Littoral Combat Ships

Relating Performance to Mission Package Inventories, Homeports, and Installation Sites

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Summary

In June 2005, workers at the Marinette Marine shipyard in Marinette, Wisconsin, laid the keel for the *USS Freedom*, the Navy's first Littoral Combat Ship.[1] The LCS constitutes a new class of fast, agile, and networked warships designed to overcome threats in shallow waters posed by mines, diesel-electric submarines, fast-attack craft, and fast inshore attack craft.

LCSs will be key components in a proposed family of next-generation surface combatants that also includes the much larger DDG-1000 destroyer and a future CG(X) cruiser.[2] LCSs will be able to deploy independently to overseas littoral regions; remain on station for extended periods of time, either with a carrier strike group or an expeditionary strike group or through a forward-basing arrangement; operate independently and/or with other LCS units; and be replenished while under way.

LCSs: Transformational Capabilities and Modular Mission Packages

LCSs will bring an array of transformational capabilities to the Navy. Able to achieve speeds of 40 to 50 knots and maneuver in waters less than 20 feet deep, LCSs will operate in environments where employ-

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1 The *Freedom*'s keel was laid and authenticated on June 2, 2005 ("Keel Laid," 2005).

2 The DDG-1000 was formerly named DD(X). See Fein, 2006. In addition, there is also considerable interest in LCS modules for future U.S. Coast Guard applications as part of the service's Integrated Deepwater System.

ing larger, multimission ships would be infeasible or ill-advised. They will be networked into the fleet, operating as part of a distributed force; sharing tactical information with other Navy aircraft, ships, submarines, and joint units; and launching manned and unmanned vehicles to execute missions. They will incorporate advanced technologies, employing cost optimized advanced weapons; sensors; data fusion; command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems; hull forms; propulsion systems; manning concepts; smart control systems; and self-defense systems (U.S. Navy Littoral Combat Ship Web site, not dated).

But perhaps the most transformational features of LCSs will be their modular capabilities. Plans call for *Freedom* and each subsequent LCS to consist of two elements:

- a core seaframe that includes the ship platform and inherent combatant capabilities. Each seaframe will be able to perform a set of primary functions—including self-defense, navigation, C4I, and launching and retrieving unmanned vehicles—that will be common to all missions.
- a set of interchangeable modular "plug-and-fight" mission packages that will allow the ship to be reconfigured, as needed, for antisubmarine warfare (ASW), mine warfare (MIW), or surface warfare (SUW) missions. A mission package may consist of a combination of mission modules, such as manned and unmanned vehicles, deployable sensors, and mission manning detachments. The components of a mission module predominantly fit inside several standard-size 20-foot cargo containers.[3] The mission modules will integrate into the seaframe, and any LCS can hold any mission package.[4] An LCS can be reconfigured with a new mission package in a few days while laying pier side.

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3 Standard 20-foot cargo containers measure 20 feet in length, 8 feet in width, and 8.5 feet in height. A standardized form factor is designed to allow them to be loaded on ships, trucks, and railroad cars.

4 Our study assumed that all seaframes could operate with all mission packages, which was consistent with U.S. Navy planning at the time of the study. However, it is probable that

At the time of the study, Navy plans included acquisition of one seaframe in fiscal year (FY) 2005, an additional seaframe in FY 2006, two seaframes in FY 2007, and three in FY 2008, after which the Navy would begin acquiring five a year.[5] At that pace, the short-term inventory of seaframes could reach 36 by FY 2014, the middle-term inventory of seaframes could reach 60 by FY 2019, and the long-term inventory of seaframes could reach 84 by FY 2024.

Issues We Addressed

In early 2005, RAND was commissioned by the LCS Program Office[6] to help it think through the cost and logistics implications of modular mission packages planned for the LCSs. In particular, the LCS Program Office was interested in gaining a clearer understanding of operational, logistics, and cost trade-offs between three interdependent elements of the program: the number of LCSs in the fleet, the number of mission packages[7] that those LCSs would require to perform a range of missions, and the number of and the locations of LCS homeports and mission package installation sites.

Methods and Data We Used

RAND analyzed these issues between January and November 2005, employing both qualitative and quantitative methodologies to examine

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there will be upgrades and modernization efforts that may pose challenges for maintaining compatibility.

5 After the conclusion of the study, the Quadrennial Defense Review recommended an increase in the Navy's annual procurement of LCSs. Francis, 2006, indicates up to six ships per year from 2009 through 2011, for a total of 55 through 2029. See also Cava, 2006.

