256.91**	**3**	**4,912.02**	**1**	**2,372.41**	**2**	**3,263.76**	**2**	**3,580.18**

FY2017-FY2020 Budget Data in PDF files below table →→→

Download Official U.S. Department of Defense (DoD) Budget Data:

Shipbuilding & Conversion | DDG-51 AEGIS Destroyer

Process Flow: Planning, Design, Construction, Integration, Trials & Commissioning



(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)

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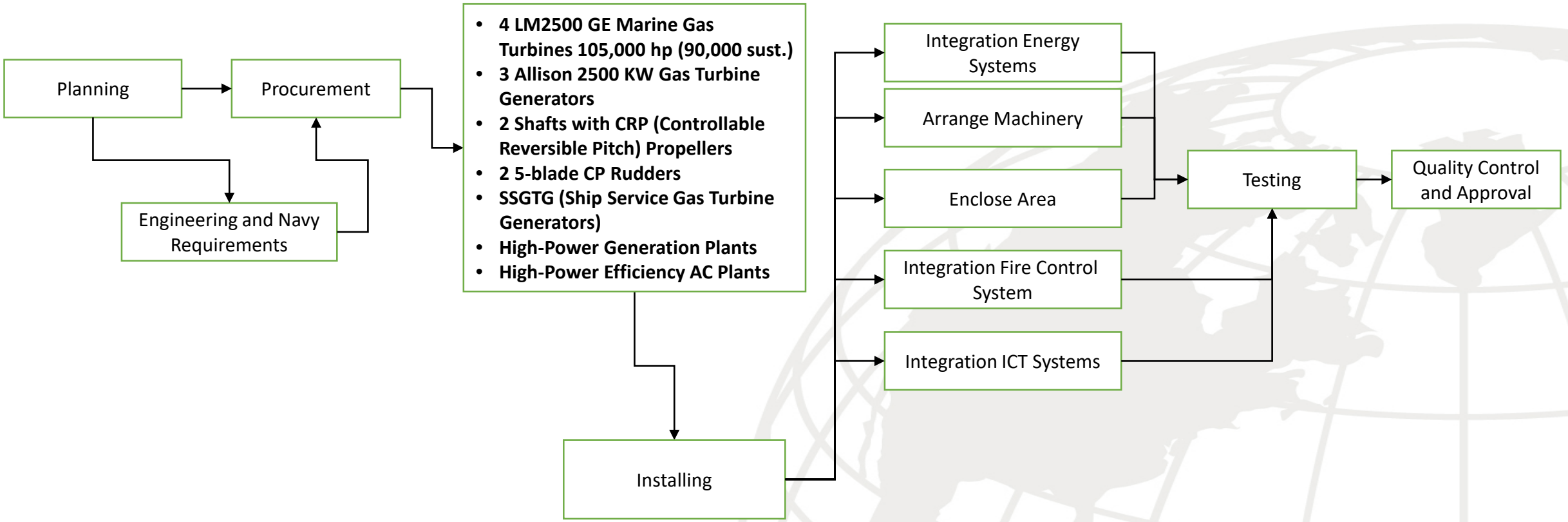
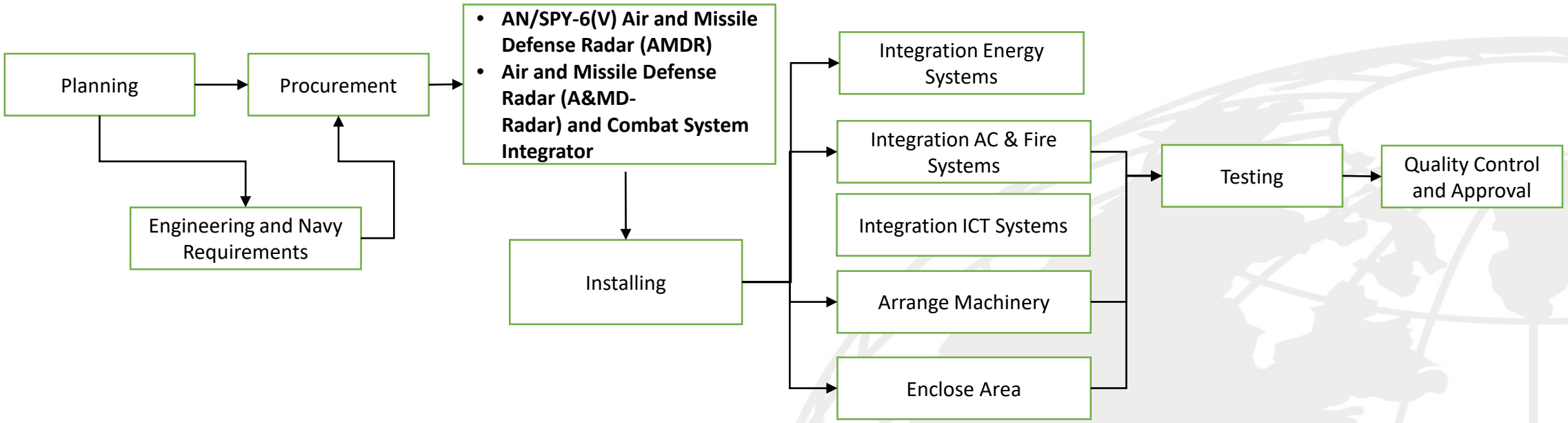


