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SEA FIGHTER ANALYSIS

SUMMARY REPORT

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16. Abstract (MAXIMUM 200 WORDS)

The U.S. Coast Guard (CG) Research & Development Center (R&DC) evaluated the U.S. Navy's Sea Fighter vessel (FSF-1) for potential applicability for CG missions. For this evaluation, the project team used a combination of engagement modeling and simulation (M&S), human systems integration (HSI) modeling, and Sea Fighter crew and shiprider insights.

Specifically, the R&DC evaluated four Sea Fighter attributes that could significantly impact CG mission effectiveness: A maximum rate of speed (50 kts); multiple deployable surface and air assets; small crew size (26); and a reconfigurable mission bay (accommodates 12 mission modules). This report analyzes and discusses the findings of these evaluations, draws conclusions from the findings, and makes recommendations concerning future application of Sea Fighter's organic capabilities.

Additional technical information that was developed in conjunction with this evaluation can be found in appendices B-E attached in electronic format.

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EXECUTIVE SUMMARY

Introduction/Objective

The U.S. Coast Guard (CG) Research and Development Center (R&DC) evaluated the U.S. Navy's Sea Fighter vessel for potential applicability to CG missions. When compared to other CG cutters, Sea Fighter has four unique capabilities/characteristics that could significantly impact CG mission effectiveness:

- High-speed (50 kts)
- Multiple deployable surface and air assets (three 11m Rigid Hull Inflatable Boats (RHIBs) (Cutter Boats Over-The-Horizon (CB-OTH)) or five 7m RHIBs (Short Range Prosecutors (SRP)), two HH-60s or two HH-65s, and multiple Vertical Unmanned Aerial Vehicles (VUAVs))
- Small crew size (26 persons)
- Reconfigurable Mission bay (accommodates 12 mission modules)

Methodology

This project evaluated Sea Fighter's unique capabilities through a combination of engagement modeling and simulation, human systems integration modeling, and Sea Fighter crew and shiprider insights (following multiple R&DC operational test and evaluation exercises).

Results

High-speed and multiple deployable assets were evaluated using engagement modeling. Scenarios were developed to simulate fishing-like vessels (lower speed with higher density) and drug smuggling-like vessels (higher speed with lower density). The results of the analysis showed that by themselves high-speed and multiple deployable assets made little improvement in mission effectiveness. However, as Sea Fighter's sensor detection range and/or its off-board detection capability (a vital contributor to maritime domain awareness (MDA)) improved, high-speed and multiple deployable assets did lead to significant improvements in mission effectiveness. In the simulated scenarios, improving components of MDA (off-board detection capability) was the critical performance driver, followed closely by increasing intercept speed (from 30 to 50 kts) and increasing the number of deployable assets from two to four (particularly increasing the number of deployable helicopters). These improvements result in an almost 30 percent increase in the number of high-speed targets that can be boarded.

Crew size, required functions, and fatigue associated with a typical CG patrol were evaluated through human system integration (HSI) modeling. With Sea Fighter's highly automated bridge and engine room, a 26-person crew can sustain many of the required functions. For a typical 14-day patrol, Sea Fighter's crew could sustain normal Condition-3 watches, multiple boardings (some simultaneously), and multiple VUAV launches. However, HSI modeling showed that Sea Fighter's crew could not sustain regularly scheduled helicopter flight operations.

To account for these deficiencies, the crew was optimized by adding two boatswain mates and a six-person detachment—Law Enforcement Detachment (LEDET), Maritime Safety and Security Team (MSST), or Maritime Security Response Team (MSRT). This 28+6 optimal crew was able to sustain all required functions. In a typical 14-day patrol scenario, the 28+6 optimal crew averaged three boardings, two helicopter sorties, and three VUAV sorties each day without exceeding acceptable fatigue levels.

Finally, crew and shipriders provided firsthand observations and insights relative to Sea Fighter's unique capabilities. Some key insights are:

- High-speed capability is a distinct advantage in a vessel accomplishing any law enforcement mission and is especially effective at intercepting fast, evasive, and uncooperative targets.
- Sea Fighter's ride quality at low speed (less than 15 kts) is very poor and can adversely affect operations or activities; however, ride quality significantly improves at higher speeds (20+ kts). The trade off is largely due to hull design consideration made during Sea Fighter's planning phase.
- RHIB launch and recovery is limited to 5 kts due to the poorly designed stern ramp and vessel movements at low (less than 15 kts) speeds.
- A crew of 26 is too small for typical CG operations.
- Overall, ship layout and configuration are excellent. Bridge layout affords excellent visibility, internal communications, and improved situational awareness with all underway watchstanders located on the bridge. Flight deck lighting, configuration, and manning are exceptional from both a crew and pilot perspective.
- Sea Fighter's mission bay can provide remarkable mission flexibility, especially for deployable teams such as MSRTs or MSSTs. However, spaces for 12 mission modules seem a bit excessive for CG needs. In addition, the design of the X-Y crane prohibits moving payloads (including extra 11m or 7m RHIBs) while underway.

Conclusion

A 50-kt Sea Fighter-like vessel with four deployable assets (two 11m OTH RHIBs and two HH-60 helicopters) can provide significant performance improvement compared to a traditional 30-kt CG vessel (CG High-Endurance Cutter (WHEC) or CG Patrol Boat (WPB)).

A highly automated Sea Fighter-like vessel, with the crew size of a patrol boat, provides more mission capability than a WHEC. The ModCAT hullform and large mission bay provide excellent flexibility for emerging CG missions and demands. Sea Fighter's speed and multiple deployable asset capability offer outstanding performance improvement potential for the CG; however, a critical enabler is improving detection capabilities – an element of maritime domain awareness. As MDA improves, a 50-kt patrol vessel capable of deploying four assets could provide a tremendous improvement over current and future 30-kt vessels.

Recommendations

The CG needs to continue to evaluate non-standard hull forms such as ModCAT-type vessels for both speed and modularity purposes. High-speed vessels normally have endurance problems based on their fuel consumption rates. This has been one of the perceived shortcomings of this hullform type. However, the ModCAT hullform (i.e. Sea Fighter) provides very good fuel economy and, given the typical patrol profile (12 kt patrol speed, 20 kt transit speed, and 50 kt intercept speed), the vessel is capable of remaining within the patrol area for an entire patrol period. Opportunities exist for the CG to further evaluate other Navy/DOD high-speed vessels (HSV) such as the M88 Stiletto for MSRT type missions and the HSV platforms, HSV Swift and HSV Joint Venture, for extended duration missions.

Additionally, the CG should look at ways to optimize the number and type of deployable and off-board assets through a more detailed M&S analysis. A 50 kt Sea Fighter-like cutter with four deployable assets (e.g., two 11 m OTH RHIBs and two HH-60 helicopters) can provide significant mission performance improvement compared to a standard 30 kt cutter. To maximize the benefit from embarking four deployable assets (two 11 m OTH RHIBs and two HH-60s), a revised approach to boardings would need to be established. Currently, boardings are to be conducted within two hours from the WHEC (at the WHEC's maximum speed). Under the MSRT CONOPs, the boarding teams would need to be trained similar to MSRTs which are able to defend themselves while conducting a boarding at greater distances from the patrol vessel.

