Unmanning the Rails: Deploying the Aviation Detachment to Support the LCS Mission

LT Sven Chrisman
LT Mike Pangrac
LT Steve Schwarzer
LT Chris Yost

THIS PAGE INTENTIONALLY LEFT BLANK

Contents

Acknowledgements

The team would like to take this opportunity to thank the people who made this presentation possible. First and foremost, we would like to thank CDR Harrison Schramm who acted as our advisor throughout the entirety of this project. Next, we would like to thank CDR Douglas Burton whose input to our presentations were invaluable in constructing a polished final product. We would like to thank the Fleet Introduction Team for their work regarding the manning of the AvDets and the breakdown of the various platforms' maintenance requirements. LT Rebecca Stockwell, COMLCSRON, provided several critical documents for LCS and LCS AvDet research and analysis. The people working at NAS Patuxent River and aboard the USS Simpson were instrumental in giving us insight into the MQ-8B's mission completion rate. Lastly, PMA-299 was able to provide the data that generated the cost per flight hour of the MQ-8B. Without the assistance of these people and organizations, this report would not have been possible.

Abbreviations

AD – Aviation Mechanic
AIMS – Asset Inventory Management System
AM – Aviation Structural Mechanic
AMCR – Aviation Maintenance Consumable/Repairable Report
AMSRR – Aviation Maintenance Supply Readiness Report
ASW – Anti-submarine Warfare
AvDet – Aviation Detachment
BLUF – Bottom Line Up Front
C3F – Commander Third Fleet
CSNF – Commanders Surface Naval Forces
CNAF – Commander Naval Air Forces
COA – Course of Action
CONOPS – Concept of Operations
CRUDES – Cruiser/Destroyer
IETMS – Interactive Electronic Technical Manual
FS – Firescout
HC – Helicopter Cargo Squadron
HSC – Helicopter Combat Support Squadron
HSL – Helicopter Anti-submarine Warfare Light Squadron
HSM – Helicopter Maritime Strike Squadron
LCS – Littoral Combat Ship
LS – Logistics Specialist
MCI – Material Condition Inspection
MCM – Mine Countermeasures
MPA – Maintenance Program Assist

MOE – Measure of Effectiveness
MOP – Measure of Performance
NAVAIR – Naval Air Systems Command
OPSUM – Operational Summary
PUK – Pack-Up Kit
SSC – Surface Surveillance & Control
SUPPO – Supply Officer
SUW – Surface Warfare
ULT – Unit Level Training
VTUAV – Vertical Takeoff Unnamed Ariel Vehicle

List of Figures

List of Tables

Executive Summary

Problem Statement

While the first three Littoral Combat Ship hulls have been delivered to the satisfaction of the surface community, and the three mission module types have been specified to satisfy the Combatant Commanders, little has been done to establish the exact makeup of the supporting aviation detachment, or AvDet. While the current Concept of Operations (CONOPS) calls for varying combinations of MQ-8B Fire Scout and MH-60 aircraft to support the various mission modules, little analysis has been done to determine how effective these varying combinations will be or if there is a better solution in terms of cost coupled with mission completion rates.

This study gives insight into how the different combinations of aircraft perform over the course of a notional 16-month LCS deployment. Incorporation of scheduled maintenance requirements and historical failure rates for each aircraft enabled the study to explore the average expected time to mission tasking and mission completion rates through Monte Carlo simulation.. Additionally, use of cost per flight hour data for each model allowed the study to analyze the costs per mission and average expected cost over the course of deployment for each combination of aircraft. Finally, these factors allowed us to highlight the benefits and tradeoffs of each AvDet and identify the optimal composition of LCS Aviation Detachments based on cost and mission completion rates.

Analytical Tools

Two different analytical tools were used in this study, namely Microsoft Excel and Rockwell Collins' Arena Simulation Software. Microsoft Excel was used to organize and graph the comparisons between the different AvDets in a functional, illustrative way. The Arena Simulation Software was used not only for its ability to operate as a Monte Carlo simulator, but also as a means of accounting for the various types of scheduled maintenance and to "show" exactly how missions were assigned and executed. It is also very flexible from a plug and play standpoint to account for differing numbers and types of aircraft or "resources. "

Conclusion/Recommendations

Based upon extensive modeling using the most recent MQ-8B, MH-60, and LCS deployment data, it has been determined that the most viable alternative for the LCS AvDet is a combination of 1 MH-60 and 2 MQ-8B's with the mission precedence assigned to the MH-60 as it provides the best combination of missions completed coupled with overall deployment costs.

THIS PAGE INTENTIONALLY LEFT BLANK

Introduction

Background

The Littoral Combat Ship (LCS) is the Navy's latest vision of a surface combatant that is capable of being employed with the latest technology to serve in a multitude of roles. By design, the Navy foresees the LCS being able to handle a broader range of mission sets with fewer people. This is accomplished through the idea of rapidly swappable mission packages. A mission package consists of three components: mission systems, support equipment, and the crew and support aircraft. Mission systems encompass things such as weapons and sensors for the vessel. Support equipment includes items such as the containers, software, and standard interfaces required to operate the mission systems. Together, the mission systems and support equipment combine to form what is known as a mission module. Lastly, by addition of the crew and support aircraft these elements become a mission package.

The types of mission modules and the objectives they support are already in development and fairly well documented. These consist of Surface Warfare (SUW), Anti-submarine Warfare (ASW), and Mine Countermeasures (MCM). What has not been well researched is the makeup of the support aircraft used to bolster the effectiveness of the mission packages. As of this date, the only detachment concept that has been deployed aboard the LCS has been that of a single MH-60S Seahawk. The current Program of Record (POR), however, indicates 140 MQ-8B Fire Scouts will be purchased in order to support 55 LCS vessels. This indicates that some combination of manned and unmanned detachment compositions will exist in the future.

Purpose

This study's purpose is to determine which AvDet composition is the most efficient in terms of mission completion percentage and overall cost. Both the MH-60 and MQ-8B have their advantages and disadvantages. While the unmanned aircraft are smaller and therefore cost less to operate, they are often plagued by software "bugs" that reduce their overall mission completion rates. On the other hand, MH-60 manned helicopters have historically high mission completion rates but are comparatively heavy on maintenance requirements and costs. These tradeoffs are even further complicated by the inclusion of composite aviation detachments (AvDets), where the unit may see both the pros and cons of each aircraft. By analyzing these attributes over the course of a simulated LCS deployment this study sought to determine the best composition of aircraft for the LCS.

Course of Action (COA) Descriptions

The possible COAs by which to outfit the LCS are numerous and are really only limited by the size and space available on the flight deck and in the hangar. As a result, the analysis focused on the four most likely COAs: a four MQ-8B Fire Scout unmanned only detachment, a one MH-60 Seahawk/two Fire Scout detachment (with Fire Scout as the priority airframe), a one MH-60 Seahawk/two Fire Scout detachment (with the MH-60 as the priority airframe), and a notional two MH-60 Seahawk detachment.[1] The last COA is notional because currently the LCS is incapable of fielding two MH-60s. However, the COA is included due to the possibility of expanding LCS capabilities or fielding the same mission on another platform, for example an FFG-7 type frigate. It also highlights the disadvantages of excluding the MQ-8B Fire Scout as part of the AvDet.

Tasking

The conduct of this study was as follows:

Task 1: Review reference material regarding airframe capabilities, costs, CONOPS, and maintenance requirements.

Task 2: Build an Arena Simulation Software model to simulate AvDet usage over the course of a 16-month LCS deployment.

Task 3: Analyze costs using cost per flight hour for each airframe and the outputs from the Arena model.

Task 4: Conduct sensitivity analysis to determine how changing the variables of aircraft mission completion rate, mission task rate, and aircraft composition alter the results.

Analytical Approach

Constraints and Assumptions

The constraints considered in this study were:

1) Space limitations onboard the LCS determined the maximum number of aircraft it could support. This correlated to four MQ-8B aircraft (unmanned-only), one MH-60 and two MQ-8B aircraft (composite), or one MH-60 (manned). However, we included a two MH-60 composition. This addressed possible modifications to the LCS or to account for similarly tasked ships capable of embarking two MH-60 aircraft.

The assumptions made in the analysis include:

1) Historical data is indicative of future future operations..
2) Unscheduled maintenance occurs at a rate of 10% per sortie, with an exponentially distributed repair time with mean length of one hour.
3) Mission lengths are three hours.
4) If a mission remains incomplete after 12 hours, it is considered a failure.
5) Missions are tasked with an exponentially distributed mean of one every eight hours.
6) Missions take five minutes to be assigned by Air Operations (AIROPS).
7) Aircraft begin the deployment at hour zero of all scheduled maintenance requirements.

[1] For the purpose of the model, the priority airframe type will always be tasked first if it is available.

Alternatives
The alternatives addressed in the study include the maximum number of airframes permitted by each combination. This includes an AvDet consisting of four MQ-8B Fire Scouts as well as one consisting of one MH-60 and two MQ-8B Fire Scouts. We eliminated the one MH-60 option as it was statistically dominated by the one MH-60/two Fire Scout option in terms of mission completion rate. Instead we included a two MH-60 AvDet to compare a more reasonable manned-only alternative.

Non-viable Alternatives
Non-viable alternatives included all those that were outside the ability of the LCS to support. This included exceeding the numbers of aircraft cited above, or including larger aircraft in the Navy inventory such as the MH-53 Sea Dragon or the MV-22 Osprey.

Determination of Measures of Effectiveness (MOE)
As the Navy often makes decisions on the rate at which it can complete missions and for how little a cost, the following MOEs were selected to assess the best aircraft composition for the LCS:

1) Mission completion rate over the course of a deployment
2) Missions completed versus time to complete the mission
3) Mission completed versus cost to complete the mission

Determination of Measures of Performance (MOP)
In order to calculate the above MOEs, the following MOPs were analyzed:

1) Total mission completed
2) Total missions failed
3) Total maintenance aborts
4) Average time from mission issue to AvDet departing on mission
5) Mission cost
6) Total deployment cost

Effectiveness Analysis
Arena Simulation Software was used to model a standard 16-month LCS deployment cycle. The Arena simulation incorporated an accurate schedule of maintenance events and easily accounted for the differing numbers and types of aircraft. Additionally, it modeled exponential distributions where appropriate over the 1,000 iterations run. Its outputs included the MOPs above which were then incorporated into Microsoft Excel. Excel was then used to calculate the MOEs above and incorporate them into easily understandable graphical representations. The Excel data is included in Appendix C.

Aircraft Assessments

MQ-8B Fire Scout
The MQ-8B Fire Scout is based off of the Schweizer 333 aircraft, which weighs approximately 1500 pounds when empty and just over 3000 pounds at max weight. As such, it has a much smaller footprint allowing for more airframes to be housed onboard ship and it has a much cheaper cost per hour than the MH-60 helicopter, which may weigh as much as 21,500 pounds at max weight. Additionally, the maintenance schedules for the Fire Scout are far less demanding than those of the MH-60, allowing for fewer maintenance personnel and less downtime between flights. However, the Fire Scout does have its drawbacks. To fly the Fire Scout the Air Vehicle Operator (AVO) needs not only the airframe but a Mission Control Station (MCS) as well. This is the electronic "box" from which the AVO controls and monitors the Fire Scout. Just like the Fire Scout airframe this MCS is very software intensive, so there is far more likelihood of a cancelled mission due to glitches or aircraft command and control issues. While a pilot in a manned aircraft has the capability to pull circuit breakers and analyze alternate solutions to complete the mission, the operator of the Fire Scout has little choice but to return the aircraft home in the case of a malfunction.