Propulsion is supported by 4 General Electric LM2500 gas turbines each generating 26,500 hp (19,800 kW);[4] coupled to two shafts, each driving a five-bladed reversible controllable-pitch propeller

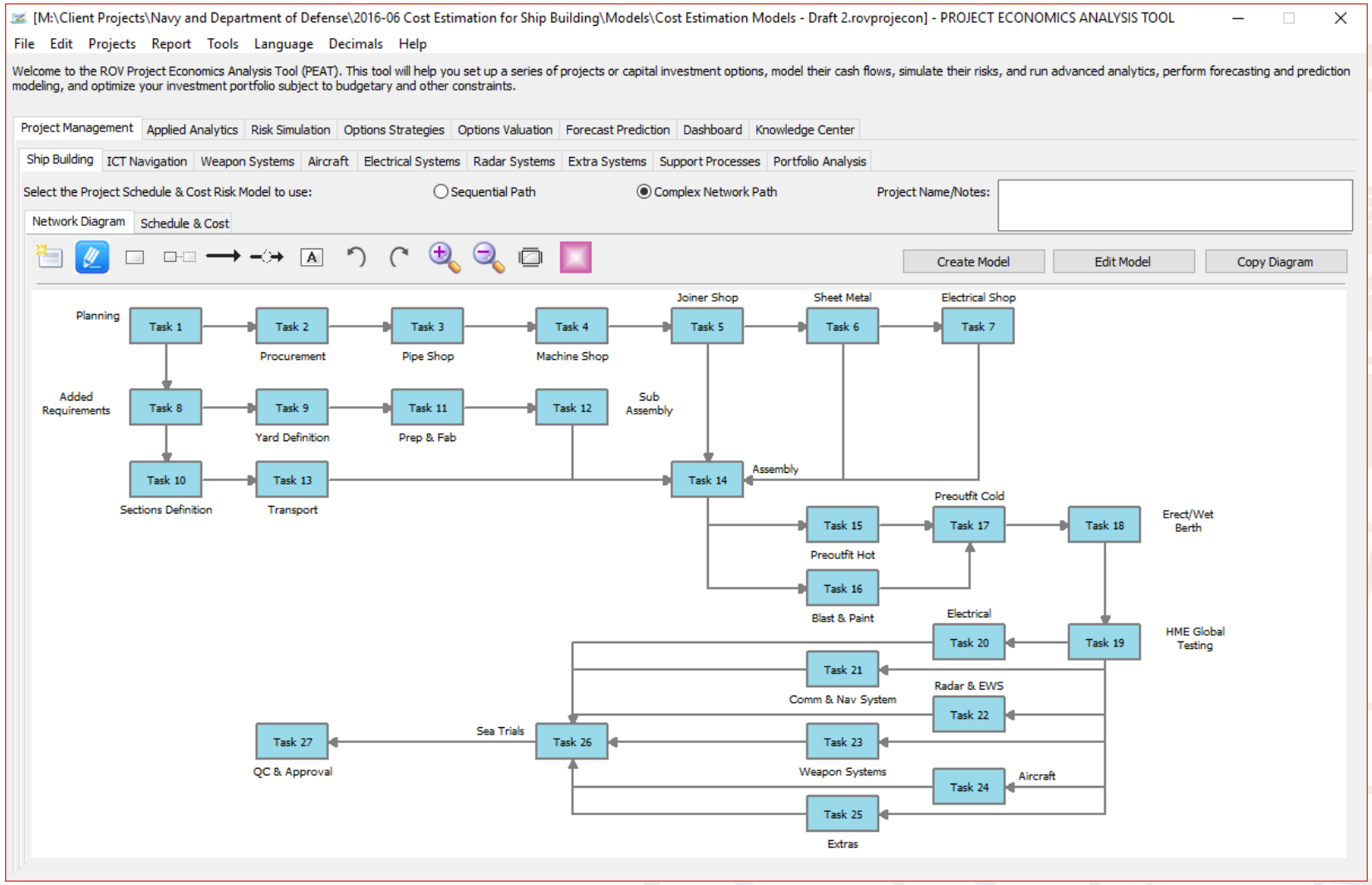
Project Tasks (Radar Systems)