6 The official name of our sponsor is PMS 501, LCS Program Office.

7 Aviation assets were assumed to be collocated with other mission package components for the purposes of this analysis. The scope of this project did not allow for evaluation of the number of aviation assets separately from mission packages.

the LCS fleet at three discrete points in the future: the short term (by 2014), middle term (by 2019), and long term (by 2024).

Qualitative Analyses: Scenarios and LCS Employment Options

To gain an understanding of what the LCS fleet might encounter over the short, middle, and long term, we examined the LCS concept of operations (LCS CONOPS) (U.S. Navy, 2004) in conjunction with the strategic environment laid out in the 2005 National Defense Strategy and amplified in various U.S. Navy documents (U.S. Navy, 2003 and 2005).[8] This research led to various scenarios in which the ships might be expected to play a part through 2024. Every scenario that we evaluated involved a simultaneous operation from each of the following four categories:

- *Major Combat Operations (MCOs)*—for example, responding to a crisis in the Western Pacific, Southwest Asia, or Northeast Asia.
- *Global War on Terrorism Operations*—for example, responding to a chemical weapons attack on UN forces, clearing mines laid by terrorists in sea lanes, or eliminating terrorist training camps.
- *Stability Operations*—for example, providing humanitarian assistance and disaster relief, supporting a friendly government against insurgents, providing maritime security for oil platforms, providing forward presence and maritime interdiction operations in the vicinity of shipping lanes, or participating in ASW exercises/submarine tracking.
- *Homeland Defense Operations*—for example, providing security and humanitarian assistance/disaster relief following terrorist attacks on U.S. seaports, providing security and humanitarian assistance/disaster relief following a natural disaster along the U.S. seaboard, or providing humanitarian assistance following a refugee crisis in the Caribbean.

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8 Our specific terms mirror "The Evolving Strategic Environment" as shown in Figure 1 of U.S. Navy, 2005.

We also examined how the Navy plans to use LCSs. The LCS CONOPS describes plans for the Navy to embed LCSs in carrier strike groups or expeditionary strike groups, to deploy them independently, or to operate them as forward deployed units. Using these deployment concepts and potential threat characteristics, we evaluated ways in which the Navy might employ LCSs in the context of each scenario. This allowed us to develop baseline LCS requirements, including expected modes of employment, operating locations, and mission tasking.

Quantitative Analyses: Transit, Logistics, and Cost Modeling

Once we had analyzed the scenarios that LCS might encounter and the ways that the Navy plans to use the vessels, we turned to our quantitative analyses. As a first step, we derived measures of effectiveness for the LCS. Because a key capability of the LCS is its ability to respond quickly to a crisis, we used the time required for all LCSs to close on the theaters of operation as our principal measure of effectiveness—we term this metric "total closure time."[9] We also derived other metrics—the number of LCS days spent in the littoral region of an area of operation in advance of a strike group, the time it takes for each LCS to arrive on station, the time it takes for each strike group to arrive on station, the number of mission package reconfigurations by type and geographic location, and the number of refueling-at-sea operations required by each LCS to reach theaters of operation.

Once we had derived metrics, we developed a series of analytical tools to evaluate them. These tools allowed us to make trade-offs among different numbers of mission packages for the proposed number of LCSs and the locations of LCS homeports and mission package installation sites.[10]

The main analytical tool that we developed was a model that we called the LCS Transshipment Model (LCSTSM). Derived from a

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[9] Our analytical framework allows prioritization of closure time for LCSs in different operations; we treated them all with equal priority for this study rather than making assumptions on the future priorities of government decisionmakers.

[10] We assume that homeports include a mission package installation site.

well-known class of transshipment models, the LCSTSM enabled us to depict how the LCS would perform under a variety of assumptions. Other models that we developed allowed us to estimate the costs of procuring seaframes and mission packages and of constructing LCS homeports and installation site facilities.

Using the LCSTSM, we varied operational and logistics elements of the LCS, including

- the number of seaframes
- the number of mission packages
- the locations of homeports
- the locations of installation sites.

We then ran multiple computer simulations with randomly selected scenarios, locations from which LCSs would start their missions, and differing availability of assets. These simulations yielded the metrics. We examined how the average values of those metrics were affected by varying the operational and logistical elements. This information allowed us to identify the optimal locations for homeports and installation sites and the optimal sizes for mission package inventories. We then used our cost models to estimate annual and total costs to procure those mission package inventories and construct homeports and installation sites.

Preferred Homeports and Installation Sites

We analyzed 15 locations around the world as potential LCS homeports or installation sites.[11] Using the LCSTSM, we tested those locations across a range of scenarios and mission package inventories to determine the sites that LCSs would most frequently visit to install or swap mission packages in the short, middle, and long term.