Manned Aircraft
LCS can embark several variants of the MH-60 and SH-60 aircraft. While the MH-60R and MH-60S are closely aligned with MPs, the ship will operate the SH-60B to execute other missions in the near term as the MH-60R is phased into the fleet. The MH-60S has been introduced into the fleet and will be available to support MCM and SUW MPs as required.

MH-60R Seahawk
When available, the MH-60R is the primary aircraft associated with the ASW and SUW MPs. The MH-60R provides the ability to conduct surveillance, prosecute and neutralize submarine contacts, or neutralize surface contacts. It is equipped with radar, forward-looking infrared (FLIR), sonobuoys, dipping sonar, inverse synthetic aperture radar, Hellfire, machine guns, and torpedoes. (Note: The MH-60R is a multi-mission aircraft which will arrive aboard LCS with inherent ASW and SUW capabilities. Given these capabilities, dual mission tasking is possible; however, given the nature of LCS mission employment (i.e., only one mission at a time), dual mission employment of the aircraft is not anticipated.) The current POR procurement plan reflects 300 aircraft. Of these aircraft, 51 are aligned to support 17 LCS fleet requirements.

MH-60S Seahawk
MH-60S is the primary aircraft associated with the MCM MP. In support of the MCM MP, the MH-60S will search for, locate, and destroy mine-like objects using the four organic airborne mine counter measures (OAMCM) systems: AN/AQS-20, Airborne Laser Mine Detection System (ALMDS), Airborne Mine Neutralization System (AMNS), and Organic Airborne and Surface Influence Sweep (OASIS). Since all of the airborne MCM (AMCM) systems will not be complete with developmental and operational testing before the first LCS deployment of the MCM MP, the decision to deploy individual AMCM systems will be based upon system maturity, mission capability, and level of risk to operate. It is anticipated that the AQS- 20, AMNS, and ALMDS at a minimum will be ready for the initial MCM deployments. In the armed helicopter configuration,

the MH-60S can provide support for SUW/MSO missions when equipped with an "armed helo kit," which includes FLIR, Hellfire, and machine guns. It can also support EMIO and has the capability to conduct fast rope evolutions. The current POR procurement plan reflects 275 aircraft. Of these aircraft, 24 are aligned to support 8 LCS fleet requirements.

Concept of Operations

Deployment Cycle

The standard LCS deployment block is 16 months long and is fielded by a "3-2-1" concept. This means that 3 crews will support 2 ships (1 deployed, 1 home for work-ups/Unit Level Training (ULT)) with 1 of those ships constantly deployed. The LCS would pull in pier-side to accomplish scheduled crew swaps over a 96 hour window every 4 months as seen in the figure below (Fig 1).

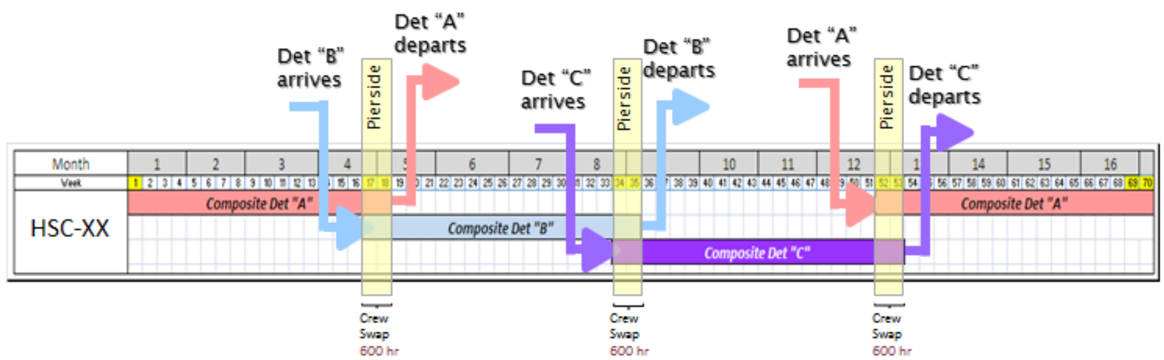


Figure (1): Helicopter Suadron Schedules to support LCS Deployments. The Helo Conops, as depicted here, include the flexibitly to swap out aircraft and crews at various points in the ship's deployment cycle.

LCS Differences

- LCS Seaframes rotate every 16 months
- Airframes will rotate every 16 months
- Ship/AvDet personnel rotate every 4 months with 2 week in port overlap
- Type Wing will conduct MPA, MCI Per CNSF/CNAF INST 4415.2
- AvDet responsible for Pack Up Kit (PUK)
- PUK responsibility of Ship SUPPO on other ships
- No LS personnel in AvDet

One of the differences between LCS and Legacy ships is the rotational crew concept. HSM and HSC Expeditionary squadrons are aligned to support LCS in a 3:2:1 concept – 3 AvDets, to support 2 LCS, 1 of which is deployed. The airframes – both the H60 and the MQ-8B – will remain with the seaframe for the entire 16-month period. The AvDets and crews, will rotate approximately every 4 months, with a two-week turnover period in between. The two-week turnover will allow the TYPE WING to perform a detailed look at both the airframes and the detachment's aviation programs. This is done via the Maintenance Program Assist (MPA) and a Material Condition Inspection (MCI). The MCI inspection is crucial to anticipating airframe swaps that may be required outside the normal airframe rotation. These procedures have been codified in the joint COMNAVSURFOR (CNSF) and COMNAVAIRFOR (CNAF) instruction 4415.2, which is in the final stage of approval.

Maintenance

1. Shift Concept

The maintenance personnel on the AvDet are divided into two shifts:

- Day Shift and Night Shift
- Each shift is 12 hours long
- Consist of approximately 6-8 maintenance personnel of varying specialties
- Manpower is divided to ensure that each shift has qualified personnel to support the following:
    - Maintenance Control functions
        - Safe-for-Flight
        - Shift management & oversight
        - Maintenance prioritization
    - Quality Assurance
        - Final checker for maintenance actions
        - Provide oversight, leadership, and experience to junior personnel
    - Maintenance Technicians for each rating:
        - Workers performing the actual maintenance on the airframes

The small maintenance 'footprint' in each shift makes it necessary for AvDet personnel to be cross-trained in multiple ratings in order to support Quality Assurance and inspection functions. For example, an AD2 (Aviation Mechanic) could be trained & qualified for Quality Assurance functions in both the AD and AM (Aviation Structural Mechanic) rating. If the AvDet had only one AM Quality Assurance representative (who was stationed on Day shift), the AD2 could be placed on Night Shift and perform the Quality Assurance duties for any AM rated work.

This concept is not a new development in the manned helicopter community, as AvDet maintenance and manning has evolved over time and was forged in the HSL and HC detachments deployed on traditional and legacy CRUDES ships. This evolution has resulted in the smallest possible footprint needed to facilitate aviation operations from air-capable ships. As a result, the LCS has incorporated these maintenance and manning concepts to more efficiently staff its detachments.

2. Schedules

Below is the current scheduled maintenance plans for the MH-60R/S Figure (2). Also provided is the current maintenance plan for the MQ-8B Figure (2).

The info from the Military Utility Assessment conducted on MCINERNEY provided a baseline; subsequent deployments, such as the MUA being conducted on HALYBURTON, will continue to feed us data that will help refine the maintenance plan.

Amplifying information: there are tolerances built into these inspection 'times' to help facilitate and plan maintenance. There is a +/- 10% tolerance for hourly inspections and a +/- 3 days for "day" based inspections.

Of particular importance is the 600 hour engine inspection requirement for MQ-8B Fire Scout. Currently, there is much speculation in the aviation community regarding the processes and procedures associated with this 600 hour inspection for the fact that the inspection has never been performed at sea or aboard an LCS due to the relative newness (less than 100 hours on any airframe). The 600 hr inspection requires an engine removal and as the contract is currently written, the inspection must be performed by the manufacturer, Rolls-Royce. As a Depot-level maintenance procedure and given that there is not an engine in the MQ-8B PUK. An engine must be shipped to the AvDet's location so that it can be installed on the MQ-8B. Proper and proactive maintenance planning, as well as daily maintenance reports – AMSRR, AMCR messages, OPSUM – provide triggers to the supply & logistic folks to ensure an engine will be available when needed. As of now, there are no limitations for engine removal and replacement while at sea (i.e. it can be done at sea). Engine removal & replacement requires the MQ-8B to be placed on 'jacks' and the engine is removed from the bottom of the air frame. Currently, the MQ-8B Interactive Electronic Technical Manual (IETMS) do not have sea/pitch/roll limitations for the removal and replacement of the engine but ultimately, sea state and sea frame stability will be primary considerations for the ship-air team when it comes to engine removal and replacement.

MH-60R/S SCHEDULED MAINTENANCE PLAN		
INSPECTION TYPE	Total	
	MH-60R	MH-60S
7 day	16.1 hrs	4.2 hrs
14 day	21.9 hrs	3.4 hrs
28 day	56 hrs	40.4 hrs
56 day	28 hrs	47.9 hrs
90 day	0.1 hrs	N/A
112 day	4.5 hrs	27.8 hrs
224 day	2.3 hrs	1.4 hrs
364 day	44.9 hrs	21.8 hrs
546 day	35.8 hrs	32.5 hrs
30 hour	7.2 hrs	9.1 hrs
60 hour	5.4 hrs	5.6 hrs
100 hour	0.9 hrs	N/A
200 hour	2.0 hrs	N/A
525 hour	3.0 hrs	3.0 hrs
700 hour	7.0 hrs	7.0 hrs

MQ-8B SCHEDULED MAINTENANCE PLAN	
INSPECTION TYPE	Total
14 Day	1.2 hrs
56 Day	4.7 hrs
90 Day	4.0 hrs
364 Day	1.3 hrs
25 Hrs	2.1 hrs
50 Hrs	0.6 hrs
75 Hrs	1.4 hrs
150 Hrs (AV INSP)	2.8 hrs
150 Hrs (ENG INSP)	0.8 hrs
300 Hrs (AV INSP)	1.5 hrs
300 Hrs (ENG INSP)	2.7 hrs
450 Hrs	15.9 hrs
600 Hrs (includes ENG Removal)	1.1 days

Table(1): Estimated times for MH-60 and MQ-8 maintenance.

3. Pack-Up Kit (PUK)

Another LCS difference is the ownership and management of the Pack Up Kit (PUK). Currently, on CRUDES and legacy ships, the ship's SUPPLY department owns and manages the PUK. The LCS concept places the ownership/management of the PUK under the AvDet's cognizance. This is an important note because, due to AvDet manning constraints, there is no Logistic Specialist (LS) assigned to the AvDet. The intent is to train one member of the AvDet in the use of the Asset Inventory Management System (AIMS), which is the inventory control software, thus facilitating efficient management and oversight of the PUK by the AvDet. CNAF's plan to mitigate any potential problems with inventory control is to perform a comprehensive PUK inventory during the two-week AvDet turnover period. This has also been codified in the draft 4415.2 Instruction.

