

# NAVAL POSTGRADUATE SCHOOL

## Monterey, California



## CROSSBOW REPORT

### CROSSBOW EXECUTIVE SUMMARY

by

The System Engineering & Integration Curriculum

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<b>13. ABSTRACT (maximum 200 words)</b>  Distributing naval combat power into many small ships and unmanned air vehicles that capitalize on emerging technology offers a transformational way to think about naval combat in the littorals in the 2020 timeframe. Project CROSSBOW is an engineered system of systems that proposes to use such distributed forces to provide forward presence, to gain and maintain access, to provide sea control, and to project combat power in the littoral regions of the world.  Project CROSSBOW is the result of a yearlong, campus-wide, integrated research systems engineering effort involving 40 student researchers and 15 supervising faculty members. This report (Volume I) summarizes the CROSSBOW project. It catalogs the major features of each of the components, and includes by reference a separate volume for each of the major systems (ships, aircraft, and logistics). It also presents the results of the mission and campaign analyses that informed the trade-offs between these components. It describes certain functions of CROSSBOW in detail through specialized supporting studies.  The student work presented here is technologically feasible, integrated, and imaginative. This student project cannot by itself provide definitive designs or analyses covering such a broad topic. It does strongly suggest that the underlying concepts have merit and deserve further serious study by the Navy as it transforms itself.				
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## **I. EXECUTIVE SUMMARY**

***CROSSBOW: A high-speed, rapidly deployable, integrated and distributed naval force with a primary mission of forward presence, littoral sea control, forced access, and access maintenance, in low to moderate threat environments around the globe. CROSSBOW is capable of augmenting and enhancing carrier battle group operations in high threat environments.***

The Naval Postgraduate School (NPS) CROSSBOW Report consists of five volumes, of which this is the first. Volume I is a product of the Systems Engineering and Integration (SEI) curriculum. It integrates and summarizes CROSSBOW's elements and missions and provides conclusions and recommendations. Volume II, a product of the Total Ship Systems Engineering (TSSE) capstone design course, provides a detailed report of the SEA ARCHER ship design. Volume III, a product of the Aeronautics and Astronautics Department's capstone design course, is a detailed report of the SEA ARROW aircraft design. Volume IV, a product of the NPS Graduate School of Business and Public Policy, provides a CROSSBOW logistics framework. Finally, Volume V is a repository for the SEI CROSSBOW Specialized Supporting Studies, as well as various background material and references.

### **A. Background**

The CROSSBOW project took shape at the Naval Postgraduate School (NPS) in response to an enquiry by the President of the Naval War College (NWC) in October 2000. The central intent was to investigate the extent to which new technology and a changing world should cause us to rethink the relative merits of dispersion versus concentration and attendant economies of scale. Specifically, he proposed studies to determine the feasibility of, and potential for, the "Corsair" -- a very small, high-speed<sup>1</sup> aircraft carrier concept for distributed operations in littoral waters. The NWC had

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<sup>1</sup> A 60-knot speed objective was imposed upon the team at the onset of the project. In the course of the study it became evident that the 60-knot objective had serious implications on ship design and cost, apparently without commensurate tactical benefit. Additional design iterations looking at a 40-50 knot range were not possible, given academic time constraints.

developed and outlined the notional concept that featured high-speed aircraft carriers as a complement to large carriers with an emphasis on obtaining access when opposed in littoral waters. Each Corsair would operate approximately 7 Joint Strike Fighters (JSF) and 2 helicopters. NPS students and faculty were given wide latitude in the conduct of the study. It is important to note that there was no specific mission need provided. Guidance given to the students was to take a hard-nosed, skeptical look at the possible capabilities.