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[11] Bahrain; Darwin and Fremantle, Australia; Diego Garcia; Guam; Japan; Mayport, Norfolk, Pascagoula, San Diego, and Hawaii in the United States; the western and eastern Mediterranean; Puerto Rico; and Singapore. We assume that an LCS homeport includes a mission package installation site.

We found that 3 of the 15 locations were best supported as homeports by our analysis in all three time frames—Norfolk, San Diego, and Japan—and two as mission package installation sites—Singapore and Bahrain.[12]

Preferred LCS Mission Package Inventories

We used the three preferred locations for LCS homeports and the two preferred locations for installation sites to help calculate the best LCS mission package inventories in the short, medium, and long term. We employed a three-step process to make this calculation. For each time frame, we

- evaluated the average proportion of each LCS mission package type that the Navy would need to meet scenario demands
- estimated the minimum number of each LCS mission package type that the Navy needs to optimize total closure time
- determined the quantities of each LCS mission package type that the Navy will need at each preferred location.

The results of this mission package inventory analysis are summarized in Table S.1, which shows the number of ASW, MIW, and SUW missions package inventories identified by our analysis for each time period.

Summing the mission package quantities listed in Table S.1 by type, we see that our analysis suggests the Navy will need a total of 89 mission packages in the short term, 104 in the middle term, and 126 in the long term to meet scenario needs with minimal closure time across the LCS fleet.

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12 The political sensitivities and space limitations for an installation site in Bahrain may be more significant than anticipated during the course of our study. A reexamination of this prospect was outside the scope of our charter. However, we would hypothesize that a location in the eastern or central Mediterranean might provide a suitable alternative. This hypothesis is supported by excursions discussed in this monograph, but it should be examined more carefully.

Table S.1
Mission Package Inventories in the Short Term, Middle Term, and Long Term

Time Period	ASW	MIW	SUW
Short term (by 2014)	20	27	42
Middle term (by 2019)	23	31	50
Long term (by 2024)	28	38	60

NOTES: Inventory levels depend on the operational availability, which is defined as the fraction of time that mission packages are available for mission use. Operational availability estimates for mission packages were not available at the time of this study. The inventory levels in this table assume that the operational availability of mission packages is 0.9. The numbers will need to be adjusted for different estimates of operational availability. For instance, if the operational availability is estimated to be x, then each number in the table should be multiplied by $0.9/x$.

Preferred LCS Mission Package Storage Locations

Our analysis also identified the number of mission packages in inventory to be stored on available seaframes, at each homeport, and at each installation site in each time period. Table S.2 lists the inventories by location for the short term, Table S.3 for the middle term, and Table S.4 for the long term.

Total Procurement Cost for LCS Seaframes, Mission Packages, and Facility Construction

We estimated the total procurement costs for seaframes, vertical takeoff unmanned aerial vehicles (VTUAVs), mission packages, and the costs of constructing homeports and installation site facilities. To make these estimations, we took a look at the significant costs involved in trading the alternatives under study rather than taking a complete life-cycle cost or total-ownership cost approach.

Table S.2
Number of Mission Packages, by Type, Stored on Available Seaframes, at Homeports, and at Installation Sites in the Short Term (by 2014)

Location	ASW Mission Packages	MIW Mission Packages	SUW Mission Packages
Available seaframes	5	8	12
San Diego	3	2	3
Norfolk	2	4	12
Bahrain	2	2	6
Singapore	4	7	6
Japan	4	4	3
Total	20	27	42

Table S.3
Number of Mission Packages, by Type, Stored on Available Seaframes, at Homeports, and at Installation Sites in the Middle Term (by 2019)

Location	ASW Mission Packages	MIW Mission Packages	SUW Mission Packages
Available seaframes	9	12	21
San Diego	2	4	10
Norfolk	1	5	5
Bahrain	3	4	1
Singapore	4	3	5
Japan	4	3	8
Total	23	31	50

The results of our simplified cost estimates for the short term, middle term, and long term are shown in Table S.5. Procurement and construction costs would be $13.8 billion in the short term, $20.7 billion the middle term, and $27.3 billion in the long term, expressed in FY 2004 dollars.