MH-60

- Line items: 700
- Consumable repair parts: 500
- Repairable repair parts: 200

MQ-8B

- Line items: 230
- Consumable repair parts: 147
- Repairable repair parts: 83

Manning

The LCS AVDET is comprised of 23 personnel for a composite (helicopter/VTUAV) detachment. Original aviation manning requirements were derived from a NAVAIR manpower study indicating that 28-31 personnel were necessary to provide around the clock aviation operations. Manning thresholds and associated ship design requirements could not support the manning levels called for in the NAVAIR analysis. C3F provided refined war fighting analysis and determined flight hour requirements appropriate to anticipated missions. These flight hour projections were used as the foundation for a more refined manning requirement analysis to established the 23-person requirement.

This 23-person limitation presents challenges in providing adequate aviation capability to support mission requirements. The composite detachment is able to provide both manned and unmanned capability; however, both capabilities cannot be maximized simultaneously due to the maintenance man-hour limitations associated with a 23-man AVDET. This will drive the need for the operational commander to determine which mix of manned and unmanned capability within the AvDet will most effectively satisfy mission requirements. Additionally, the AvDet will provide personnel to perform limited aviation supporting functions when OPTEMPO permits. The AvDet will be unable to support other operations (e.g., small boat operations, maintenance on ship systems (ship control station, UAV Common Automatic Recovery System, landing grid, etc), and certain force protection roles in port) that are not directly related to AvDet operations or sustainment.

	HSM	HSC	LCS	LCS	CRUDES	MCI	LHD SAR
	1 MR-60R	1 MH-60S	1MH-60S	1MH-60R	2 MH-60R	1 SH-60B	2 MH-60S
			1 MQ-8B	2 MQ-8B		2 MQ-8B	
PILOTS	4	4	4	4	6	6	6
LDO							1
CPO	1	1	1	1	1	1	1
LPO	1	1	1	1	1	1	1
AD	2	2	2	3	3	3	4
AE	2	2	3	3	3	4	2
AM	2	2	3	3	3	4	3
AO	1	1	1	1	1	1	1
AT	2	2	2	3	3	3	4
AW	2	4	5	3	3	4	6
AZ	1	1	1	1	1	1	1
HM							1
SK							1
Tech Rep						1	
TOTAL	18	20	23	23	25	29	32
Total O	4	4	4	4	6	6	7
Total E	14	16	19	19	19	22	25
Maint'er	10	10	12	14	14	16	15

Table (2): Manning requirements for aviation detachment options.

Methodology and Analytical Framework

Model

Arena Simulation Software by Rockwell Collins was used to simulate mission tasking during the notional LCS deployment. It allowed us to capture such things as scheduled and unscheduled maintenance, mission completion rates, and the process of entertaining a hierarchy of platforms. It also allowed for a rapid conversion between types and number of platforms.

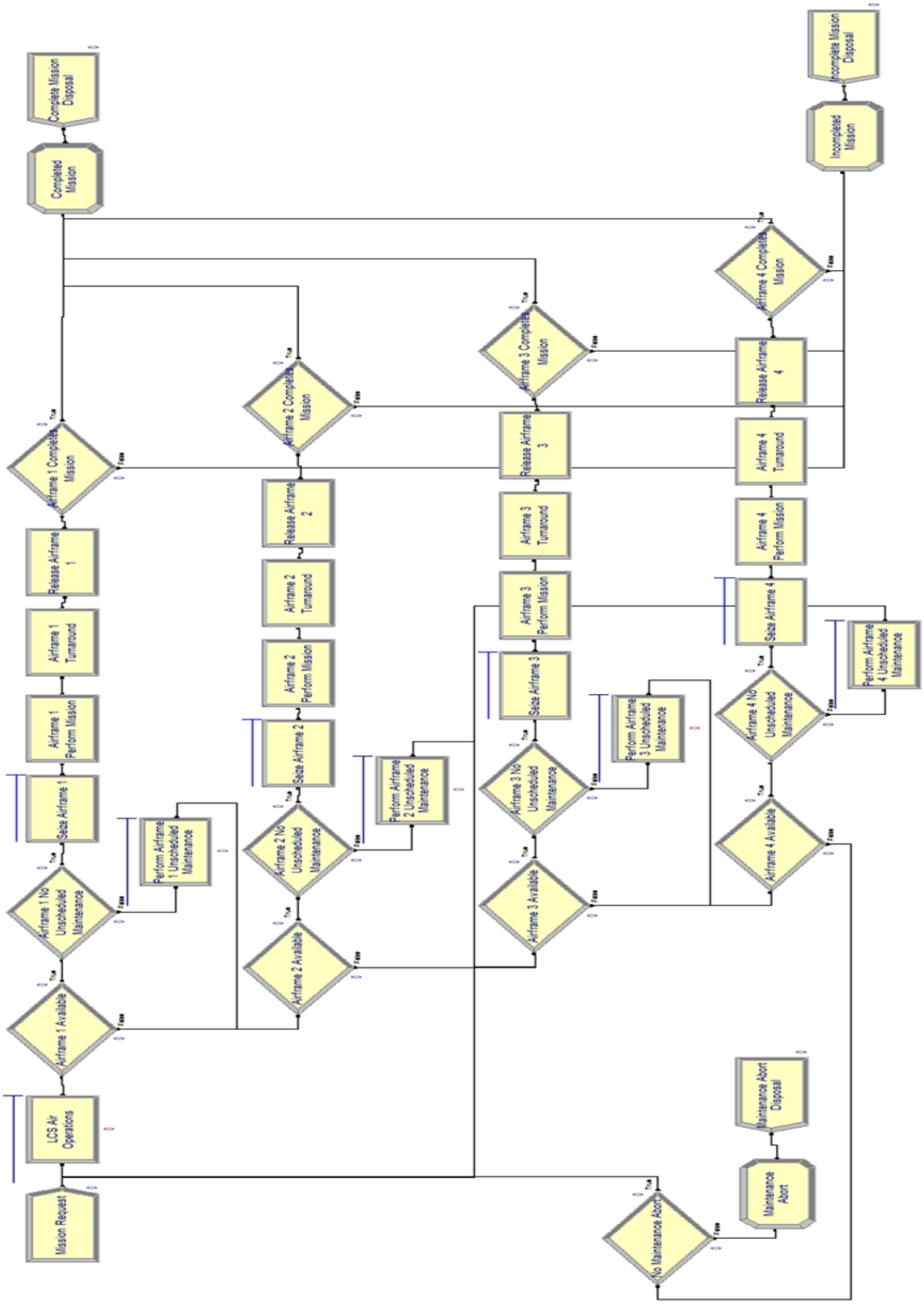


Figure (2): Block Diagram of Arena Simulation

Simulate Mission Tasking for LCS Aviation Platforms

In order to generate the simulation model, several decisions needed to be made to shape the desired analysis. The team arrived at the following solutions through consideration of LCS CONOPS and historical data.

1. 3 hour mission followed by 1 hour turnaround
    a. Typical MH-60 mission length
    b. Fuel load suitable for 3 hours
    c. Ship aircraft launch and recovery schedules
2. Scheduled maintenance based on calendar and flight hour requirements
    a. The OPNAV 4790 Naval Aviation Maintenance Publication sets forth procedures for maintenance action of all naval aircraft
    b. In order to remain Ready for Tasking (FRT), naval aircraft are required to undergo several inspections after flying a specific number of hours and/or number of days of passed
3. Unscheduled maintenance was based on historical MH-60 abort rates using an exponential time distribution
    a. Ten-percent probability with down time exponentially distributed with a mean of one-hour length of maintenance action time.
4. Missions assigned in order of availability and priority
    a. Model assigns missions to the priority platform. The study varied the priority platform in the composite detachments
    b. The first platform available is assigned the mission
5. Missions completed, missions failed, and applicable time metrics recorded

Simulation Output

Measures of Performance (MOP)

The following measures of performance provide several useful quantities for side-by-side comparison of each COA. Values are derived from simulation outputs. (Appendix C)

-Missions completed (Average Number Completed over 1000 Simulations)

4 UAS	2 UAS H60	H60 2 UAS	2 H60
864.11	891.21	980.66	1095.35

-Missions incomplete (Maintenance Abort or Failure to complete)

4 UAS	2 UAS H60	H60 2 UAS	2 H60
287.93	259.99	172.49	57.35

Table (3): Simulation Mission Outcome Results

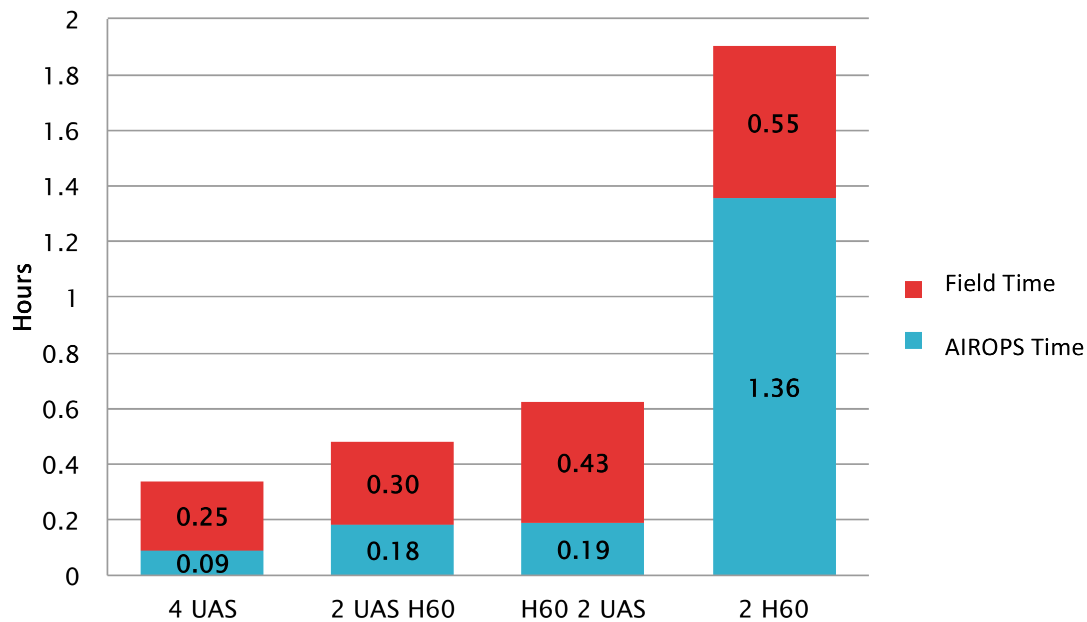


Figure (3): COA Time to Mission Execution

Captured in this figure is the speed with which the various AVDET compositions complete the mission tasking (excluding the three hours to execute the mission itself). The AIROPS time (blue portions) represent the amount of time the missions spent in air operations, otherwise known as the wait time for an aircraft to become available. The additional time required for the mission to be executed (red portions) was the compilation of the time the missions were in transition from one phase to another (i.e. moving from air operations to being seized by an airframe or from execution to mission disposal). The key takeaway from this figure is that the number of airframes varied the transition time (red) very little, specifically less than 20 minutes between the two ends of the spectrum. What is telling is the increase in the amount of time the missions spent in air operations as the number of total assets decreased, most noticeably a sevenfold increase from the composite detachment to the all-manned detachment.