The CG needs to continue to incorporate more automated systems on-board cutters, but have contingency plans (both personnel and equipment) in place for changes in operational requirements or causalities. In order to derive optimal mission effectiveness, the patrol cutter must be able to safely navigate and operate deployable assets in varying sea states and at a reasonable speed. Sea Fighter's automated systems allow for these evolutions to be conducted with fewer crew members and with an acceptable margin for safety.

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LIST OF ACRONYMS

AFFF	Aqueous Film Forming Foam
AMIO	Alien Migrant Interdiction Operations
AVGAS	Aviation Gasoline
BM	Boatswain Mates
CB-OTH	Cutter Boats Over-The-Horizon
CG	Coast Guard
CG-37RCU-2	Cutter Platforms Division
COMMS	Communications
CONOPS	Concept of Operations
EOW	Engineer of the Watch
FSF-1	Fast Sea Frame-1
ft	Foot or feet
HH-60	Medium-range Recovery Helicopters
HH-65	Multi-mission Cutter Helicopters
HSI	Human Systems Integration
HSK	Helicopter support kit
IBNS	Integrated Bridge and Navigation System
ISO	International Standards Organization
kt(s)	Knot(s)
LCS	Littoral Combat Ship
LEDET	Law Enforcement Detachment
LSE	Landing Signal Enlisted
m	Meter or meters
M&S	Modeling and Simulation
MCS-5	Machinery Control System
MDA	Maritime Domain Awareness
MSRT	Maritime Security Response Team
MSST	Maritime Safety and Security Team
nm	Nautical mile(s)
NOW	Navigator of the Watch
NSC	National Security Cutter
ONR	Office of Naval Research
OOD	Officer of the Deck
OPTEMPO	Operations Tempo
OT&E	Operational Test & Evaluation
R&DC	Research & Development Center
RHIB	Rigid Hull Inflatable Boat
SOLAS	Safety of Life at Sea
SRP	Short Range Prosecutors
SWATH	Small Water-Plane Area Twin Hull
TCM	Total Crew Model
TEU	Twenty-foot Equivalent Units
USCG	U.S. Coast Guard
USN	U.S. Navy

VUAV	Vertical Unmanned Aerial Vehicles
WHEC	Coast Guard High-Endurance Cutter
WPB	Coast Guard Patrol Boat
WQ&SB	Watch, Quarters, and Station Bill

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1. INTRODUCTION

In 1998 the United States Navy (USN) Office of Naval Research (ONR) contracted with Nigel Gee Naval Architects to design a small, fast, highly capable Littoral Surface Craft with a calm water speed of 50 kts, a range of 4,000 nautical miles, unlimited operations in Sea State 4 (~ 8-foot seas), with maximum possible operations in Sea State 5 (~ 10-foot seas). Nigel Gee "modified" the design of a traditional catamaran and developed "ModCAT" to achieve improved seakeeping without a significant degradation to the ships powering. Essentially the high-speed qualities of a catamaran were merged with the seakeeping qualities of a Small Water-Plane Area Twin Hull (SWATH) design as seen in Figure 1.

Figure 1. Sea Fighter during construction (ModCat hull form visible).

ONR contracted with the Titan Corporation (since acquired by L3 Communications) to design and build the Nigel Gee designed ModCAT, artist rendering seen in Figure 2. The USN christened this vessel "Sea Fighter" Fast Sea Frame-1 (FSF-1). ONR developed an Operational Test & Evaluation (OT&E) program to fully assess Sea Fighter's capabilities/characteristics as a potential low-cost alternative for their Littoral Combat Ship (LCS) program.

Sea Fighter's Principle Characteristics

Figure 2. Artist rendering of Sea Fighter.

Table 1. Sea Fighter characteristics.

Length (overall):	79.9 m (262 ft)
Length (waterline):	73 m (240 ft)
Range:	4,000 nm @ 20+ kts
Light Ship Displacement:	960 metric tons
Full Load Displacement:	1150 long tons
Beam:	22 m (72 ft)
Draft:	3.5 m (11.5 ft)
Speed:	50 kts up to Sea State 3 40 kts in Sea State 4
Survivability:	Operational through Sea State 4; Survivable through Sea State 6
Mission Bay:	Support mission modules in ISO TEU (20'×8'×8' containers) Multipurpose stern ramp (launch/recover up to 11 m RHIBs) Side RO/RO ramp (support fully loaded HMMWV)
Flight Deck:	Landing spots for (2) SH-60Rs (day VFR; night NVD/NVG compatible) Refueling capability but no maintenance facilities (no hangar)
Crew:	26 (which includes 10 permanent Coast Guard crew members)

When compared to other U.S. Coast Guard (CG) cutters, Sea Fighter has four unique capabilities/characteristics that could significantly impact CG mission effectiveness:

High-speed

Sea Fighter can achieve 50 kts (sea conditions permitting). CG legacy and proposed Deepwater surface assets do not have this capability. Sea Fighter is seen conducting high-speed maneuvers in Figure 3.

Figure 3. Sea Fighter during high-speed maneuvering off the coast of San Diego.

Multiple Deployable Surface and Air Assets

Sea Fighter has the capability of deploying multiple 11 m rigid hull inflatable boats (RHIB), cutter boats over-the-horizon (CB-OTH) or 7 m RHIB short-range prosecutors (SRP), two medium-range recovery helicopters (HH-60) or two multi-mission cutter helicopter (HH-65) and multiple vertical takeoff and landing unmanned aerial vehicles (VUAV). Two HH-65C helicopters can be seen operating from Sea Fighter's flight deck in Figure 4.

Figure 4. Two HH-65Cs from Air Station LA conducting simultaneous flight operations on Sea Fighter.

Small Crew Size

Sea Fighter's capabilities are comparable to a CG High Endurance Cutter (WHEC), yet her crew size (26 personnel) is comparable to a CG Patrol Boat (WPB). The vessel is highly-automated, with all underway watchstanders located on the bridge. Figure 5 shows part of the integrated bridge console that allows for a 4-person watch section.

Figure 5. Sea Fighter's integrated bridge console.

Modularity

Sea Fighter can accommodate and quickly change-out up to 12 mission modules [20'×8'×8' International Standards Organization (ISO) Twenty-foot Equivalent Units (TEU) containers] in port. Each mission module can be outfitted with mission specific equipment to perform various operational functions. Sea Fighter's mission bay, seen in Figure 6, is where mission modules for specialized teams such as Maritime Safety and Security Teams (MSST) and Maritime Security Response Teams (MSRT) could be deployed.