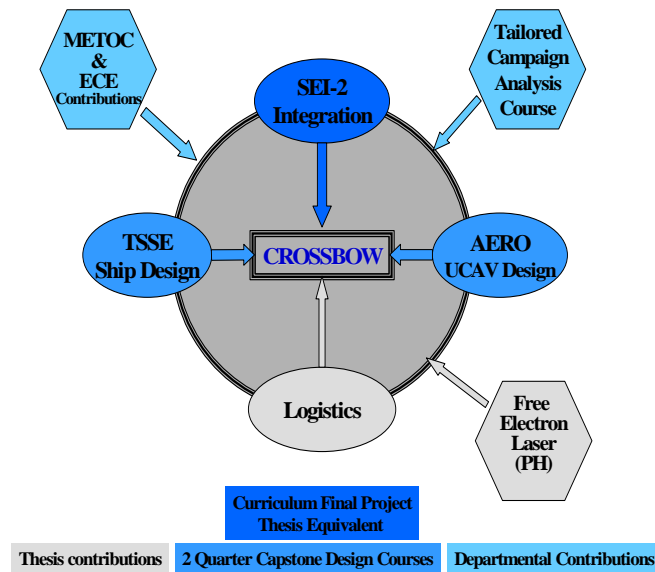
An exploratory study of this breadth required a level of interdisciplinary collaboration not previously attempted at NPS, and not possible without recent curriculum and organizational changes. However, project planning for the yearlong study was constrained by existing schedules for the ship and aircraft capstone design classes and by faculty availability, thereby resulting in some academic artificialities.

NPS elements contributing to the project are presented in Figure 1. The second cohort of students enrolled in the Systems Engineering and Integration (SEI) Curriculum were assigned CROSSBOW as their integration project. Students in the Total Ship Systems Engineering (TSSE) Capstone Ship Design Courses constituted the ship design team. The Capstone Aircraft Design Courses provided the air vehicle design team.

Students from the Graduate School of Business and Public Policy produced a thesis on the requirements and cost of CROSSBOW logistics and maintenance. Another contributing thesis explored a free electron lasers as “electric warship” weapons. In addition, the Operations Research Department tailored an existing campaign analysis course for the express purpose of evaluating a notional CROSSBOW force in scenarios representing the full spectrum of conflict. Also, the project benefited greatly from expertise and advice provided by the Electrical and Computer Engineering Department, as well as the Meteorology and Oceanography Department.

Allied officers made significant contributions to the CROSSBOW effort. Eight of the fifteen SEI-2 students were combat officers from the Singapore Armed Forces. The eleven members of the ship design team included two naval officers from Turkey, one MOD civilian from Singapore and one naval officer from Greece. Finally, senior naval leadership, Navy and government laboratories, and industry visitors provided valuable insights and inputs.

Figure 1: CROSSBOW Project Organization



## B. Considerations

We learned the following in the process of defining the CROSSBOW force.

- (1) CROSSBOW is not a suitable candidate to replace a Carrier Battle Group (CVBG);
- (2) CROSSBOW platforms are best designed as “combat consumables”<sup>2</sup>, austere manned, intended for short duration cyclic operations, and whose loss can be sustained without catastrophic degradation of mission capability;
- (3) The force was structured to best advantage as a high-speed, distributed force exploiting advances in Network Centric Warfare and distributed logistics;
- (4) As such, it had significant potential for independent operations that contribute to the Navy’s global capabilities.

For study purposes, ship and aircraft designs were limited by a 2012 technology maturation date. However, less integrated subsystems and weapon design concepts used a maturation date of 2020. As the centerpiece of the CROSSBOW force, students chose

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<sup>2</sup> A term introduced to us by VADM Cebrowski.



a high-speed ship design that supports an air wing comprised primarily of Unmanned Air Vehicles (UAVs). This was done for the following reasons.

- (1) Such a CROSSBOW force was thought to be more affordable;
- (2) A force like this had not yet been seriously studied;
- (3) Such a force concept is clearly dissimilar to current CVBGs;
- (4) Such a force, combined with maturing UAV technology, would be a significant move toward unmanned naval flight operations.

The United States Navy has recently begun to explore seriously the concept of a small, distributed littoral surface combatant, first referred to as Street Fighter and now known as SEA LANCE<sup>3</sup>. The original concept lacked organic air cover and a viable scouting capability, both of which are critical for mission success<sup>4</sup>. The CROSSBOW force we defined combines a SEA LANCE variant, called SEA LANCE II, with SEA ARCHER, a small, high-speed aircraft carrier (or UAV Tactical Support Ship)<sup>5</sup>, and SEA QUIVER, a notional high-speed support ship. The SEA ARCHER air wing is comprised of 8 multi-mission SEA ARROW Unmanned Combat Air Vehicles (UCAVs), 8 support UAVs with multi-mission capabilities, and 2 MH-60 multi-mission helicopters.