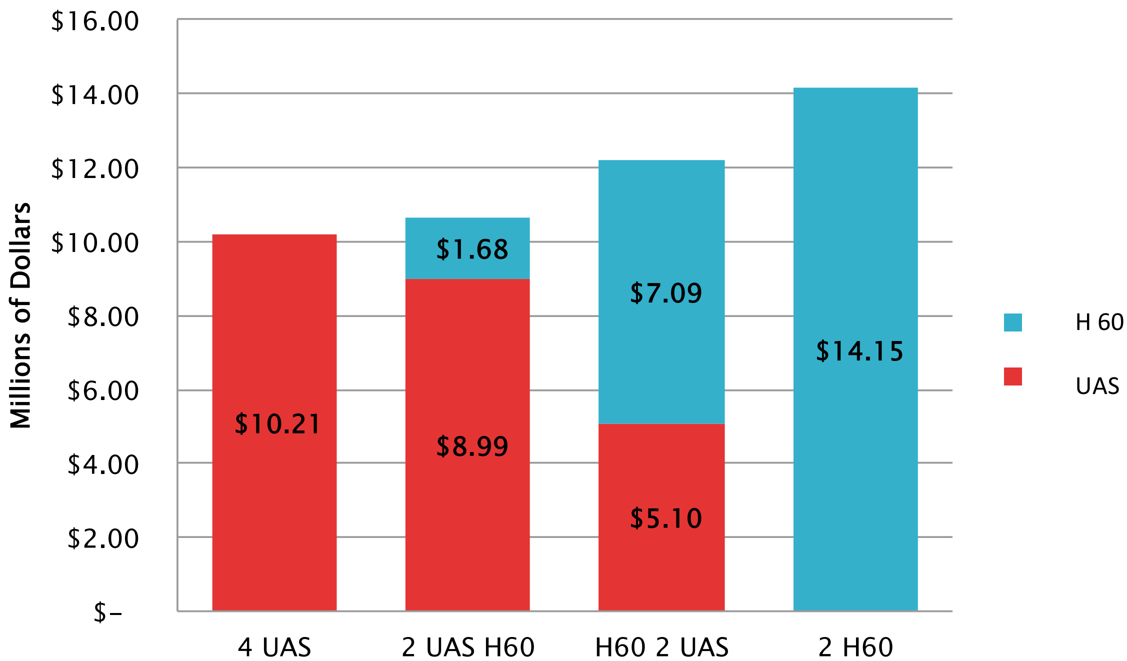


Figure (4): COA Total Deployment Cost

The key to this graph is that it illustrates the cost of each COA to complete an equivalent number of missions (the average deployment value of 1153 missions). It reflects the fact that the MQ-8B is far cheaper to operate than a manned only option – approximately 28% cheaper. It also shows that the difference between making the MH-60 the priority asset versus the MQ-8B in the combined AvDet is about $1.5 million.

Cost Analysis

1. Collect cost per flight hour data for each platform. This study elected to utilize the higher MH-60R cost data to determine the "worst" case universal cost of the MH-60.

Used for Flying Hour Program (Unit Level Consumption)

UNIT OPERATIONS	**$75**
MAINTENANCE	**$2,877**
TOTAL	**$2,952**

Table (4): MQ-8B Unit CPH (Courtesy Julia Lopez, NPS PHD Dissertation)

The cost per flight hour for the SH-60R and CH-60S were calculated using historical data from the SH-60B and the HH-60H respectively. The aircraft were chosen due to similarities in airframe, components, avionics, and mission. The cost per flight hour is provided in Table 4.

Type Aircraft	VAMOSC '92 – '97 (CY01$)
SH-60R	$4089
CH-60S	$3880

Table 4: VAMOSC '92-'97 Costs per Flight Hour for the SH-60R and CH-60S Helicopters. The values were determined using the VAMOSC database for the similar aircraft.

Table (5): MH-60 Unit CPH- (Courtesy Julia Lopez, NPS PHD Dissertation)

2. In order to calculate cost per completed mission for an individual platform, the cost per flight hour for each type of platform was multiplied by the mission length of 3 hours

MQ-8B = $2,952 x 3 = $8,856
MH-60 = $4,089 x 3 = $12,267

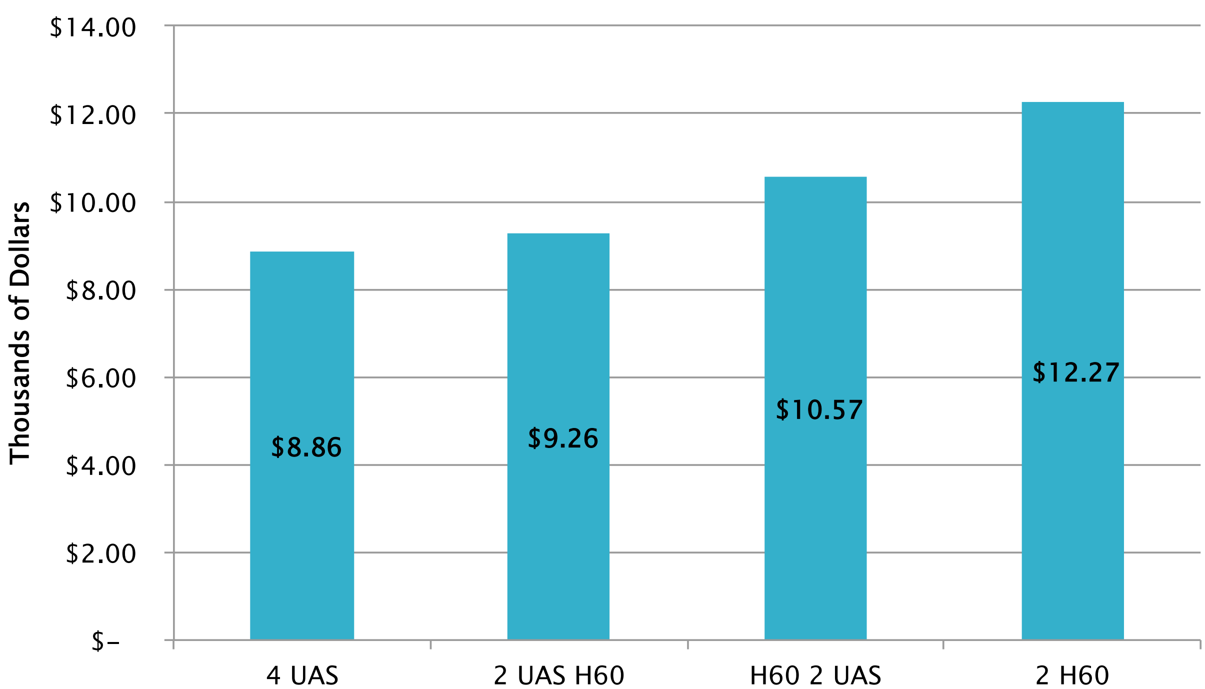


Figure (5): COA Completed Mission Cost

3. The Arena model simulated total number of missions completed during 16-month deployment for each AvDet based on an exponential distribution with a mean of 8 hours and λ = 1/8 hours. Over the 16-month deployment, the LCS CONOPS assumes 24 hours of air operations per day and 24 air operations days out of the month.

4. Total deployment cost was calculated using the sum of two products, one for each platform within the COA. In this case the products are cost per mission completed and number of missions completed determined in steps 2 and 3.

Total deployment cost = ($8,860 x MQ-8B mission count) + ($12,267 x MH-60 mission count)

5. The final cost analysis step compared the number of completed missions versus total deployment cost for each COA determined in steps 3 and 4. Results are included in the following section.

Measures of Effectiveness (MOE)

The following measures of effectiveness were derived after consultation with various experts within the LCS, MQ-8B, and MH-60 fields. Each MOE highlights a quantifiable metric of comparison providing a quality performance assessment of each COA.

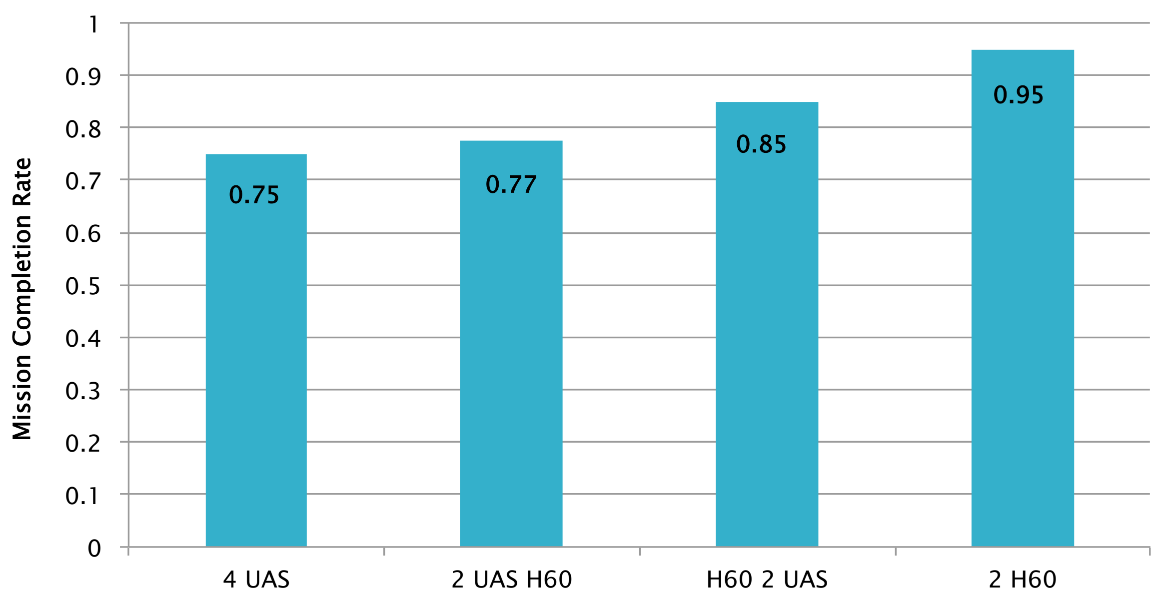


Figure (6): COA Mission Completion Rate Over Deployment

The 8% increase in mission completion rate between the two combined AvDets reflects an additional 90 missions completed over the course of the deployment. The additional 10% for the option with 2 MH-60 reflects an additional 115 mission completed.