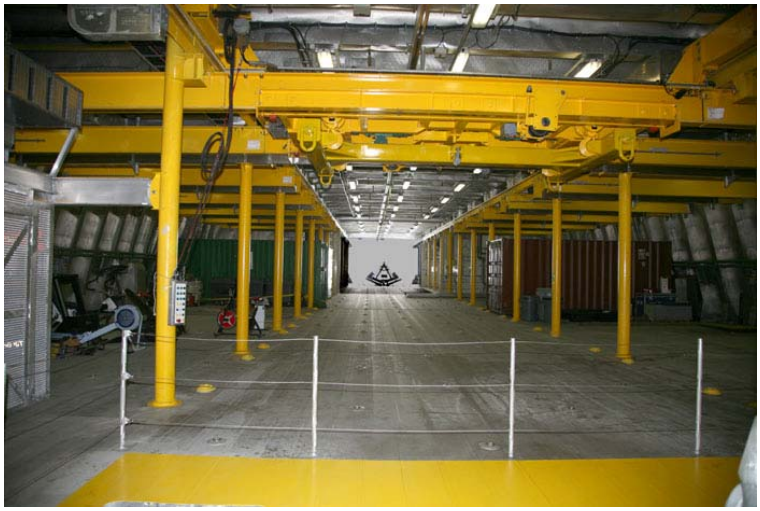

Figure 6. Sea Fighter's mission bay.

Since the inception of the LCS program, the USN and the CG have been discussing the potential applicability for CG missions. In 2004, ONR invited the CG to jointly evaluate Sea Fighter. The CG's Response Directorate, Chief, Cutter Platforms Division (CG-37RCU-2) was assigned as the Program Manager. CG-37RCU-2 leveraged support from the CG Research & Development

Center (R&DC) for the joint evaluation.

The CG provided 10 members of the 26-person crew, including the Executive Officer, for the evaluation of Sea Fighter. With a combined CG and Navy crew, the vessel was scheduled for 13 months of OT&E—8 weeks of which were allocated for strictly CG OT&E. The CG realized that 8 weeks of OT&E were too short to properly evaluate Sea Fighter's unique capabilities. Given Sea Fighter's status as an experimental vessel, the vessel could not be used to execute actual missions. In addition, it is costly and impractical to try to replicate many CG missions, demands, and operating environments.

In order to fully evaluate Sea Fighter's unique capabilities and their impact on CG missions, modeling & simulation (M&S), crew insights obtained through crew surveys/interviews, and contracted shiprider post-sailing reports were developed and studied.

- **OT&E** was used to evaluate the vessels' capabilities, such as speed in various sea states, stability, critical operating parameters, flight operations, launch and recovery of deployable surface assets, and typical shipboard evolutions.
- **Engagement M&S** was used to evaluate two of Sea Fighter's unique capabilities (*high-speed* and *multiple deployable assets*) in executing CG missions.
- **Human Systems Integration (HSI) M&S** was used to determine the capabilities and limitations of the 26-person crew on a highly automated vessel during a typical CG WHEC / national security cutter (NSC) patrol.
- **Crew Insights** were gained through surveys, interviews, and shiprider observations. The combined CG and USN Sea Fighter crew was on-board for the entire OT&E period and gained a wealth of knowledge about the vessel that was invaluable in the overall evaluation of vessel capabilities.

This technical report focuses on the evaluation of Sea Fighter's unique capabilities (*high-speed*, *multiple deployable assets*, *small crew size*, and *modularity*) through engagement M&S, HSI M&S, and crew insights. Conclusions integrate the findings from these three evaluation areas with findings from OT&E and engineering/physical reality.

2. ENGAGEMENT MODELING

Objectives and Approach

The objective of engagement modeling was to determine the impact of *high-speed* and *multiple deployable assets* on CG mission effectiveness. OT&E provided a means to verify and validate certain Sea Fighter characteristics, but did not provide a means to evaluate the impact those characteristics have on mission effectiveness. In addition, the aim of this type of modeling was not necessarily to model Sea Fighter exactly, but to model two of the unique aspects of Sea Fighter: *high-speed* and *multiple deployable assets*.

In this approach, the modeling environment was simplified and leveled so that the impact of *high-speed* and *multiple deployable assets* could be isolated and scrutinized. This "controlled" environment consisted of:

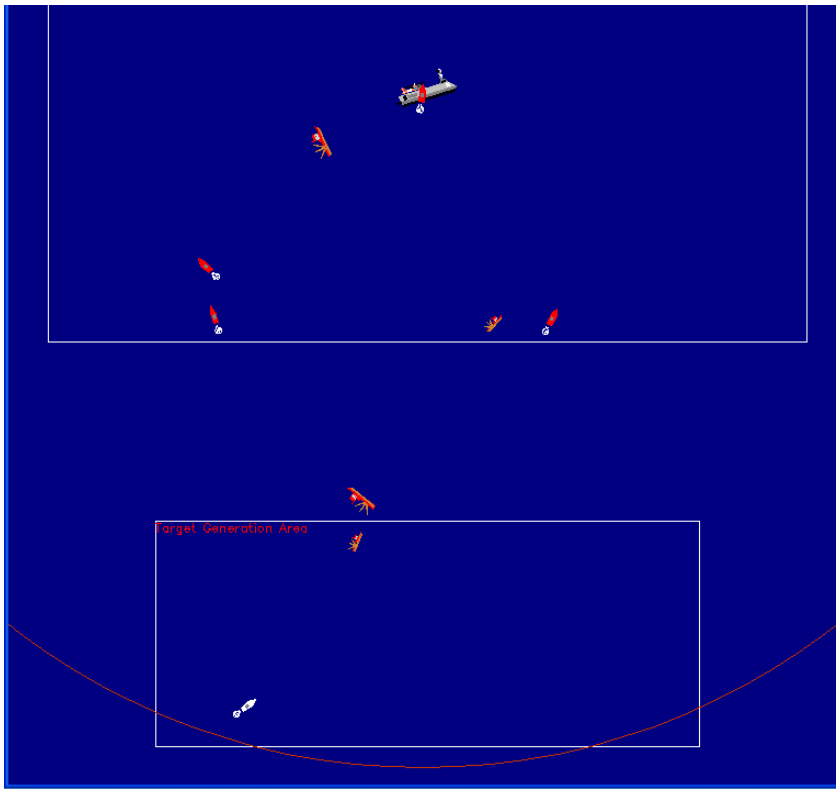

Figure 7. Visual representation of the modeling environment.

- A 160 nm by 350 nm operation area, shown above in the Figure 7; the lower box is the target generation area. The size of the operation area was based on the speeds of Sea Fighter and various targets.
- Calm seas and weather (Sea State 1).
- Sensors were used in daytime configurations only.
- A 14-day continuous patrol (Selected based on typical High Endurance Cutter patrol—14

days underway, mid-patrol break for replenishment, followed by another 14 days underway).