### C. Why Force Distribution?<sup>6</sup>

Analytical results obtained from the quantitative analyses shown in Volume V indicate that distribution of offensive and defensive power offers the following advantages in general:

- increased force effectiveness;<sup>7</sup>

<sup>3</sup> The technical report for SEA LANCE is available at <http://web.nps.navy.mil/~me/tsse/files/2000.htm>

<sup>4</sup> These issues were discovered during our campaign analyses, presented in Volume V.

<sup>5</sup> "Small aircraft carrier" may not be an appropriate description for SEA ARCHER. Reasonable people might well prefer "UAV Tactical Support Ship", which perhaps, better describes the platform. However, for the purposes of this report, "small aircraft carrier", "small high-speed aircraft carrier", and "UAV Tactical Support Ship" are all synonymous descriptions of SEA ARCHER.

<sup>6</sup> "An Analysis of Distributed Combat Systems"- Keith, Jude, Ho; A CROSSBOW Specialized Supporting Study, December 2001. See Volume V.

<sup>7</sup> In an experiment conducted and documented in volume V, it was found that a fleet that has all of its offensive assets on board a few large ships is consistently outperformed by a fleet possessing the same amount of offensive assets that are distributed among many smaller ships; where performance is measured by the number of own and enemy ships that are put out of action. Note that this analysis compares only combat effectiveness without any consideration of cost.

- flexibility to act in more places at the same time;
- denial of the enemy's opportunity to exercise concentration of firepower;
- increased robustness of a fleet in that the fleet still maintains a significant portion of its original capabilities even after sustaining predictable losses;
- increased robustness and connectivity given a distributed command and control architecture;
- increased requirement for enemy surveillance to detect the distributed fleet and complication of the enemy's acquisition and targeting problem;
- increased flexibility in fleet composition to meet a variety of mission requirements.

Distribution also allows the fleet the opportunity to employ numerous small ships to carry its firepower. A distributed fleet of small ships provides a number of inherent advantages, among which are the following.

- Small ships are inherently more defensible by soft kill defenses because of their size.
- Small, powerfully armed ships are suitable for high-risk missions, sanitizing dangerous waters for high-value ships.
- An increased number of combatants allows for faster searches and more accurate situational updates, particularly in the littorals.

Though those advantages are important, the logistical and communication support required for a distributed force are more complex. A distributed fleet's main advantage lies in its apparent lack of a single point of failure. Hence, the logistical, communications, or any other part of the distributed fleet's support must not provide single points of failure. Otherwise the benefits of distribution are reduced, if not negated. A distributed fleet hence loses 'economy of scale' benefits.

## **D. Missions**

### ***a. Forward Presence***

The changing political climate places increased international demands on the United States, and there has been a growing demand for naval involvement in Military Operations Other Than War (MOOTW) and Small Scale Conflicts (SSC). This has increased the Navy's operational tempo and placed great strain on naval forces. Commanders-in-Chiefs (CINCs) of the Unified Commands all desire a higher level of presence in their respective theaters than the Navy can provide today.

CROSSBOW can be an effective independent and enabling force in areas of low to moderate threat where demands for firepower and operational coverage do not require the full-time presence of a Carrier Battle Group (CVBG). CROSSBOW's distributed nature and speed can relieve some of the unfilled CINC operational commitments while expanding the Navy's area of influence to additional regions of national interest.

***b. Littoral Operations***

Littoral operations constitute a fundamental task in the successful execution of the Navy's maritime strategy as articulated in *Operational Maneuver From The Sea* and *Forward From The Sea*. The littoral is defined in the CROSSBOW context as a region 100nm from shore and 100nm inland. This region is often cluttered with heavy coastal shipping and fishing traffic; intense air traffic; oil rigs; small islands; shallow water influences; many sources of electronic radiation from land and sea (commercial and military); and a wide variety of threats from land, sea and air. These characteristics all have adverse implications for naval operations. However, demographic trends indicate that 90% of the world's population will be concentrated in littoral regions by 2025. Also, as numbers of US overseas bases continue to decrease, the littorals will be the main means of access into a crisis area.

***c. Access and Escalation***

Forcible littoral access requires combat capabilities and power projection superior to the denial capabilities of the opponent. In contrast, the nearly continuous presence of a credible naval force in an area of national interest enables the more desirable situation of access maintenance, thus reducing or avoiding the additional combat power needed to gain access. Maintaining access is a means of deterrence.