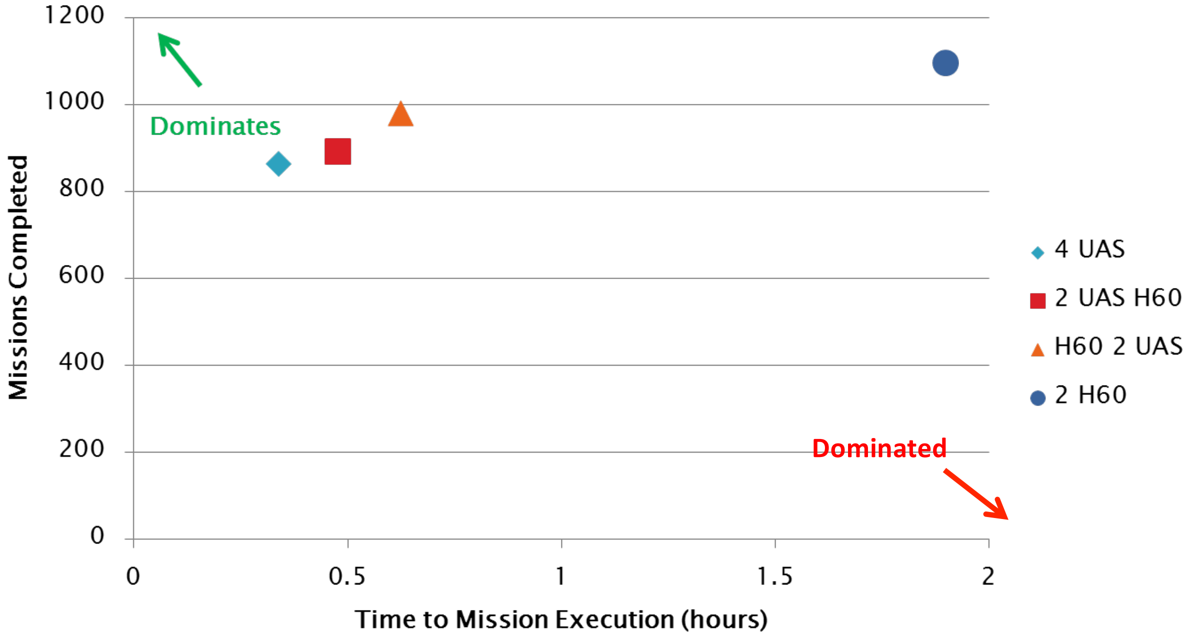


Figure (7): COA Missions Completed vs Time to Mission Execution

While none of the COAs are overwhelmingly dominated, this graph illustrates that the 2 MH-60 COA is exceedingly dominated by the other 3 COAs in terms of time to mission execution.

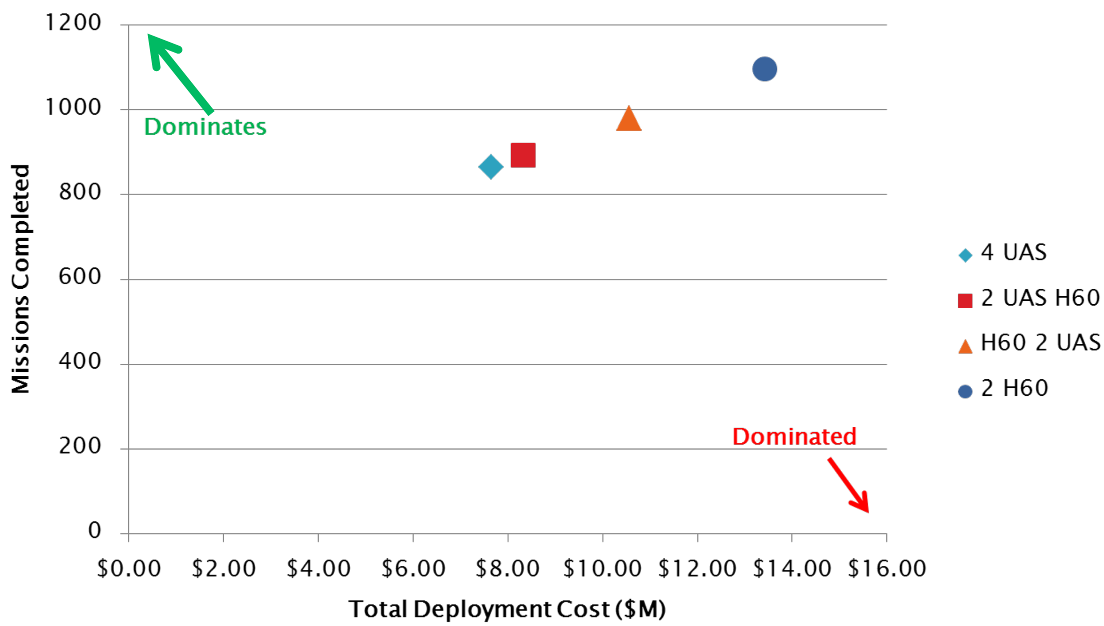


Figure (8): COA Missions Completed vs Total Deployment Cost

None of the COAs overwhelmingly dominated in terms of mission completed or total deployment cost. In fact, there is a fairly linear tradeoff between the two outputs regarding these four COAs.

Sensitivity Analysis

The MQ-8B Fire Scout is still relatively new from an airframe perspective and as a result there were a number of opportunities to conduct sensitivity analysis. We focused on three primary areas: changing the mission completion rate of the Fire Scout for each AvDet, ramping up the mission tasking, and altering the composition of the airframes to see how taking fewer aircraft would affect mission completion rates. Additionally, we combined the last two aspects to see how taking a smaller AvDet would be affected by an increase in mission tasking.

Mission Completion Rate

Having used a 75% mission completion rate for the MQ-8B as our baseline, we assessed how changing this value to 65%, 85%, and 95% would affect the AvDets, most notably the ones containing a combination of manned and unmanned aircraft. We chose 65% as it illustrated how the mission completion might be affected in an operational environment vice a testing one for which we had the data. We chose the values of 85% and 95% to illustrate how technological improvements and practice of use might increase the MQ-8B's mission completion rate. The results are shown below Figure (9).

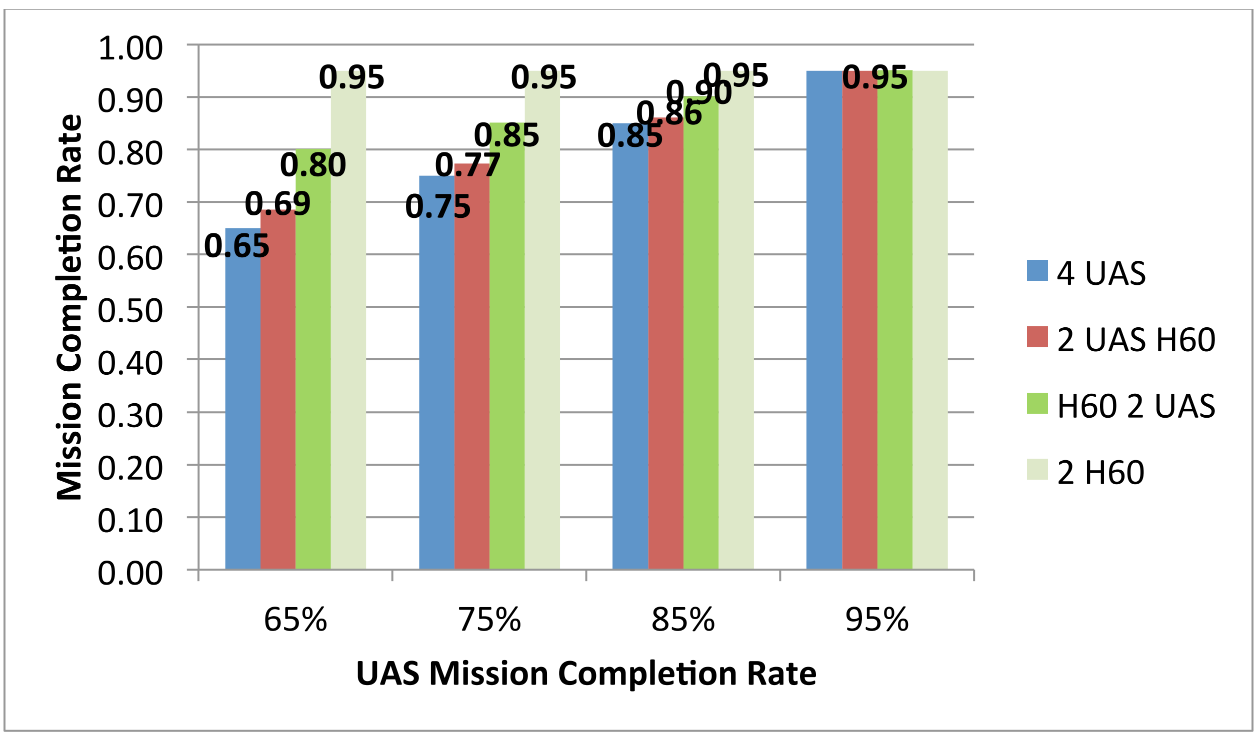


Figure (9): UAS Mission Completion Rate

Of interest here is the fact the 1 H60/2 UAS AvDet where the UAS is the primary asset sees far more benefit from an increased sortie completion rate than the one where the H60 is the primary asset though it still falls short of its completion rate. In the first case there is a delta of .08/.09/.09 while in the second case the increase is only .05/.05/.05.

Increased Mission Tasking

To increase the model mission tasking, we changed the values of our mission distribution to exponential with a mean of 4 hours and a λ of 1/4. This yielded the output in Figure (10).

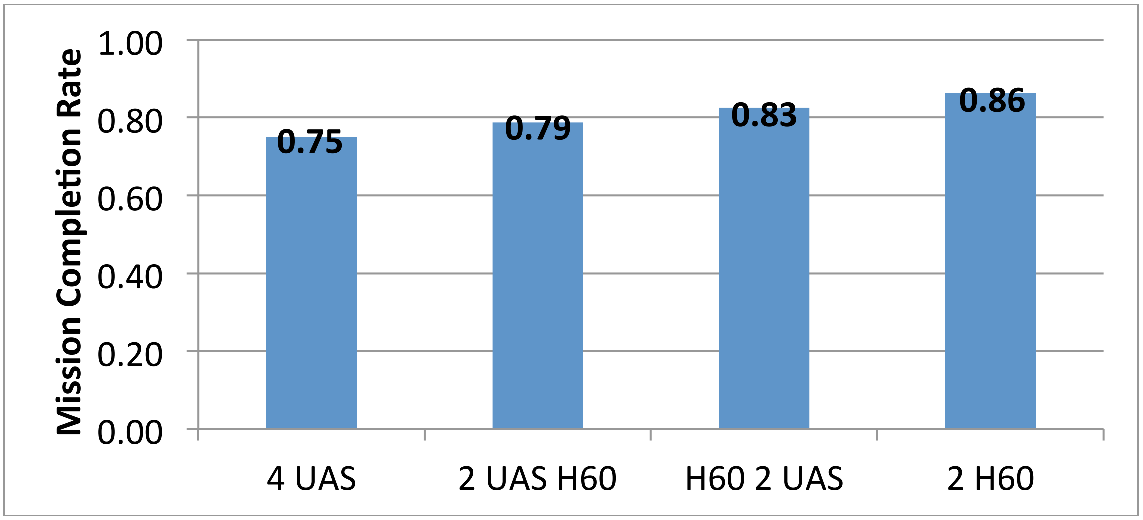


Figure (10): Increased Mission Tasking

The 4 UAS AvDet was unaffected by the increase in mission tasking due to the fact it had the largest number of airframes available and could keep up with the demand. Next, the mission completion rate for the 1 H60/2 UAS with the UAS as the priority asset actually increased under greater mission tasking. This occurs because the H60 is used more frequently in this scenario, so its higher individual mission completion rate drives up the overall mission completion rate. Next, the 1 H60/2 UAS AvDet with the H60 as the priority asset saw a slight decrease (2%) in its mission completion rate as this AvDet was forced to use the lower mission completion rate MQ-8Bs more often. Lastly, the 2 H60 AvDet saw the largest decrease (9%) as the small number of available platforms could not keep up with the increased mission tasking thus increasing the number of failures.