- Unlimited fuel. Although fuel was assumed to be "unlimited," fuel was monitored in the model. Based on the operational profile of 12 kts patrol speed, 20 kts transit speed, and sprinting at max speed for target vessel intercepts, the Sea Fighter has sufficient fuel capacity to sustain a 14-day continuous patrol with more than a 10 percent fuel reserve upon arrival in port for the mid-patrol break.
- To evaluate mission effectiveness, two CG mission-like scenarios were developed:
  - **High-speed (35+ kts) targets/low density (2–5 targets in the patrol area per day).** This scenario corresponds to counterdrug, counterterrorism, and a small subset of Alien Migrant Interdiction Operations (AMIO) missions. In this scenario, Sea Fighter's Concept of Operations (CONOPS) was to patrol using a random search, detect as many targets as possible, and where possible intercept and board those targets moving at a high-speed.
  - **Low speed (less than 15 kts) targets/high density (5–10 targets in the patrol area per day).** This scenario corresponds to fisheries and other missions that involve less evasive targets in greater numbers. In this scenario, Sea Fighter's CONOPS was to patrol using a random search, detect, intercept, and board as many targets as possible.
- All targets were non evasive, and target capture was based on proximity of either Sea Fighter or deployed asset.

Additional details regarding the scenarios (including inputs, outputs, assumptions, variables, CONOPS, etc.) are contained in Appendix B.

During these studies, the M&S team conducted detailed reviews of the outputs. Models were either corrected/adjusted or validated for reasonableness. When the M&S team found outputs to be counterintuitive or intriguing, additional "follow-on" studies were conducted. The findings from these studies are discussed below.

Study Findings

Intercept Speed Study

An intercept speed study was used to determine the impact of cutter intercept speed on targets detected and boarded. The cutter's surface search radar, with base ranges of 18 nm for high-speed targets and 24 nm for low-speed targets, was assumed to be the only means of detecting targets. Cutter intercept speeds were selected based on the maximum speeds of legacy cutters (20 kts), the planned Deepwater NSC (30 kts), and Sea Fighter (50 kts). Two surface boarding assets were used in all modeling runs. Figure 8 illustrates the impact of intercept speed on boarding and detection rates achieved during the modeling runs. These results are discussed below.

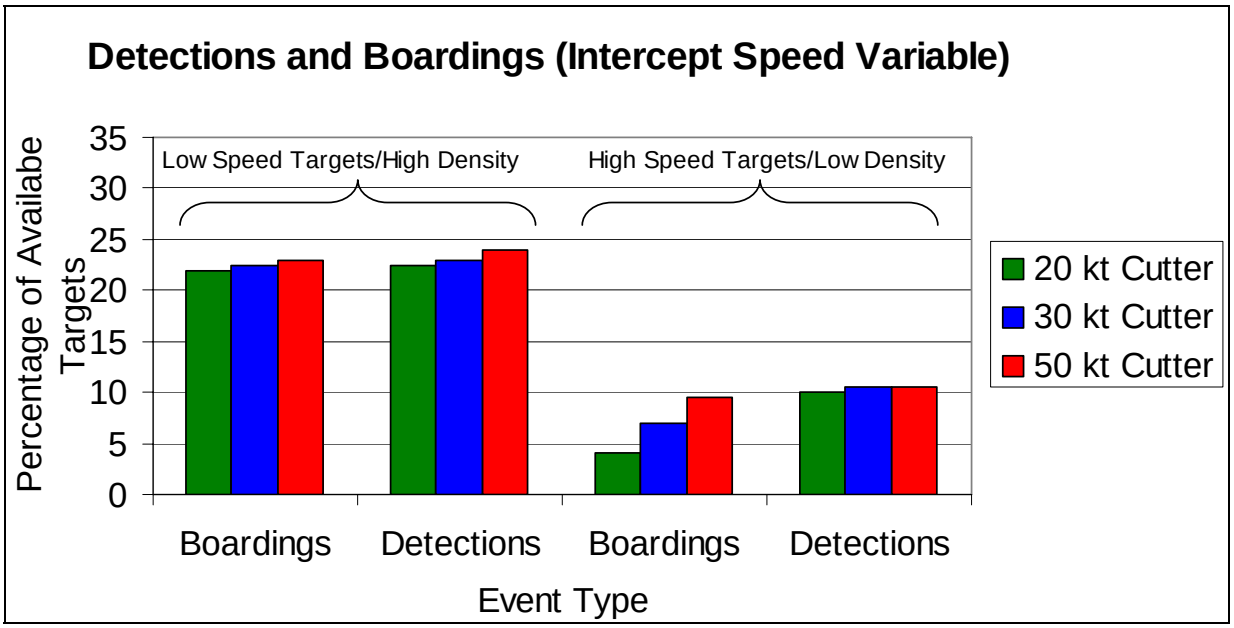

Figure 8. Cutter Intercept Speed verses targets detected and boarded.

<u>Intercept Speed Study Results:</u>

- Cutter intercept speed had little to no impact on targets detected (for both high- and low-speed targets).
- Cutter intercept speed had limited impact on low-speed targets boarded. The percentage of targets boarded increased from 22 percent to 24 percent as intercept speed was raised from 30 to 50 kts, (a 10 percent increase over the baseline value).
- Cutter intercept speed had a significant impact on high-speed targets boarded. The percentage of targets boarded increased from 4 percent to 9 percent as intercept speed was raised from 30 to 50 kts, (a 100 percent increase over the baseline value).
- The cutter sensor range alone provides limited detection capabilities, which in turn results in limited boardings.

<u>Intercept Speed Follow-on Study</u>

Given the cutter's inability to detect the majority of targets in the patrol area (regardless of intercept speed), a follow-on study was developed to determine the impact intercept speed would have with better on-board sensor detection capabilities.

Cutter Sensor Range Study

A cutter sensor range study was conducted to determine the impact on targets boarded with higher cutter intercept speeds given improved detection capabilities. Cutter sensor ranges were varied between base range, 2× base range, and 10× base range. Cutter intercept speeds were modeled at 20 kts, 30 kts, and 50 kts. Two surface deployable assets were used in all modeling runs. Figure 9 illustrates the impact of on-board sensor detection range and cutter intercept speed on boarding rates achieved during the modeling runs.