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

WBS and Global Network Diagram of Warship Building



Cost Modeling (Research and Data Analysis)

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 MK 6 MOD 4D Digital Dead Reckoning Tracer	1	8	14	20	14.00
	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*	*15.84*	*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

Expected Project Schedule (Shipbuilding)

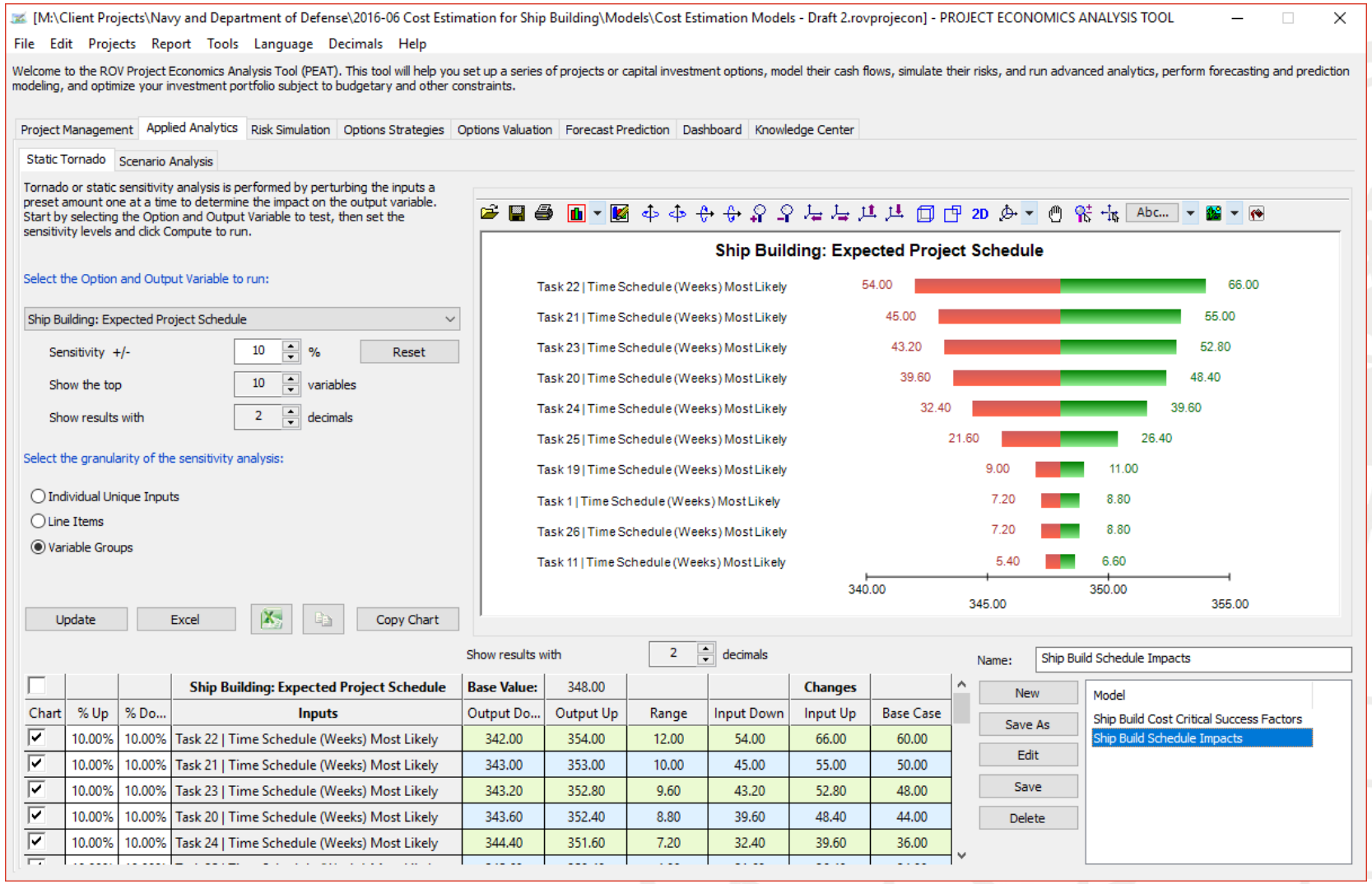


Chart	% Up	% Do...	Ship Building: Expected Project Schedule Inputs	Base Value: Output Do...	348.00 Output Up	Range	Input Down	Changes Input Up	Base Case
☑	10.00%	10.00%	Task 22 | Time Schedule (Weeks) Most Likely	342.00	354.00	12.00	54.00	66.00	60.00
☑	10.00%	10.00%	Task 21 | Time Schedule (Weeks) Most Likely	343.00	353.00	10.00	45.00	55.00	50.00