Analysis of Alternatives

Under baseline mission tasking, very few missions were going unfulfilled due to aircraft availability. As a result, to increase the data provided by the model and study it was necessary to analyze the effect of reducing the total aircraft for each of our COAs with regard to mission completion rate. This included a 3 UAS AvDet, a 1 H60/1 UAS AvDet with the UAS as the priority asset, and a 1 H60 AvDet. The results can be seen in Figure (11).

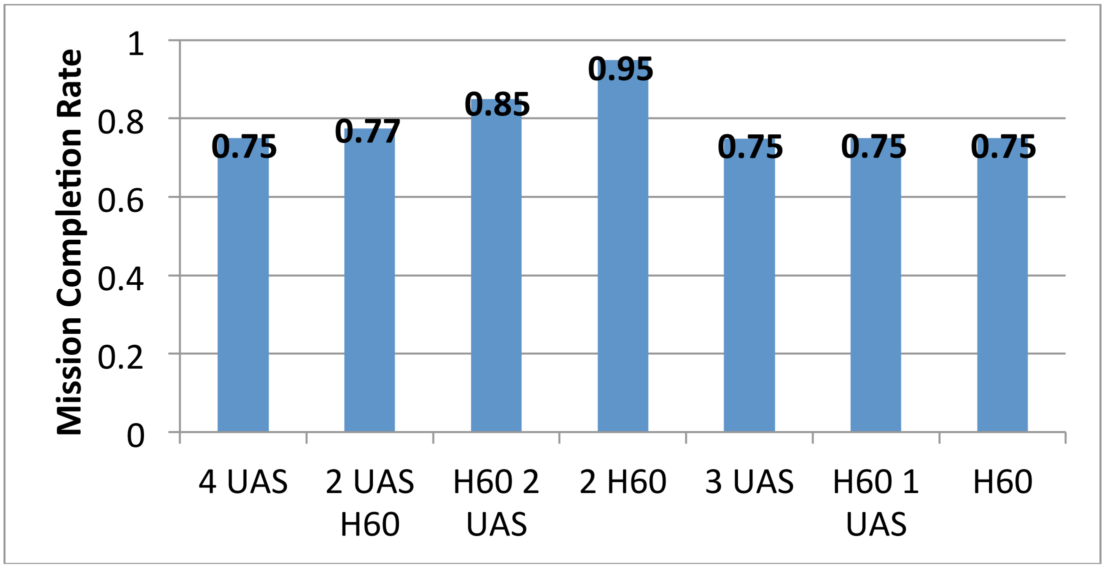


Figure (11): Analysis of Alternatives

Under the normal mission tasking rate, there is no effect on mission completion rate between an AvDet of 4 Fire Scouts and one of 3 Fire Scouts. Eliminating a UAS from the combined AvDet yields a small reduction in mission completion rate (2%) from the 1 H60/2 UAS AvDet. Finally, with only one platform, the 1 H60 option sees a huge decrease in mission completion rate (20%) from the 2 H60 option.

Analysis of Alternative - Increased Mission Tasking

Lastly, to illustrate the effect that the decreased number of platforms has on a high operational tempo we ran the Analysis of Alternatives in combination with an increase in mission tasking. The results are below Figure (12).

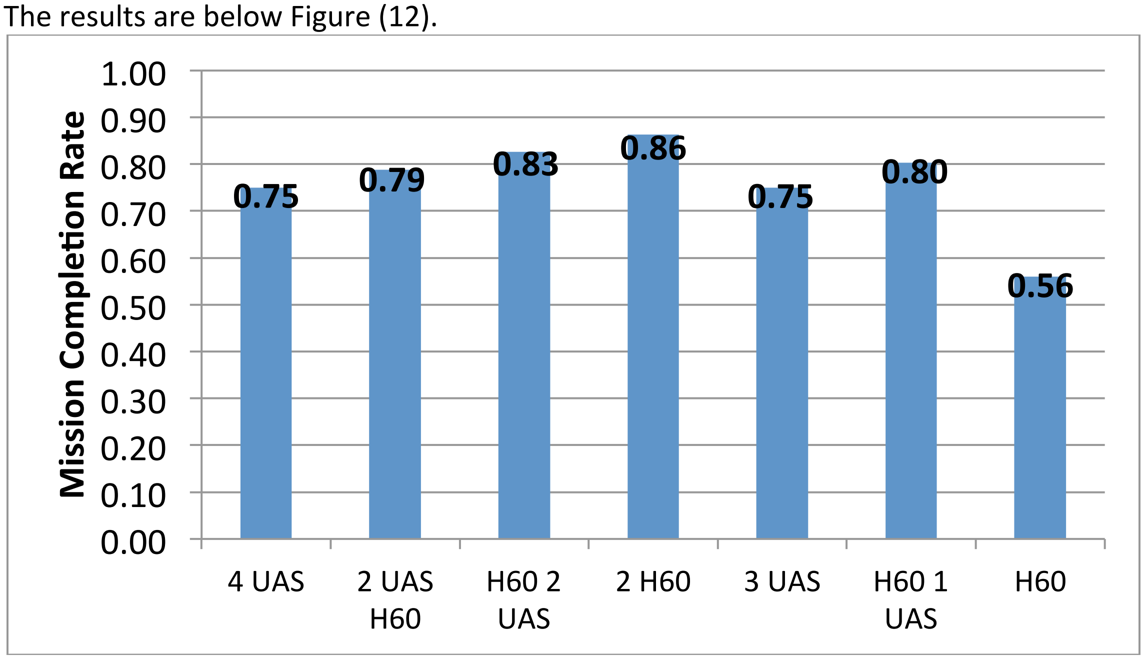


Figure (12): Analysis of Alternatives – Increased Mission Tasking

Having already seen the output for the original COAs, the results are as expected. The 3 UAS option is still able to provide mission completion rate equal to that of the 4 UAS AvDet. The combined AvDet sees an increase in mission completion rate much like before due to greater use of the H60 asset. Finally, with only 1 airframe, the 1 H60 AvDet sees enormous drop off (19%) due to an inability to meet the increased demand.

Conclusions

Based upon the simulation outputs utilizing the aforementioned assumptions, it has been determined that the most viable alternative for the LCS AvDet is a combination of 1 MH-60 and 2 MQ-8B's with the mission precedence assigned to the MH-60. As the data demonstrates through the established Measures of Effectiveness, this alternative matches or exceeds the performance of the other viable options. While the notional 2 H-60 detachment has a 10% greater number of missions completed over the course of a deployment, its cost per completed mission and overall deployment cost is 20% greater than the choice alternative. Additionally, the H-60 priority AvDet outperforms the 2 H-60 detachment when conditions are changed in the sensitivity analysis. The 2 H-60 AvDet is not nearly as flexible when faced with increased mission tasking and coupled with projected improvements to UAS reliability in the coming years, the combined detachment makes more sense based on cost as well as mission completion. With the large cost per mission, this course of action is not viable when compared to the others.

When compared to the UAS only AvDet and UAS priority combined AvDet, UAS only alternative performs admirably. While the cost of the UAS only detachment is 16% less than the H-60/UAS combination, it completes 13% less missions and is therefore dominated by the preferred alternative. Although this is the case under the given assumption of a UAS sortie completion rates 75%, this recommendation might need to be reexamined when more historical UAS data becomes available. As demonstrated in the sensitivity analysis, improving the sortie completion rate to a level comparable to the MH-60's will give the MQ-8B a significant cost advantage over the course of a 16-month LCS deployment and should be reexamined in future studies.

Overall, the H-60/UAS Combined AvDet is the preferred alternative as it executes the most number of missions at the most cost effective rate.

Recommendations

The planned composition of aircraft onboard the LCS *is* the most effective at meeting primary LCS mission tasking considering average mission completion rate, average mission completion time, and total deployment cost. Employing the LCS AvDet with 1 MH-60 as the primary asset in terms of tasking along with 2 MQ-8B provides drastically increases mission completion rates, reduces mission completion time, and marginal total deployment cost increase when compared to all other alternatives. This study limited the scope of alternatives to current, planned AvDet compositions onboard the LCS.

Items for further study include:

- Incorporate more refined Fire Scout data as it becomes available
- Capture limitations of AvDet manning
- Update LCS mission tasking and deployment cycles as CONOPS changes
- Evaluate resourcing AvDet maintenance requirements to other LCS within the group sail
- Include further cost analysis regarding personnel and support equipment
- Increase the complexity of AvDet mission tasking beyond an exponential mission tasking
- Incorporate costs associated with pilots and aircrew utilized in the MH-60

Additionally, this study utilized a model that did not take into account the inability of the MQ-8B to conduct the various secondary missions required to support the aviation role onboard the LCS. The MH-60 is extremely capable at accomplishing all secondary missions as aircrew conduct significant readiness training in all areas.

These missions include and are not limited to:

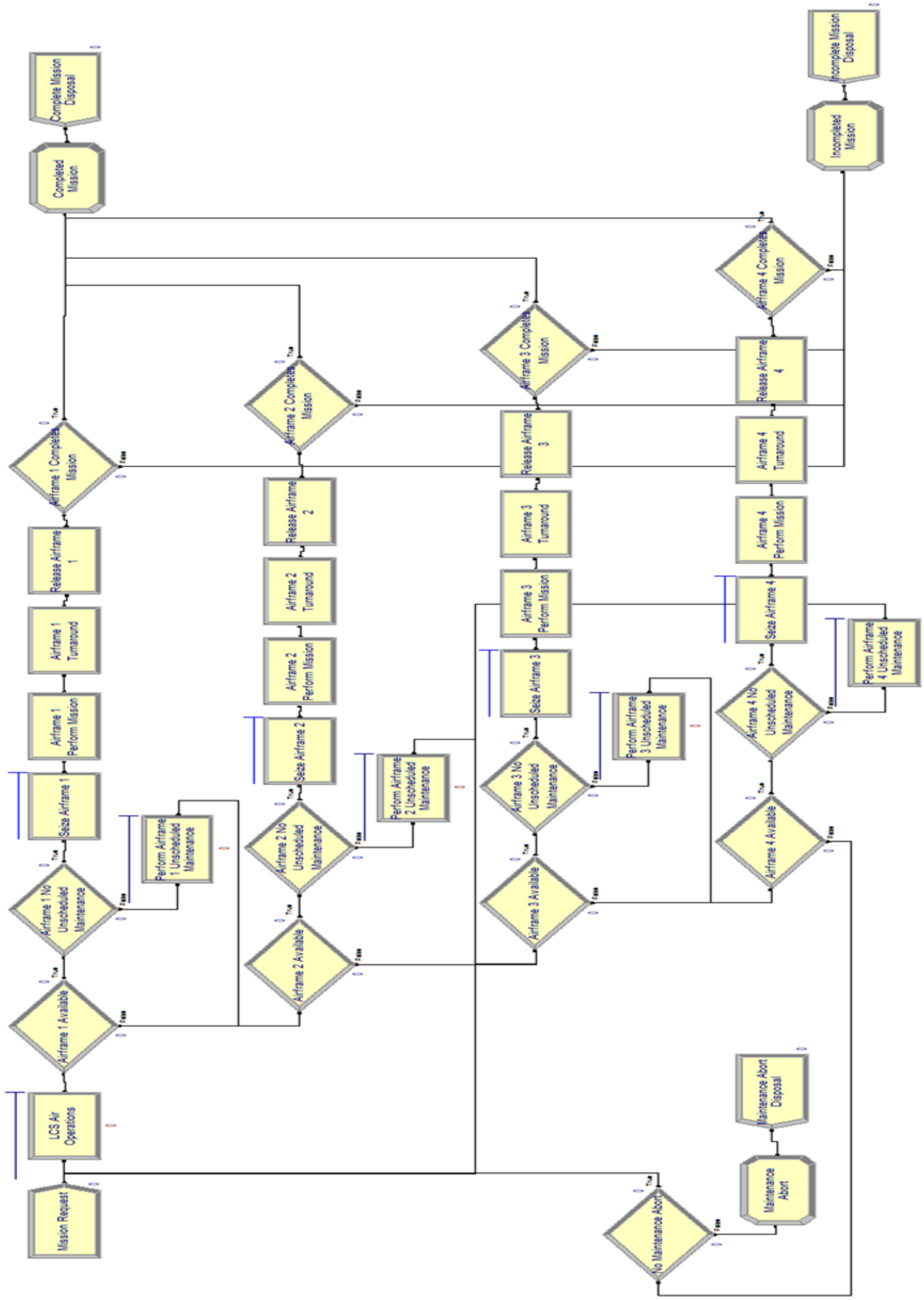
- Passenger and Cargo Transfer (PAX Transfer)
- Vertical Replenishment (VERTREP)
- Search and Rescue (SAR)
- Special Operation Forces (SOF)
- Medical Evacuation (MEDEVAC)