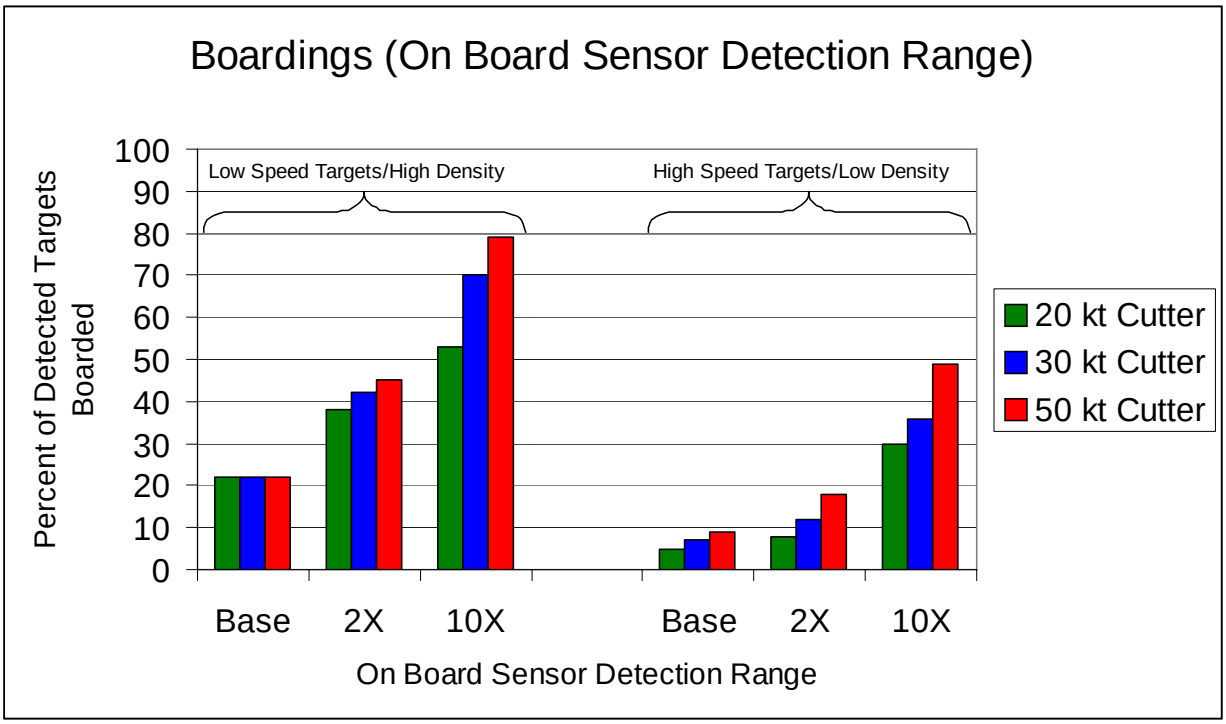

Figure 9. Cutter speed and on-board sensor detection range verses targets boarded.

<u>Cutter Sensor Range Study Results (Low Speed Targets):</u>

- As detection range increases, cutter intercept speed has a significantly greater impact on the percentage of boardings.
- With just a doubling of the cutter's sensor range, the percentage of targets boarded increased from 22 percent to 38 percent for a 20 kt vessel (an increase of 72 percent over the baseline), from 22 percent to 42 percent for a 30 kt vessel (an increase of 90 percent over the baseline), and from 22 percent to 45 percent for a 50 kt vessel (an increase of 104 percent over the baseline).
- At 10× the base cutter sensor range, the patrol vessel can essentially detect all targets within the patrol area. Hence, intercept speed becomes even more of a factor affecting the percentage of targets boarded. The percentage of targets boarded increased from 22 percent to 53 percent for a 20 kt vessel (an increase of 140 percent over the baseline), from 22 percent to 70 percent for a 30 kt vessel (an increase of 218 percent over the baseline), and from 22 percent to 79 percent for a 50 kt vessel (an increase of 260 percent over the baseline).

<u>Cutter Sensor Range Study Results (High-speed Targets):</u>

- Vessel speed has a more significant impact on percent boardings as detection range increases. The high-speed targets are faster than both the 20 kt and 30 kt vessels; therefore, 50 kt vessels can intercept more high-speed targets. The percentage of high-speed targets intercepted by the slower 20 and 30 kt vessels was based solely on being in a positive initial detection position with a non-evasive target.

- By doubling the base cutter sensor range, a 50 kt vessel doubles target boardings from 9 percent to 18 percent, a 30 kt vessel increases boardings from 7 percent to 12 percent (a 71 percent increase over the baseline value) and a 20 kt vessel increases boardings from 5 percent to 8 percent which is a 60 percent increase over the baseline value.
- At 10× base sensor range, a 50 kt vessel increases boardings from 9 percent to 49 percent which represents an increase of 450 percent over the baseline value, a 30 kt vessel increases boardings from 7 percent to 36 percent which is a 414 percent increase over the baseline value and a 20 kt vessel increases boardings from 5 percent to 30 percent which is a 500 percent increase over the baseline value.

Cutter Sensor Range Follow-on Study

Physical constraints such as horizon limits and the physics of sensor technology make it unrealistic to expect a 10× increase in shipboard sensor range anytime soon. However, the CG is increasing its emphasis on improving MDA. Detection capabilities within patrol areas, an important element of MDA, can be improved dramatically through off-board sensors. Off-board sensors on fixed-wing aircraft, long-range UAVs, and satellite coverage can (and do) provide a significant amount of detection capability. Since improved and increased off-board detection capabilities are more realistic than a 10× shipboard sensor, the next study investigated the impact of intercept speed with increasing off-board sensor coverage.

Off-board Sensor Study

The off-board sensor study investigated the impacts cutter speed had on targets boarded based on detections from off-board sensors. In the controlled modeling environment, off-board sensors were assumed to detect targets in the entire patrol area; however, the amount of time the off-board sensors were available was varied from 10 percent per day to 100 percent per day (i.e., 2.4 hours of total area coverage per day to 24 hours of total area coverage per day) for the entire patrol period. Cutter intercept speeds varied between 20 kts, 30 kts, and 50 kts. Two surface deployable assets, RHIBs, were used in all modeling runs. Figure 10 illustrates the impact of off board sensors coverage and cutter intercept speed on boarding rates achieved during the modeling runs. These results are discussed below.

Off-board Sensor Study Results (Low Speed Targets):

- For low-speed targets, the percentage of boardings is dramatically improved with just 10 percent off-board sensor coverage. Since the target vessels are operating at low speeds, they are in the patrol area for a longer period of time. In this scenario even a limited period of complete sensor coverage permits higher speed vessels to effect more boardings.
- With the patrol area covered 10 percent of the time, the percentage of targets boarded increased from 22 percent to 42 percent for a 20 kt vessel (an increase of 91 percent over the baseline), from 22 percent to 60 percent for a 30 kt vessel (an increase of 173 percent over the baseline), and from 22 percent to 70 percent for a 50 kt vessel (an increase of 254 percent over the baseline).
- Increasing off-board sensor coverage time from 10 percent to 80 percent had only a small impact on low speed target boarding rates.