☑	10.00%	10.00%	Task 23 | Time Schedule (Weeks) Most Likely	343.20	352.80	9.60	43.20	52.80	48.00
☑	10.00%	10.00%	Task 20 | Time Schedule (Weeks) Most Likely	343.60	352.40	8.80	39.60	48.40	44.00
☑	10.00%	10.00%	Task 24 | Time Schedule (Weeks) Most Likely	344.40	351.60	7.20	32.40	39.60	36.00

Sea Hunter Cost & Analysis of Alternatives

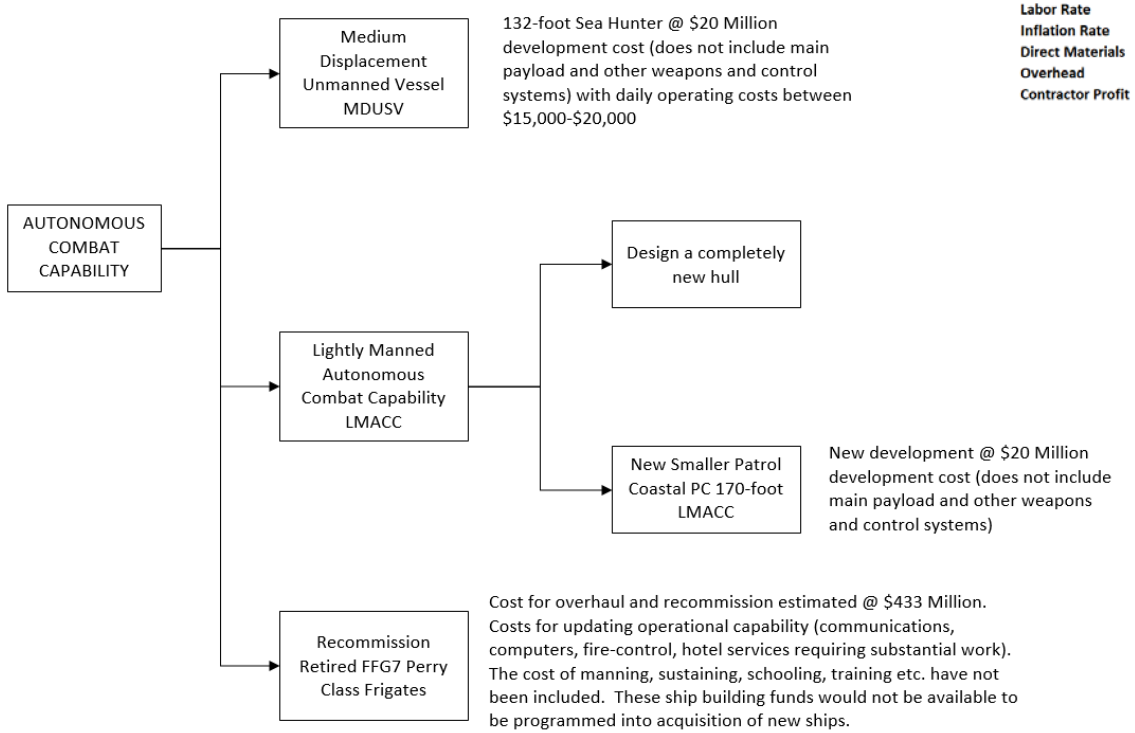
- The figures illustrates the analysis of alternatives or strategic options. Based on the pricing policy on PC 14 at the Bollinger Machine Shop and Yard, we were able to extrapolate the data for 1990 to current dollar values (2020) for patrol coastal (PC) boats. The Monte Carlo simulated cost shows a 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.