Moreover, if deterrence fails, CROSSBOW also provides a means of first response to an attack and improves prospects for escalation control. It is not always in the national interest to destroy completely a belligerent's defensive capability and communications infrastructure. If this can be avoided, then postwar rebuilding and stabilization tasks may well be less expensive and completed more promptly.

Presence, deterrence and escalation control are military missions that require anticipatory force deployments. Forces performing these missions will frequently

participate in small-scale exercises with allied nations, and operate independently near-shore for extended periods. Under low to moderate threat conditions, naval forces like CROSSBOW are well suited for these tasks.

*d. Complementing the Carrier Battle Group*

The CVBG remains the force of choice to provide maritime dominance in the oceans of the world and to project power ashore. It is also capable of effectively operating in the littorals, as are Amphibious Ready Group (ARGs). However, the number and complexity of low to moderate threat regions, the increasing need to engage and exercise with smaller allied navies, and the projected asymmetric threat indicate an operational niche for a naval force structured specifically for littoral operations. This niche, plus progress in technologies associated with unmanned vehicle and other forms of automation, points to CROSSBOW.<sup>8</sup>

Although designed to operate independently in low to moderate threat environments, CROSSBOW can also complement the CVBG during theater war. CROSSBOW can tackle many of the dull, dirty and dangerous missions in order to help prepare the littoral battle-space for follow-on operations. It can be used to clear out and identify coastal “clutter” and eliminate significant numbers of tactical targets in the littoral, freeing CVBG forces to focus on deep strike, and more challenging targets. In summary, CROSSBOW provides the “stunning” jab, while the CVBG delivers the “knockout” punch.

CROSSBOW may also be employed during theater war to provide relief in place for CVBG forces moving from regions of significant national interest to the higher threat region of theater war.

*e. CROSSBOW Lethality*

CROSSBOW operates with 20 SEA LANCE II small combatants and eight distributed SEA ARCHERS. CROSSBOW conducts coordinated and simultaneous air operations and can either rapidly launch one large pulse of airborne combat vehicles

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<sup>8</sup>. This littoral force for low to moderate threats can potentially account for only 10-15% of the future naval force but provide major new capabilities in the missions above. Verbal comments by CAPT Wayne Hughes, USN (Ret) - 8 Nov 2001.

on a wide range of missions or many small to medium packages launched around the clock.

The force brings the following to the fight:<sup>9</sup>

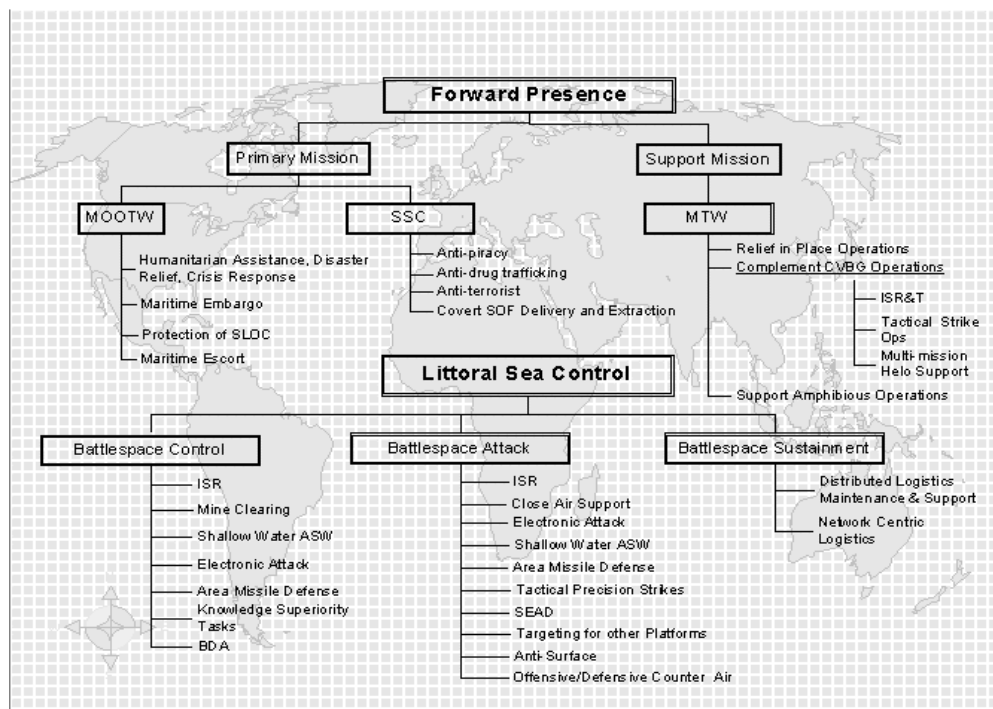
- 1020 x VLS Tubes (small 15-25nm Standard Missile variant)
- 80 x Ship Launched HARPOON Missiles
- 1024 x Small Smart Bombs (per day –all SEA ARROWS dedicated)
- 768 x Air-to Surface Missiles (per day –all SEA ARROWS dedicated)
- 512 x HARM circa 2020 (per day –all SEA ARROWS dedicated)
- 200 x ASROC (assumes 10 per SEA LANCE II)