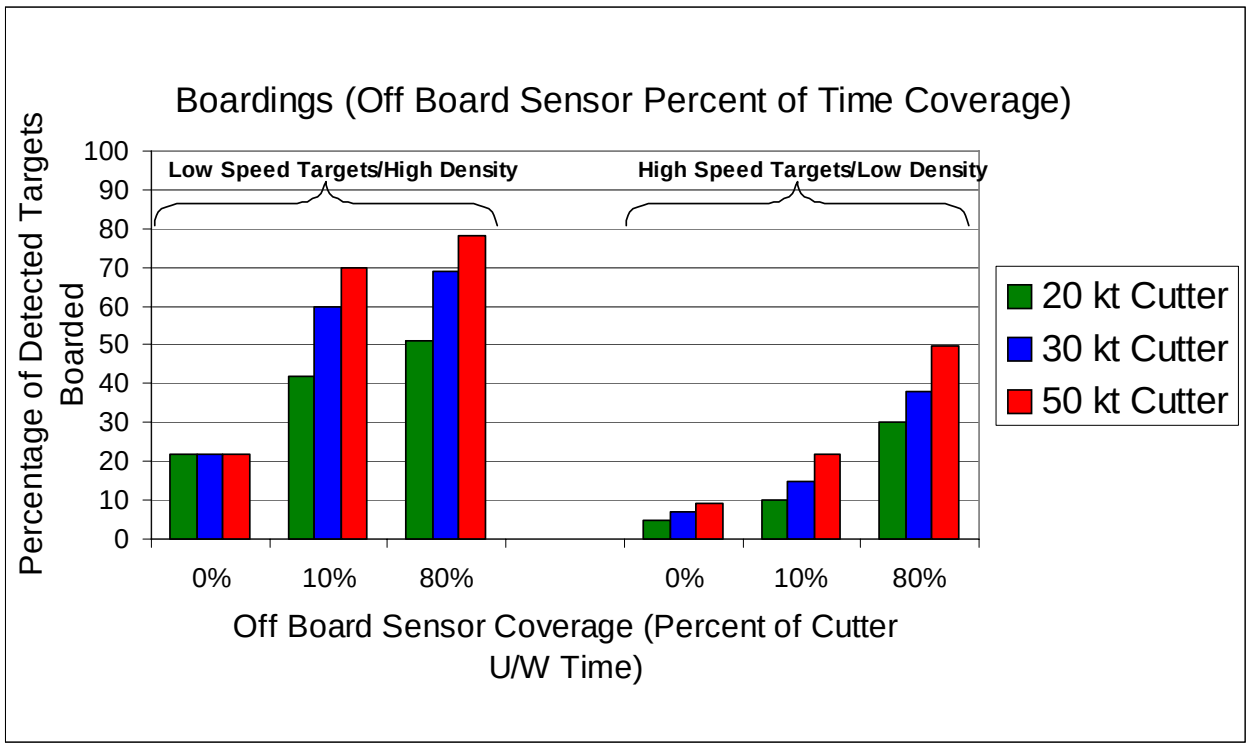

Figure 10. Cutter speed and off board sensor percent of time coverage verses targets boarded findings.

Off-board Sensor Study Results (High-speed Targets):

- For high-speed targets, the percentage of boardings gradually improves with increased sensor coverage time. At around 80 percent coverage time, improvement in boardings due to intercept speed levels off. Unlike low-speed targets, high-speed targets have far less exposure time in the patrol area; therefore, off-board sensors must be available a greater percentage of the time.
- With the patrol area covered 80 percent of the time, the percentage of targets boarded increased from 5 percent to 30 percent for a 20 kt vessel (an increase of 500 percent over the baseline), from 7 percent to 38 percent for a 30 kt vessel (an increase of 442 percent over the baseline), and from 9 percent to 50 percent for a 50 kt vessel (an increase of 455 percent over the baseline).

Off-board Sensor Follow-on Study

The cutter sensor range and off-board sensor studies illustrated that with improved detection capabilities, a 50 kt vessel provides a significant improvement in boardings of both high- and low-speed targets compared to a 30 kt vessel. The next phase of engagement modeling analysis focused on the effects of varying the number and type of deployable assets to execute the boardings. These assets include combinations of 11 m OTH RHIBs and HH-60 helicopters. To help isolate the impact of deployable assets, only 50 kt and 30 kt patrol vessels were evaluated in the multiple deployable assets study.

Multiple Deployable Assets Study

The multiple deployable assets study analyzed the impact of using two, three, or four deployable assets (tethered and untethered).

- Tethered deployable assets are only allowed to affect boardings within 2 hours of the patrol cutter (at the patrol vessel's maximum speed).
- Untethered deployable assets affect boardings within two hours of the patrol cutter at the deployable asset's speed (30 kts for an 11 m OTH RHIB and 150 kts for an HH-60).

The deployable asset configurations were:

- Two deployable assets: two 11 m OTH RHIBs
- Three deployable assets: two 11 m OTH RHIBs and one HH-60
- Four deployable assets: two 11 m OTH RHIBs and two HH-60s

The HH-60s used vertical insertion to transfer boarding teams to the target vessels. Cutter intercept speed was fixed at 30 kts or 50 kts.

This study assumes that cutter sensor range was fixed at 10x base range.

Figure 11 illustrates the impact of number and type of deployable assets, incorporated with cutter intercept speed, on boarding rates achieved during the modeling runs. These results are discussed below.

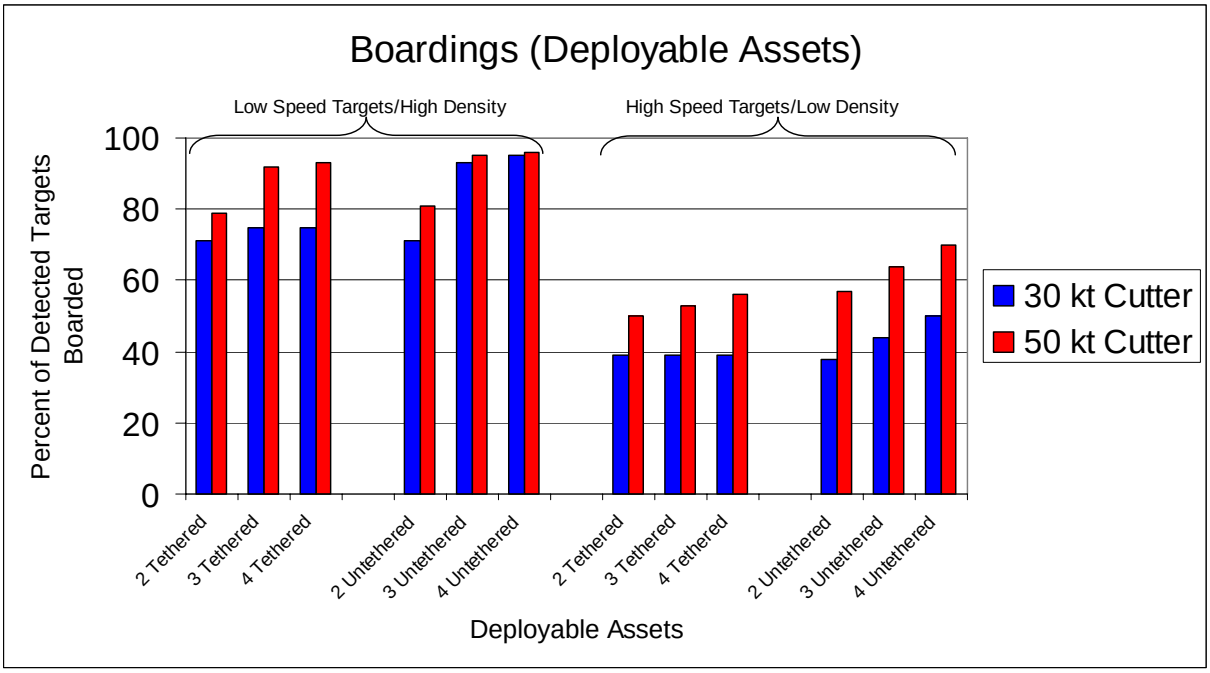

Figure 11. Cutter speed and deployable assets (tethered and untethered) verses targets boarded findings.