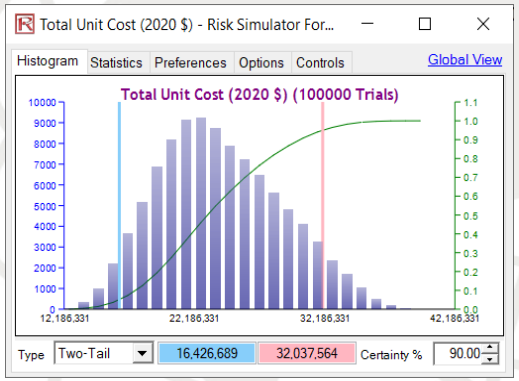
170 foot Patrol Coastal (PC) by Bollinger Shipyards

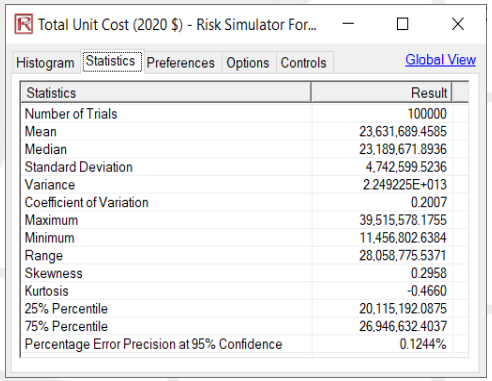
	1990	$11.42				2020	$23.06	Inflation	2.37%	
	Direct Labor		Direct Materials & Overhead		Total	Direct Labor		Direct Materials & Overhead		Total
ITEMIZATION	Hours	Dollar	Materials	Overhead		Hours	Dollar	Materials	Overhead	
Hull Structure	41,734	$476,602	$122,800	$738,733	$1,338,135	41,734	$962,359	$247,959	$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