Table S.4
Number of Mission Packages, by Type, Stored on Available Seaframes, at Homeports, and at Installation Sites in the Long Term (by 2024)

Location	ASW Mission Packages	MIW Mission Packages	SUW Mission Packages
Available seaframes	13	18	29
San Diego	2	2	13
Norfolk	0[a]	5	4
Bahrain	4	5	2
Singapore	4	4	4
Japan	5	4	8
Total	28	38	60

[a] Observe that our results suggest that no ASW mission packages are stored ashore in Norfolk. Care should be taken in interpreting this result. It does not imply that no ASW mission packages are available to LCSs in Norfolk, since they may be stored aboard available seaframes. Other considerations, such as training needs, should be taken into account when determining if a small number of ASW mission packages should be stored ashore in Norfolk.

LCS Performance With Our Recommended Inventories and Locations

How well would the LCS perform with the recommended inventories of mission packages in the short, middle, and long term, assuming the preferred locations for homeports and installation sites? The results are shown in Figure S.1.

Using the performance metrics that we described above, the figure shows that the average total closure time would be 43 days in the short term, 26 days in the middle term, and 23 days in the long term. The number of LCS days in the littoral would increase from about nine in the short term, to 17 in the middle term, to 23 in the long term.[13] The

[13] The number of LCS days in the littoral is defined as the sum of the days spent by each LCS in the littoral region of the area of operation in advance of the arrival of a carrier or expeditionary strike group.

Table S.5
Estimated Cumulative Procurement and Facilities Construction Costs for the Short Term, Middle Term, and Long Term

	Cost (billions of 2004 dollars)		
Item	**Short Term**	**Middle Term**	**Long Term**
Seaframes	\$8.00	\$13.2	\$18.3
Mission packages	\$4.56	\$5.50[a]	\$6.34
VTUAVs	\$1.07	\$1.75	\$2.42
Construction of facilities (includes Singapore security personnel)	\$0.183	\$0.199[b]	\$0.210
Total	\$13.81	\$20.65	\$27.27

NOTE: Totals may not sum because of rounding.

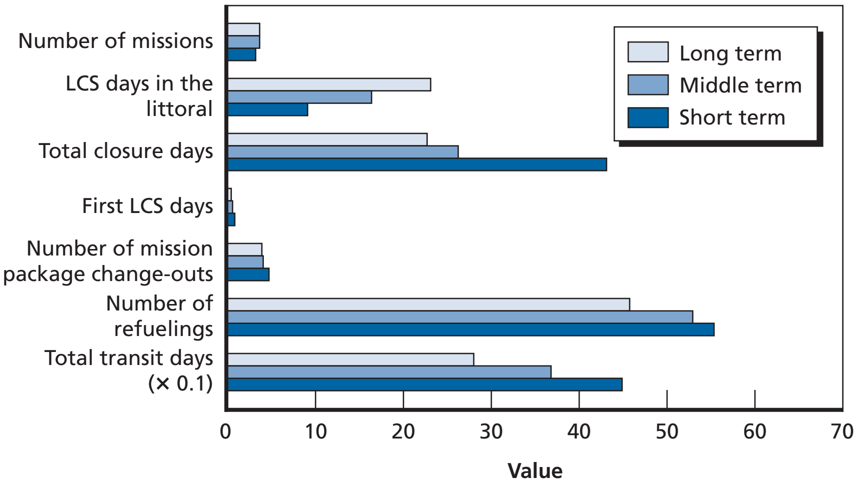
[a] More mission packages than required are purchased to maintain the production base along the way to the long-term case. The estimate for only those mission packages indicated by the transportation model is \$5.2 billion in FY 2004 dollars.

[b] This is the short-term cost incremented to reflect additional mission package storage requirements. Some sites (such as Norfolk) will have excess capacity.

figure also shows that the number of underway refueling operations would decrease in transitioning from the short to middle to long term, as does the total number of transit days.

We note from Figure S.1 that the marginal improvement in total closure days is significant between the short and middle term, but less significant between the middle and long term. That is, there are diminishing returns on the improvement in total closure days as the number of LCSs in the fleet increases. On the other hand, the marginal improvement in LCS days in the littoral is fairly linear between the short, middle, and long term. We also note from Figure S.1 the very high number of refuelings required by LCSs while under way. Although it was beyond the charter of our study to determine means of refueling LCSs, our results highlight the refueling issue and the need to align fleet logistics with LCS CONOPS.

Figure S.1
Performance Metrics for Short-, Middle-, and Long-Term Solutions



NOTES: The metric values for the middle term and long term assume scenarios involving one MCO simultaneously occurring with three non-MCOs. There is an insufficient number of LCSs in the short term to satisfy scenarios involving one MCO simultaneously occurring with three non-MCOs. The metric values for the short term assume scenarios involving one MCO simultaneously occurring with an average of 2.4 non-MCOs.

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