Multiple Deployable Assets Study Results (Low Speed Targets):

- With three or four untethered assets, a 30 kt cutter and a 50 kt cutter can execute virtually the same percentage of boardings. In these scenarios, the addition of untethered HH-60 helicopters (boarding range of 300 nm) is the performance driver.
- Compared to a 30 kt cutter, a 50 kt with tethered deployable assets increases the percentage of boardings from 70 percent to 78 percent with two deployable assets and from 74 percent to 93 percent with three or four deployable assets.
- A 30 kt cutter with tethered deployable assets does not gain a significant advantage by increasing the number of deployable assets beyond two, since the assets can only board within two hours of the patrol vessel (or 60 nm for a 30 kt patrol cutter).
- The addition of a fourth deployable asset (a second HH-60) does not improve boarding performance for either cutter speed.

Multiple Deployable Assets Study Results (High-speed Targets):

- With tethered deployable assets, a 50 kt cutter compared to a 30 kt patrol cutter increases the percentage of boardings from 40 percent to 53 percent with two deployable assets and from 40 percent to 57 percent with three or four deployable assets.
- Compared to a baseline 30 kt cutter with two untethered deployable assets, a 50 kt cutter with four untethered deployable assets can nearly double boarding percentage from 37 percent to 67 percent.
- Increasing the number of tethered assets had minimal impact on boarding rates at either cutter speed.
- Increasing the number of untethered assets at either cutter speed provides small, incremental improvements in boarding rates.
- A 50 kt cutter has a consistent advantage over a 30 kt cutter in all modeled deployable asset configurations.

3. HUMAN SYSTEMS INTEGRATION MODELING

Objectives and Approach

The HSI modeling was conducted using the total crew model (TCM). The TCM is a dynamic simulation architecture built using the task-network modeling tool, Micro Saint, which was developed to simulate shipboard manning requirements for naval surface vessels. The development of crew schedules and watch, quarters, and station bill (WQ&SB) assignments in a static fashion often left gaps or inconsistencies that were not easy to uncover, but would reveal themselves in a dynamic environment. Therefore, the TCM was developed to look at manning demands from a dynamic perspective to determine the adequacy of a proposed crew complement. In order to do this, the simulation considers the combined effects of crew complement, daily schedules, WQ&SB assignments, and specific manning requirements for special evolutions and other crew activities. These input data are integrated dynamically over the course of a designed reference mission scenario to assess the adequacy of the proposed manning structure in performing the scenario. A detailed description of the TCM, along with detailed HSI modeling results, is contained in Appendix C.

ONR determined that a crew of 26 personnel could operate Sea Fighter. The vessel seldom achieved its planned OT&E schedule due to cutter system malfunctions, thus the crew size was not fully tested in an operational environment. HSI modeling was used to determine the capabilities of a 26-person crew and the crew structure (size and ratings) needed to sustain the operations of a typical WHEC / NSC patrol.

The WHEC / NSC patrol profile provided for 14 continuous underway days, a mid-patrol in-port replenishment break, followed by another 14 continuous underway days. A 14-day patrol profile was used, since this is the longest continuous underway period. The profile provided for manned and unmanned flight operations in the patrol area for 18 hours per day and an average of three target vessel boardings per day.

The first HSI study entailed applying the 26-person crew against the 14-day patrol profile. Underway operations (e.g., flight operations, boardings) were systematically eliminated from the patrol profile to determine the operations tempo (OPTEMPO) the crew could achieve within acceptable fatigue limits for safe operations. A second HSI study entailed building an optimal crew augmented with detachments that could sustain the 14-day patrol profile and remain within acceptable fatigue limits for safe operations. In both studies, an all-Coast Guard crew was used for analysis, as opposed to the current combined Coast Guard and Navy crew.

Study Findings

Current Crew Structure

Table 2 shows the assignment to condition-3 watches, the assignments to positions for each of the major evolutions modeled, and the manning requirements for each evolution. The major details of the structure of the current 26-person crew are detailed in Table 3. The manning requirements list the positions and numbers required to perform each of the major evolutions included in the TCM. These positions are filled by the billets assigned in Table 3. Note that

there are often more billets listed for a given position than are required in Table 2. For example, during helo flight quarters, one HCO is required but two are identified. The billets identified as HCOs are in essence a resource pool for this position. The model uses a priority or "Trump" matrix in conjunction with task priority weights to identify the most appropriate individual(s) from the pool to fill that position at that time.

Table 2. Summary of major evolution manning requirements (26-person crew).

Helo Flight Quarters	VUAV Flight Quarters	Boat Launch	Boarding
Command (1) HCO (1) LSE (1) Hot Suit (2) Chock & Chain (2) Boat Deck Crane (1) Boat Deck OIC (1) Boat Engineer (1) Coxswain (1)	Command (1) HCO (1) LSE (1) Chock & Chain (2) CIC (1)	Boat Deck Safety (1) Boat Deck Crane (1)	Command (1) Boat Engineer (1) Coxswain (1) Boarding Team (4)

Table 3. Summary of billet assignment to condition-3 watches and major evolutions (26-person crew).

Billet	Cond.-3 Watch	Helo Flight Quarters	VUAV Flight Quarters	Boat Launch	Boarding
C101 – LCDR		Command	Command		Command
C102 – LT		Coxswain	Command		Coxswain
C103 – LTJG	OOD				Boarding Team 1
C104 – LT JG	OOD	Boat Deck OIC		Boat Deck Safety	
C105 – CWO3					Boarding Team 2
C106 – CWO2	NOW	Boat Deck OIC	CIC		
E101 – MKC	EOW	LSE	LSE	Boat Deck Crane	
E102 – MK1	EOW	Boat Engineer			Boat Engineer
E103 – MK1		Boat Engineer			Boarding Team 1
E104 – MK1	EOW	Boat Engineer			Boat Engineer
E105 – MK2		Boat Engineer			Boat Engineer
E106 – EM1	EOW	Boat Engineer			Boat Engineer
E107 – MK2		Chock & Chain	Chock & Chain		
E108 – MK3		Boat Engineer			Boarding Team 2
O101 – ETC	OOD	HCO	HCO	Boat Deck Crane	
O102 – FS1					
O103 – QM1	NOW				Boarding Team 2
O104 – HS1	COMMS	HCO	HCO		
T102 – ITC	NOW		CIC		
T103 – ET1	NOW	Hot Suit			
T104 – IT2	COMMS	Hot Suit			Boarding Team 2
T105 – OS3	COMMS	Chock & Chain	Chock & Chain		Boarding Team 1
W101 – BMC		LSE	LSE	Boat Deck Safety	
W102 – BM1	OOD	Coxswain			Coxswain
W103 – GM2		Boat Deck Crane			Boarding Team 1
W108 – BM2	COMMS	Boat Deck Crane	Chock & Chain		Coxswain

The crew structure detailed above was run against a 14-day patrol scenario with the following characteristics:

- Average three two-hour boardings a day, with several instances of two simultaneous boardings
- Two two-hour manned helicopter flight operations a day
- Three four-hour VUAV flight operations a day

- One all-hands drill performed daily
- Four Condition-3 watch stations—Officer of the Deck (OOD), Engineer of the Watch (EOW), Navigator of the Watch (NOW), Communications (COMMS) Watch—continuously manned in a 1 in 4 rotation

The scenario run in the model included three additional days after the 14-day patrol in order to assess fatigue recovery times. These days are reflected in the model outputs.