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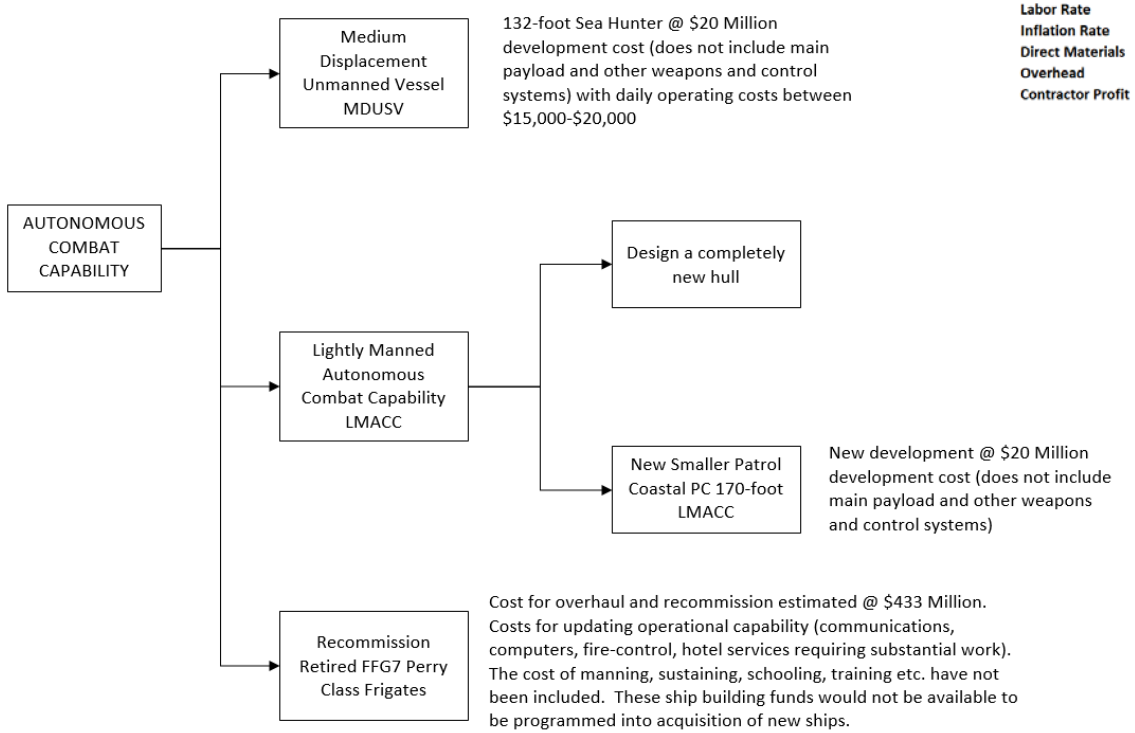
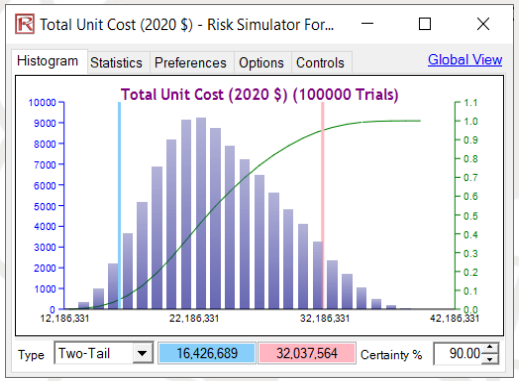
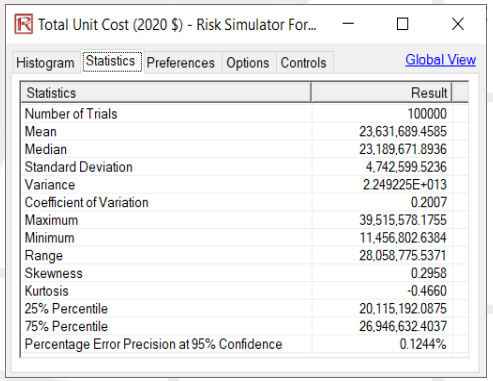
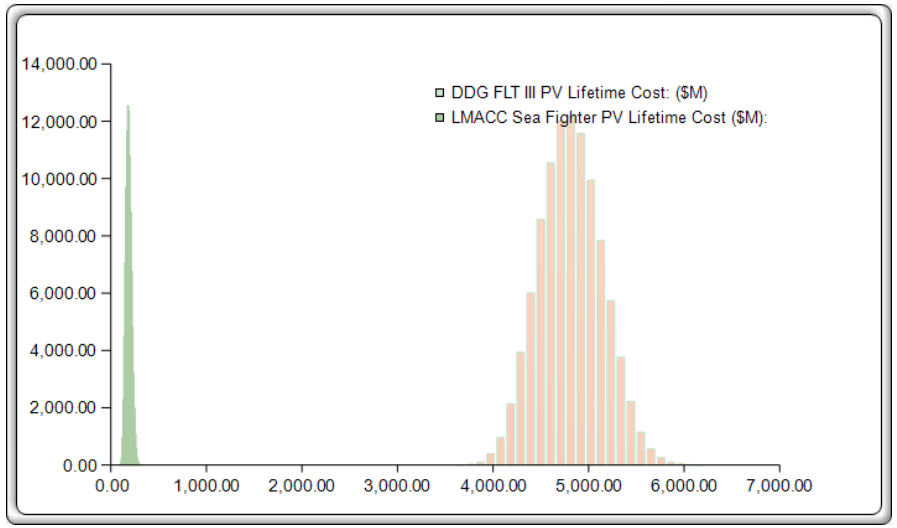






Sea Fighter Cost & Analysis of Alternatives

- 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													

Conclusions & Recommendations

- The current research is still progressing, but preliminary results show a promising trajectory with the cost savings on Sea Hunter.
- This current study is based on publicly available information and data. In addition, when necessary, rough order magnitude notional values were used and assumed. In addition, a standard hull configuration is assumed instead of specific design specifications with more detailed cost data and precise modeling.