



The Lightly Manned Autonomous Combat Capability (LMACC)

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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.



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.





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

		A	ACTUAL		ACTUAL		ACTUAL		PRELIMINARY		REQUESTED	
DDG 51 AEGIS Destrover		FY2012 Total		FY2013 Total		FY2014 Total		FY2015 Total		FY2016 Total		FY20
Procurement		QTY	Million \$	QTY	Million \$	QTY	Million \$	QTY	Million \$	QTY	Million \$	017-F) DF file
Shipbuilding & Conversion	NAVY	1	2,081.43	3	4,497.01	1	1,985.12	2	2,795.95	2	3,149.70	Y2020 s belo
Ship Modifications Completion Costs	NAVY NAVY		126.37		407.71		285.99		324.22 129.14		364.16) Bud
Outfitting & Post Delivery	NAVY		49.10		7.30		1.30		6.50		62.10	get ole -
Total Procurement		1	2,256.91	3	4,912.02	1	2,372.41	2	3,255.81	2	3,575.96	¥ ⊒a
RDT&E (Hybrid Electric Drive)	NAVY		-		- 0	and the	ALL		7.95		4.22	v ™
Total RDT&E			-		-	N 1	· · ·	~ 1	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	

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

Shipbuilding & Conversion | DDG-51 AEGIS Destroyer



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





Project Tasks (Energy Systems)

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 <u>controllable-pitch propeller</u>



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

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WBS and Global Network Diagram of Warship Building

🐹 [M:\Client Projects\Navy and Department of Defense\2016-06 Cost Estimation for Ship Building\Models\Cost Estimation Models - Draft 2.rovprojecon] - PROJECT ECONOMICS ANALYSIS TOOL – 🗌

File Edit Projects Report Tools Language Decimals Help

Welcome to the ROV Project Economics Analysis Tool (PEAT). This tool will help you set up a series of projects or capital investment options, model their cash flows, simulate their risks, and run advanced analytics, perform forecasting and prediction modeling, and optimize your investment portfolio subject to budgetary and other constraints.

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



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

			Min Unit	Aveg Unit	Max Unit		
Category	Items	Quantity	Cost	Cost	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	chin Puil	dina				
	TRADS UND GIODUI NELWOIK DIUGIUM OJ VVUM	SIIIP2DUII	UII 29 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 selfdefense 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						



Expected Project Schedule (Shipbuilding)

[M:\Client Projects\Navy and Department of Defense\2016-06 Cost Estin	mation for Ship	o Building\Mo	dels\Cost Esti	imation Model	s - Draft 2.rov	/projecon] - Pl	ROJECT	ECONOMICS	ANALYSIS TO	OL —	
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elcome to the ROV Project Economics Analysis Tool (PEAT). This tool will help you odeling, and optimize your investment portfolio subject to budgetary and other o	ı set up a series onstraints.	of projects or o	apital investm	ent options, moo	del their cash f	lows, simulate t	their risk	s, and run adva	anced analytics,	, perform forecastin	g and prediction
Project Management Applied Analytics Risk Simulation Options Strategies	Options Valuation	on Forecast Pr	ediction Das	hboard Knowle	edge Center						
Static Tornado Scenario Analysis											
Tornado or static sensitivity analysis is performed by perturbing the inputs a preset amount one at a time to determine the impact on the output variable. Start by selecting the Option and Output Variable to test, then set the sensitivity levels and click Commute to run.	🖻 🖪 é	j 🖬 - 🛛] ¢ ¢ ()))))))))))))))))))	ر چر چر (1,14 🗍 [∱ 2D	∲▼ (1)	¶t +j _{it} Abo	• 🎥 • 🥐	}
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Ship Building: Expected Project Schedule 🗸 🗸	1 1	fask 21 Time S	chedule (Wee	ks) MostLikely		45.00				55.00	
Sensitivity +/- 10 🔦 % Reset	1	Task 23 Time S	chedule (Wee	ks) MostLikely		43.20				52.80	
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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.



Recommission

Retired FFG7 Perry

Class Frigates

development cost (does not include main payload and other weapons and control systems) with daily operating costs between



Cost for overhaul and recommission estimated @ \$433 Million. Costs for updating operational capability (communications, computers, fire-control, hotel services requiring substantial work). The cost of manning, sustaining, schooling, training etc. have not been included. These ship building funds would not be available to be programmed into acquisition of new ships.