Recommend adjusting airframe-tasking prioritization based on the particular mission. The captain of the LCS would do this instinctively. For example, the mission is simply Surface Surveillance & Control (SSC) can be done with the same capability as the MQ-8B. Therefore, the LCS captain would send the MQ-8B because of it's lower cost while maintaining the AvDet's ability to conduct any of the secondary missions listed above.

Appendix A – Model Details

Overview

Arena Simulation Software was employed to simulate LCS aviation deployment detachments. The components of the aviation detachment consisted of an air operations department, MQ-8 aircraft, and MH-60R aircraft. The model schedule was built with the current LCS CONOPS in mind simulating 24 hour operational days for 24 days a month over a sixteen month period. This simulation would be repeated for 1000 iterations. The output was analyzed while varying the number of resources available, the rate of mission generation, and sortie completion rates.


Mission Request
LCS Air Operations
Airframe 1 Available
Airframe 1 No Unscheduled Maintenance
Perform Airframe 1 Unscheduled Maintenance
Seize Airframe 1
Airframe 1 Perform Mission
Airframe 1 Turnaround
Release Airframe 1
Airframe 1 Completes Mission
Completed Mission
Complete Mission Disposal
Airframe 2 Available
Airframe 2 No Unscheduled Maintenance
Perform Airframe 2 Unscheduled Maintenance
Seize Airframe 2
Airframe 2 Perform Mission
Airframe 2 Turnaround
Release Airframe 2
Airframe 2 Completes Mission
Airframe 3 Available
Airframe 3 No Unscheduled Maintenance
Perform Airframe 3 Unscheduled Maintenance
Seize Airframe 3
Airframe 3 Perform Mission
Airframe 3 Turnaround
Release Airframe 3
Airframe 3 Completes Mission
Airframe 4 Available
Airframe 4 No Unscheduled Maintenance
Perform Airframe 4 Unscheduled Maintenance
Seize Airframe 4
Airframe 4 Perform Mission
Airframe 4 Turnaround
Release Airframe 4
Airframe 4 Completes Mission
Incompleted Mission
Incomplete Mission Disposal
No Maintenance Abort
Maintenance Abort
Maintenance Abort Disposal

Mission Entity

The entity that travelled through the simulation was a generic mission. For the base model they were generated with an exponential distribution (for the heavy tail) once every eight hours (or three missions a day). The rate of generation was increased to and exponential distribution of one every four hours (or six missions a day) to analyze the effect of maintenance schedules on the ability of the AVDET to field missions in higher tempo operations. Upon receipt by air operations five minutes would pass for the mission to be fielded to an aircraft. If no aircraft were made available this process would return to air operations for another five minutes and then attempt to be fielded. This process would repeat for up to twelve hours at which point it would be changed to an aborted mission and removed from the system. Once a mission was fielded it would pass through the respective airframe and be disposed of either as a complete or incomplete mission, decided by the airframe sortie completion rate.

Air Operations

The air operations process was a queue that accepted new missions and recycled old missions that had yet to be fielded by an aircraft. Each time a mission went through air operations it would acquire five minutes for processing and it would release the mission that had been in the system the longest, specifically the mission with the oldest creation time. There was no limit to the size of the air operations queue and it was operating continuously during flight operations.

Aircraft Maintenance

There were six resources available, two MQ-8 and 2 MH-60R, to appease every possible combination of AVDET composition. Each airframe took in to account actual calendar, actual hourly, estimated daily, and estimated unscheduled maintenance requirements. Calendar maintenance was simulated with a calendar schedule for availability of the airframe. These schedules were staggered to best mimic actual operations, I.e. deployed maintainers won't have all aircraft down at the same time rather stagger them accordingly. Hourly maintenance was executed by employing failures for the airframes so that for every number of flight hours flown they would be unavailable for the prescribed period of time. After a mission had been executed the airframe would be unavailable for one hour for turnaround and daily maintenance. The unscheduled maintenance requirement was exponentially distributed (again for the heavy tails) for one hour with a 10% probability of occurrence (we employed 10% due to a lack of historical data). If a resource was engaged in any of the three forms of maintenance it would be unavailable until that maintenance was completed.

Aircraft Logic Process

A mission arrived at the aircraft and first inquired if the airframe was available. Airframe availability was dependent on not only the aforementioned maintenance requirements but also if it was in the middle of executing a mission. Missions would arrive to the first airframe and then continue to the next based on the availability of the first and continue downward. As a result there was an inherent favoritism according to the order of the airframes. In order to understand how this affected AVDET effectiveness the order would be shuffled (MH-60R before the MQ-8B, vice versa). Once the mission arrived at an airframe that was available it would then seize the specified resource (one of the aircraft) and execute the mission for three hours. After the mission the airframe would be unavailable for a follow-on hour for turnaround and daily maintenance. The mission entity would then release the resource and enter a sortie completion decision module where the probability of sortie completion was based on both fleet statistics (75% for the MQ-8B and 95% for the MH-60R) and varying figures (MQ-8B 65%-95%).

Output Statistics

At the completion of the 1000 simulations the output statistics tallied several measures of performance related to time, utilization, and mission statistics. Mission entity statistics were gathered for time required for a mission to be received by an airframe and total time required (outside of maintenance and mission execution) to disposal. The airframe utilization statistics were compiled to identify how many missions were seized by which airframe. It was with that information we were able to extrapolate costs given we have historical data for cost per flight hour. The output also included mission statistics, specifically the number of completed mission, incomplete missions, and aborted missions.

Appendix B – Performance Assumptions

To establish the baseline for our model, a number of performance assumptions needed to be made. These regarded platform mission completion rates, mission times, and rate of mission tasking.

Mission Completion Rate

First, the mission completion rate for the MH-60 was based off performance data issued by Sikorsky and Lockheed Martin after the MH-60R's first deployment aboard the USS John C Stennis. During that deployment HSM-71 flew 2,700 hours and achieved a 95% mission completion rate. For the MQ-8B, data was collected for all Fire Scout flights originating from Patuxent River, MD, between 2010 and 2012. That information can be seen below. (Provided courtesy of PMA-299- PAX River)

Grand Totals: Oct 2010 - Mar 2012																	
We have flown a total of 515.2 hours of the 1825 hours scheduled (28% airspace usage) We have flown a total of 297 sorties of the 455 sorties scheduled (65% sortie rate)																	
		Cancel Reasons								Total Flt	Airspace	Airspace	Hrs	Airspace	Sched	Sorties	Sorties
AV		WX	Maint	Sig Evt	NR	LL	Proj	TP	IFC	Hrs Canx	Canx	Sched	Flown	Used	Sorties	Flown	Rate
Hours		***204.6***	***421.2***	***38***	***18***	***20***	***58.3***	***4***	***12***	***776.1***	***43%***	***1825***	***515.2***	***28%***	***455***	***297***	***65%***
Percent		11%	23%	2%	1%	1%	3%	1%	1%								

The effective mission completion rate over that time was 65%. As 11% of all cancellations were due to weather, we factored that out and rounded to a 75% mission completion rate based on aircraft performance.

Mission Times

Based on the combined deployment experience of the members of the group, we utilized a 3 hour average mission time. The deployment experiences ranged from both HSC and HSM communities, based on both big deck (LHA, LHD, and CVN platforms) and CRUDES hulls, and encompassed missions including ASW, SUW, and SOF support.

Rate of Mission Tasking

To model the rate of mission tasking an approximation of 3 missions per day was utilized. In order to incorporate this into Arena, a conversion to 1 mission every 8 hours was utilized. To further model real world mission tasking, we used an exponential distribution with a mean of 8 hours and a λ of 1/8.

Appendix C – Simulation Output Data

Baseline Comparison

		4 UAS	2 UAS H60	H60 2 UAS	2 H60	H60	H60 1 UAS	3 UAS
	Sortie Completion	75%	75%	75%	95%	95%	75%	75%
	Average M	1152.53	1151.74	1153.64	1153.31	1154.11	1154.23	1152.08
	Min Average M	1052	1041	1054	1035	1053	1038	1048
	Max Average M	1252	1259	1260	1256	1312	1252	1257
Units Seized		706.84	729.65	642.16	760.8	1281.39	715.88	721.58
		370.98	398.02	431.2	520.43		566.87	388.29
		151.99	151.74	208.18				170
		50.74						
Completed Missions	Average	864.11	891.21	980.66	1095.35	864.46	865.49	863.45
	Min Average	771	797	896	980	776	773	770
	Max Average	958	997	1087	1207	982	992	962
	Average Xfer T	0.0918	0.1842	0.1822	1.3557	14.8867	0.8889	0.144
	Min Average Xfer T	0.0835	0.1233	0.1177	0.8113	9.9759	0.581	0.1036
	Max Average Xfer T	0.1264	0.3188	0.3002	2.0213	35.7206	1.2653	0.2158
	Average Wait T	0.2463	0.3058	0.4543	0.5459	0.5357	0.4436	0.2475
	Min Average Wait T	0.1905	0.1733	0.2279	0.2987	0.2828	0.1652	0.1931
	Max Average Wait T	0.3052	0.5102	0.7661	0.8514	0.8738	0.7475	0.3193
Incompleted Missions	Average	287.93	259.99	172.49	57.35	288.15	288.06	287.93
	Min Average	237	205	136	35	239	237	231
	Max Average	342	318	215	86	356	343	354
	Average Xfer T	0.092	0.1799	0.233	1.3653	14.855	0.8929	0.1435
	Min Average Xfer T	0.0833	0.1009	0.1026	0.3622	9.0452	0.436	0.0892
	Max Average Xfer T	0.1453	0.4619	0.4919	3.3492	33.865	1.7278	0.3163
	Average Wait T	0.2467	0.2624	0.3205	0.5365	0.5409	0.4432	0.2486
	Min Average Wait T	0.1548	0.1304	0.0976	0	0	0.0627	0.1585
	Max Average Wait T	0.3446	0.5713	0.8922	2.8585	1.1902	1.0614	0.3953
Weighted Statistics		636.156	656.685	577.944	684.72	1153.251	644.292	649.422
		333.882	358.218	388.08	468.387		510.183	349.461
		136.791	136.566	187.362				153
		45.666						
	Average Xfer T	0.08800	0.183142969	0.189718129	1.355460327	14.85943	0.8893745	0.1437875
	Min Average Xfer T	0.07996	0.118185688	0.115392285	0.788538749	9.730563	0.5444702	0.0999381
	Max Average Xfer T	0.12537	0.350953452	0.328735102	2.086262648	35.21088	1.3799802	0.2407860
	Average Wait T	0.23608	0.295859651	0.434101525	0.545143838	0.536302	0.4432388	0.2476245
	Min Average Wait T	0.17448	0.163534642	0.208321	0.283688726	0.211824	0.1395218	0.1843353
	Max Average Wait T	0.30131	0.523753303	0.78462883	0.950755621	0.951660	0.8253993	0.3381000