This is a very significant amount of lethality, roughly comparable to that of a CVBG but for only a single pulse.

#### *f. CROSSBOW Missions Summary*

A summary of CROSSBOW missions, organized by conflict type, is presented below in Figure 2.

Figure 2. CROSSBOW Missions



<sup>9</sup> SEA ARCHER magazine capacity not considered – these are maximum numbers for the force for each type of munition. Trades between capabilities will need to be conducted based on specific mission and threat.

**Table 1. CROSSBOW COST ESTIMATE**

<b>Total Acquisition and Operating and Support Cost (FY02 \$M)</b>					
<b>Acquisition</b>					
	# in Squadron	<u>Price Each</u>		<u>Total</u>	
		From	To	From	To
Sea Archer	8	\$763	\$924	\$6,104	\$7,392
Sea Quiver	2	\$197	\$197	\$394	\$394
Sea Lance	20	\$72	\$80	\$1,440	\$1,600
Sea Arrow	64	\$11	\$11	\$672	\$672
Helicopters	16	\$23	\$23	\$368	\$368
UAVs	64	\$8	\$8	\$498	\$498
<b>Total Acquisition Cost</b>				<b>\$9,475.92</b>	<b>\$10,923.92</b>
<b>Operating and Support</b>					
		<u>O&amp;S Each</u>			
		From	To		
Sea Archer	8	\$24.00	\$28.00	\$192.00	\$224.00
Sea Quiver	2	\$29.00	\$29.00	\$58.00	\$58.00
Sea Lance	20	\$1.80	\$1.80	\$36.00	\$36.00
Sea Arrow	64	\$0.09	\$0.09	\$5.63	\$5.63
Helicopters	16	\$1.70	\$1.70	\$27.20	\$27.20
UAVs	64			\$0.00	\$0.00
UAV O&S Cost Consolidated with Acquisition					
<b>Total Annual O&amp;S Costs</b>				<b>\$318.83</b>	<b>\$350.83</b>
<b>Total Life-Cycle Costs</b>					
<b>Total Life-Cycle Costs</b>				<b>\$15,852.56</b>	<b>\$17,940.56</b>
<b>Annualized LCC (20 Yrs)</b>				<b>\$792.63</b>	<b>\$897.03</b>

Source: A. Brent Carroll, *CROSSBOW Cost Estimation*, Specialized Supporting Study in Volume V of this report.

#### **E. Crossbow Cost Estimate**

Estimates of the costs to acquire operate and support a CROSSBOW force of 32 ships and 144 aircraft are presented in Table 1. Although varying degrees of confidence were achieved with the six different models used in the analysis, the overall confidence is medium. It is important to note that a philosophy of “roughly right rather than precisely

wrong” was used in ascertaining the estimates. For example, no learning curves were assumed. Details may be found in Volume V. The annualized cost of our notional CROSSBOW force is about 1% of the Navy’s current annual budget.

## **F. Conclusion**

The CROSSBOW project has given students the rare opportunity to coordinate requirements, conduct tradeoff studies and function as an integrated and interdisciplinary team. The experience, unique to NPS, helped students appreciate the complexities associated with the transformation of technology into a viable naval force for the future.

CROSSBOW is not, and cannot be a substitute for the open -ocean Navy, but we feel it is viable, desirable, and affordable. It is designed to fill a specific niche in the low to moderate threat littoral regions of the world. As a complementary force, it brings robustness to the combined force, greatly compounding the enemy’s area denial problem.

*This study does not provide sufficient depth to endorse the CROSSBOW concept completely. We do find that the concept is sufficiently meritorious to warrant serious further investigation by the US Navy.*





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