LMACC



	2.37%	Inflation	\$23.06	2020
Total	ls & Overhead	Direct Materia	Labor	Direct
	Overhead	Materials	Dollar	Hours
\$2,701,974	\$1,491,656	\$247,959	\$962,359	41,734
\$6,682,452	\$67,801	\$6,570,907	\$43,744	1,897
\$1,010,337	\$237,326	\$619,897	\$153,114	6,640
\$1,723,277	\$67,801	\$1,611,732	\$43,744	1,897
\$2,281,007	\$406,814	\$1,611,732	\$262,462	11,382
\$2,132,163	\$542,420	\$1,239,794	\$349,949	15,176
\$303,761	\$33,919	\$247,959	\$21,883	949
\$179,781	\$33,919	\$123,979	\$21,883	949
\$960,546	\$508,501	\$123,979	\$328,065	14,227

\$2,187,203 \$12,397,938 \$3,390,156 \$17,975,297 94.851 \$1,797,530 \$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

R Total U	Init Cost (2	2020 \$) - Risk	Simulato	or For	— C	X
Histogram	Statistics	Preferences	Options	Controls		Global View
10000 - 9000 - 8000 - 7000 - 6000 - 5000 - 4000 - 3000 - 2000 - 1000 - 12,186,33	Tota	al Unit Cost (2020 \$)	(100000	Trials)	1.1 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0 42,186,331
Type Two	-Tail 🔻	16,426,68	9 32	.037,564	Certainty %	90.00

listogram Statistics Preferences Options Control	s <u>Global V</u>
Statistics	Result
Number of Trials	100000
Mean	23,631,689.4585
Median	23,189,671.8936
Standard Deviation	4,742,599.5236
Variance	2.249225E+013
Coefficient of Variation	0.2007
Maximum	39,515,578,1755
Minimum	11,456,802.6384
Range	28,058,775.5371
Skewness	0.2958
Kurtosis	-0.4660
25% Percentile	20,115,192.0875
75% Percentile	26,946,632.4037
Percentage Error Precision at 95% Confidence	0.1244%

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Sea Hunter Cost & Analysis of Alternatives

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Recommission

Retired FFG7 Perry

Class Frigates

development cost (does not include main payload and other weapons and control systems) with daily operating costs between

> New development @ \$20 Million development cost (does not include Coastal PC 170-foot main payload and other weapons and control systems)

Cost for overhaul and recommission estimated @ \$433 Million. Costs for updating operational capability (communications, computers, fire-control, hotel services requiring substantial work). The cost of manning, sustaining, schooling, training etc. have not been included. These ship building funds would not be available to be programmed into acquisition of new ships.

LMACC

170 foot Patrol Coastal (PC) by Bolling	er Shipyards					
	1990	\$11.42]			
	Direc	t Labor	Direct Materia	als & Overhead	Total	
ITEMIZATION	Hours	Dollar	Materials	Overhead		
Hull Structure	41,734	\$476,602	\$122,800	\$738,733	\$1,338,135	
Propulsion Plant	1,897	\$21,664	\$3,254,200	\$33,578	\$3,309,442	
Electric Plant	6,640	\$75,829	\$307,000	\$117,534	\$500,363	
Command and Surveillance	1,897	\$21,664	\$798,200	\$33,578	\$853,442	
Auxiliary Systems	11,382	\$129,982	\$798,200	\$201,472	\$1,129,654	
Outfit and Furnishings	15,176	\$173,310	\$614,000	\$268,630	\$1,055,940	
Armament	949	\$10,838	\$122,800	\$16,798	\$150,436	
Integration and Engineering	949	\$10,838	\$61,400	\$16,798	\$89,036	
Ship Assembly and Support Services	14,227	\$162,472	\$61,400	\$251,832	\$475,704	
SUBTOTAL CONTRACTOR PROFIT @ 10% GRAND TOTAL UNIT PRICE	94,851	\$1,083,198	\$6,140,000	\$1,678,953	\$8,902,151 \$890,215 \$9,792,367	
	Min	Likely	Max	Simulation	40,002,000	
Manhours	65,000	94,851	125,000	94,851		
Labor Rate	\$13.11	\$23.06	\$47.97	\$23.06		As
Inflation Rate	0.46%	2.37%	4.90%	2.37%		Co
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	t for Ship Only (2	020 Dollars)	\$19,772,827		
Total 0	Unit Cost (2020	\$) - Risk Simulato	or For —		E	🕄 Total U
Histogram	Statistics Pref	erences Options	Controls	Global View	н	listogram
10000 -	Total Un	it Cost (2020 \$)	(100000 Trials)	c 1.1		Statistics

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R Total U	Init Cost (2	2020 \$) - Risk	Simulate	or For	- 1	
Histogram	Statistics	Preferences	Options	Controls		Global View
10000 9000 - 8000 - 7000 - 6000 - 5000 - 4000 - 3000 - 2000 - 1000 - 12.186,33	Tota	al Unit Cost (2020 \$)	(100000	Trials)	1.1 - 1.0 - 0.9 - 0.8 - 0.7 - 0.6 - 0.6 - 0.4 - 0.3 - 0.2 - 0.1 - 0.0 - 0.1 - 0.0 - 0.1 - 0.0 - 0.2 - 0.1 - 0.0 - 0.1 - 0.0 - 0.1 - 0.1 - 0.2 - 0.1 - 0.5 - 0.1 - 0.5 - 0.1 - 0.5 - 0.5 - 0.1 - 0.1 - 0.5 - 0.1 - 0.1 - 0.5 - 0.1 - 0.1 - 0.1 - 0.5 - 0.1 - 0.0 - 0.0 - 0.0 - 0.1 - 0.0 - 0.
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25% Percentile	20,115,192.0875			
75% Percentile	26,946,632,4037			
Percentage Error Precision at 95% Confidence	0.1244%			

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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												



- 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.