Increased Mission Tasking

	Sortie Completion	4 UAS	3 UAS	2 UAS	2 UAS H60	H60 2 UAS	H60 1 UAS	H60	2 H60
	Average M	2305.83	2306.83	2305.16	2308.21	2307.16	2304.53	2302.25	2306.12
	Min Average M	2155	2147	2148	2159	2156	2162	2127	2143
	Max Average M	2460	2464	2461	2465	2443	2445	2447	2468
Units Seized	H60 A	0	0	0	511.52	990.22	1180.14	1505.79	1234.89
	H60 B	0	0	0	0	0	0	0	1093.11
	UAS A	1067.25	1135.22	1360.69	1161.73	916.7	1244.77	0	0
	UAS B	764.5	851.26	1145.17	885.46	651.11	0	0	0
	UAS C	474.65	575.46	0	0	0	0	0	0
	UAS D	256.21	0	0	0	0	0	0	0
Completed Missions	Average	1728.89	1728.28	1690.61	1817.9	1842.4	1635.95	1016.63	1570.45
	Min Average	1607	1593	1567	1660	1689	1538	953	1461
	Max Average	1840	1860	1800	1964	1967	1749	1077	1693
	Average Xfer T	0.1576	0.4288	1.6125	0.5674	0.6025	2.0113	4.5374	2.3663
	Min Average Xfer T	0.1199	0.3173	1.2807	0.3892	0.4431	1.7225	3.9726	1.9968
	Max Average Xfer T	0.2167	0.604	2.0022	0.7757	0.7743	2.438	5.1596	2.6964
	Average Wait T	0.2479	0.2508	0.2512	0.3387	0.3861	0.4188	0.5951	0.5809
	Min Average Wait T	0.2084	0.2142	0.2126	0.2012	0.2453	0.2829	0.2985	0.3552
	Max Average Wait T	0.2856	0.2858	0.2847	0.4767	0.5387	0.5805	0.8715	0.8041
Incompleted Missions	Average	575.89	576.06	563.79	484.05	458.04	545.97	337.99	524.62
	Min Average	501	496	496	409	398	483	288	455
	Max Average	654	644	636	551	537	624	388	589
	Average Xfer T	0.1583	0.4284	1.6181	0.5551	0.5295	2.0072	4.5388	2.3596
	Min Average Xfer T	0.1037	0.2817	1.2447	0.3505	0.3162	1.6345	3.8088	1.881
	Max Average Xfer T	0.2291	0.708	2.1151	0.7784	0.7488	2.4205	5.1725	2.8292
	Average Wait T	0.2487	0.2515	0.251	0.2734	0.4257	0.4175	0.5906	0.5707
	Min Average Wait T	0.1875	0.1915	0.1892	0.1439	0.1159	0.1428	0.0703	0.092
	Max Average Wait T	0.3254	0.3216	0.3257	0.4423	0.8027	0.7591	1.1953	1.1647
Maintenance Aborts	Average	0.024	1.233	49.283	5.153	5.544	120.97	947.64	209.4
	Min Average	0	0	22	0	0	75	822	138
	Max Average	3	9	89	14	19	197	1065	286
	Average Xfer T	0.2411	7.7347	12.0494	11.7469	11.7588	12.0485	12.0492	12.0485
	Min Average Xfer T	0	0	12.0224	0	0	12.0336	12.0433	12.0353
	Max Average Xfer T	12.0833	12.0833	12.0791	12.0833	12.0833	12.0654	12.0554	12.0605
	Average Wait T	0.0015	0.0191	0.0238	0.0262	0.0333	0.0333	0.0173	0.0264
	Min Average Wait T	0	0	0	0	0	0	0	0
	Max Average Wait T	1.5	1.5	0.1531	4.2083	4.2083	0.3673	0.1094	0.4185

Weighted Statistics

H60 A	0	0	0	460.368	891.198	1062.126	1355.211	1111.401
H60 B	0	0	0	0	0	0	0	983.799
UAS A	960.525	1021.698	1224.621	1045.557	825.03	1120.293	0	0
UAS B	688.05	766.134	1030.653	796.914	585.999	0	0	0
UAS C	427.185	517.914	0	0	0	0	0	0
UAS D	230.589	0	0	0	0	0	0	0
Average Xfer T	0.15770	0.432371	1.835971	0.5895063	0.6145082	2.5357727	7.629592	3.2422445
Min Average Xfer T	0.11579	0.308067	1.500726	0.3800287	0.4166159	2.2416789	7.270588	2.8805424
Max Average Xfer T	0.21982	0.635777	2.243968	0.8011380	0.7960178	2.9374830	7.999929	3.5749592
Average Wait T	0.24798	0.250714	0.246128	0.3241459	0.3929172	0.3979582	0.356610	0.5278143
Min Average Wait T	0.20308	0.208300	0.202195	0.1886380	0.2188957	0.2346572	0.142132	0.2628175
Max Average Wait T	0.29542	0.295233	0.291731	0.4775880	0.5996551	0.6112079	0.605348	0.8505444

Adjusted Sortie Completion Rate

	UAS Eff	4 UAS	2 UAS H60	H60 2 UAS	2 H60
	65%	749.6	789.98	923.29	
Completed	75%	864.11	891.21	980.66	
Missions	85%	979.74	992.82	1037.99	
	95%	1094.93	1094.18	1095.84	1095.35

Time to Mission Execution (Hours)

		4 UAS	2 UAS H60	H60 2 UAS	2 H60
	Max	0.13106794	0.350953452	0.328735102	2.086262648
Xfer	Min	0.083414535	0.118185688	0.115392285	0.788538749
	Ave	0.091810936	0.183142969	0.189718129	1.355460327
	Max	0.314913321	0.523753303	0.78462883	0.950755621
Wait	Min	0.181500281	0.163534642	0.208321	0.283688726
	Ave	0.246295215	0.295859651	0.434101525	0.545143838

		4 UAS	2 UAS H60	H60 2 UAS	2 H60
T to Ex	0	0.338106151	0.47900262	0.623819653	1.900604165
M Comp	0	864.11	891.21	980.66	1095.35

Total Deployment Cost

	Seized	Rate	Comp	Cost
UAS A	636.156	0.75	477.117	$4,225,348.15
UAS B	333.882	0.75	250.4115	$2,217,644.24
UAS C	136.791	0.75	102.59325	$908,565.82
UAS D	45.666	0.75	34.2495	$303,313.57
Total			864.37125	$7,654,871.79

UAS A	656.685	0.75	492.51375	$4,361,701.77
UAS B	358.218	0.75	268.6635	$2,379,283.96
H60	136.566	0.95	129.7377	$1,591,492.37
Total			890.91495	$8,332,478.09

H60	577.944	0.95	549.0468	$6,735,157.10
UAS A	388.08	0.75	291.06	$2,577,627.36
UAS B	187.362	0.75	140.5215	$1,244,458.40
Total			980.6283	$10,557,242.86

H60 A	684.72	0.95	650.484	$7,979,487.23
H60 B	468.387	0.95	444.96765	$5,458,418.16
Total			1095.45165	$13,437,905.39

Cost Analysis

		4 UAS	2 UAS H60	H60 2 UAS	2 H60	3 UAS	H60 1 UAS	H60
Missions per Airframe	H60 A		136.566	577.944	684.72		644.292	1153.251
	H60 B				468.387			
	UAS A	636.156	656.685	388.08		649.422	510.183	
	UAS B	333.882	358.218	187.362		349.461		
	UAS C	136.791				153		
	UAS D	45.666						
	Total	1152.495	1151.469	1153.386	1153.10	1151.883	1154.475	1153.251
	H60 Cost ($M)	$-	$1.68	$7.09	$14.15		$7.90	$14.15
	UAS Cost ($M)	$10.21	$8.99	$5.10	$-	$10.20	$4.52	
	Total Cost ($M)	$10.21	$10.66	$12.19	$14.15	$10.20	$12.42	$14.15

References

Alkire, Brien and others. *Littoral Combat Ships: Relating Performance to Mission Package Inventories, Homeports, and Installation Sites.* Santa Monica: National Defense Research Institute, 2007.

Commander, U.S. Fleet Forces Command. *Littoral Combat Ship Platform Wholeness Concept of Operations.* San Diego: Commander, Naval Surface Forces, October 2011.

Commander, Naval Air Systems Command. *NATOPS Flight Manual Navy Model MQ-8B Unmanned Aerial Vehicle*, PMA-266: Patuxent River, 2011.

Commander, Naval Surface Force, U.S. Pacific Fleet. *Littoral Combat Ship Training Manual.* San Diego: Commander, Naval Surface Forces, September 2011.

Fire Scout UAV Integrated Test Team. *Amendment 1 to MQ-8B Fire Scout Ship Suitability Testing Aboard USS Freedom (LCS-1) Test Plan.* Patuxent River: HX-21, November 2011.

Harrison, Frank. "Composite AvDet Maintenance and Rotational Planning Aboard LCS." Power Point Presentation presented to VADM Daly, Deputy Commander, Fleet Forces Command, San Diego, California, April 4th, 2011.

Lopez, Julia. "Cost-Attribute Analysis of Restructuring H-60R/S Fleet Replacement Squadrons." PhD diss., Naval Postgraduate School, 2011.

Murphy, Robert. *Installation Design Requirements (IDR) Vertical Take-off and Landing Tactical Unmanned Aerial Vehicle MQ-8B Fire Scout.* Patuxent River: NAVAIR PMA-266, April 2008.

Office of the Chief of Naval Operations. *MQ-8B Naval Aviation Technical Information Product (NATIP): NTRP 3-22.4-MQ8B,* Airworthiness Office: Patuxent River, February 2011.

O'Rourke, Ronald. *Navy Littoral Combat Ship (LCS) Program: Background, Issues, and Options for Congress.* Washington D.C.: Congressional Research Service, April 6th, 2012.

Program Executive Officer Littoral & Mine Warfare. *Annual Report FY2010*. Washington Navy Yard: Washington D.C. 2010.

Research, Development, Test & Evaluation, Navy. "Exhibit R-2, RDT&E Budget Item Justification: PB2013 Navy- PE 0305231N: MQ-8 UAV." February 2012.

Schweizer Aircraft. *Schweizer Model 333.* Stratford: Sikorsky.