Current Crew Results

When the current 26-person crew was run against the scenario described above, several issues were found:

- The crewing made it unfeasible to man the flight deck for helo flight quarters while simultaneously launching a RHIB for a boarding and keeping all condition-3 watches manned.
- Helo flight operations were causing excessive fatigue for many members of the crew, as shown in the Figure 12 for the engineering department. In the fatigue chart, areas under the curves in excess of 6 are considered excessive fatigue (cannot be sustained for more than a day), and areas below 6 are considered acceptable. Areas above 10 are considered dangerously excessive fatigue (microsleeps and attention lapses are frequent) and cannot be sustained even for a day.
- The crew could not perform two simultaneous boardings with the initial six-man boarding teams.

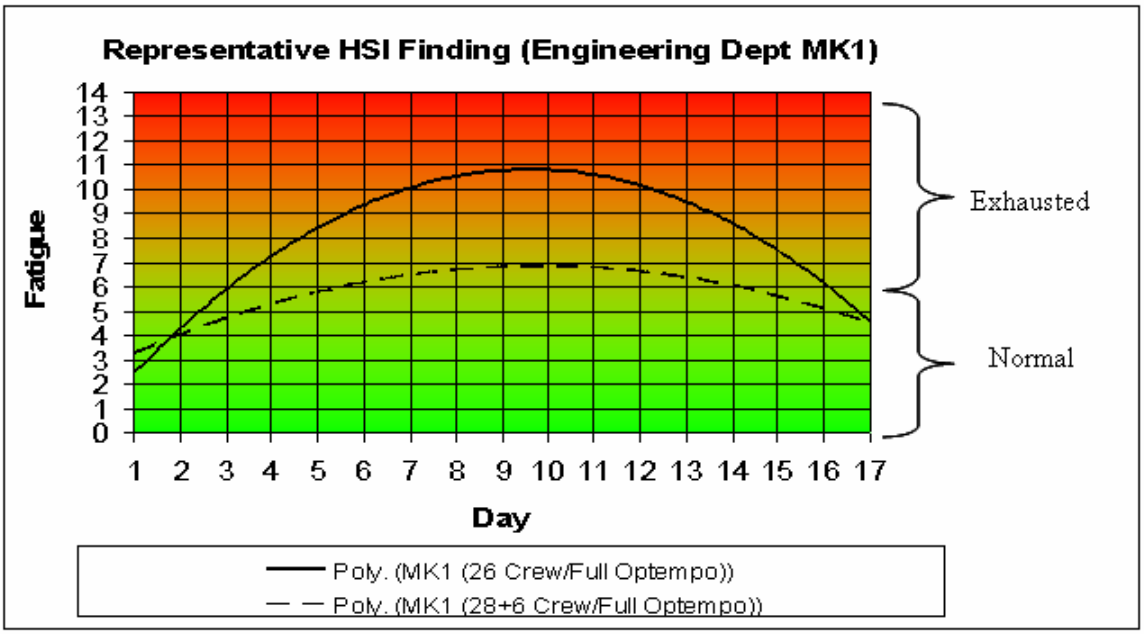

Figure 12. Graphical representation of Human Systems Modeling results.

Based on these results, it was determined that the 26-person crew was unable to run helo flight operations in conjunction with any boarding activities. In addition, in order to run two simultaneous boardings, the boarding teams would have to be reduced to four-man teams.

The 26-person crew was then run against a modified scenario, with the helo flight operations removed and with four-man boarding teams. This resulted in a significant reduction in crew fatigue to acceptable levels. In addition, the crew was able to perform all remaining evolutions, including all boardings and VUAV flight operations successfully while keeping Condition-3 watches continuously manned.

In summary, the current 26-person crew is able to successfully sustain a rather high OPTEMPO that includes an average of three boardings a day with instances of two simultaneous boardings (with four-man boarding teams) and VUAV flight operations. However, this current crew is unable to perform helo flight operations within this OPTEMPO.

Optimal Crew Structure

Building on lessons learned from the analysis of the current 26-person crew, an effort was made to define a new crew structure that could sustain the desired OPTEMPO as detailed in the original scenario. The new crew makeup should not only be able to perform helo flight operations, but also to run six-man boarding teams. In addition, the optimal crew structure should be as small as possible while not inducing excessive fatigue.

The original 26-person crew was determined to be quite efficient with a few exceptions, namely helo flight operations and simultaneous boardings. Therefore, the revisions to the crew size specifically addressed these deficiencies. The result was the addition of two boatswain mates (BM1, BM2). These two additional crewmembers resolved the flight ops/ boarding issues. In addition, a six-person law enforcement detachment was added to create the primary boarding team. Within the new 28+6 crew structure, two boarding teams are used, one organic and one from the detachment, and each consists of five boarding team members plus a boarding officer.

The manning requirements for each evolution are detailed in
Table 4. The major details of the structure of the new optimized 28+6 crew are detailed in Table 5.

Table 4. Summary of major evolution manning requirements (optimal crew).

Helo Flight Quarters	VUAV Flight Quarters	Boat Launch	Boarding
Command (1) HCO (1) LSE (1) Hot Suit (2) Chock & Chain (2) Boat Deck Crane (1) Boat Deck OIC (1) Boat Engineer (1) Coxswain (1)	Command (1) HCO (1) LSE (1) Chock & Chain (2) CIC (1)	Boat Deck Safety (1) Boat Deck Crane (1)	Command (1) Boat Engineer (1) Coxswain (1) Boarding Officer (1) Boarding Team (5)

Table 5. Summary of billet assignment to condition-3 watches and major evolutions (optimal crew).

Billet	Cond.-3 Watch	Helo Flight Quarters	VUAV Flight Quarters	Boat Launch	Boarding
C101 – LCDR		Command	Command		Command
C102 – LT		Coxswain	Command		Coxswain
C103 – LTJG	OOD				Boarding Officer
C104 – LT JG	OOD	Boat Deck OIC		Boat Deck Safety	
C105 – CWO3					Boarding Officer
C106 – CWO2	NOW	Boat Deck OIC	CIC		
E101 – MKC	EOW	LSE	LSE		
E102 – MK1	EOW	Boat Engineer			Boat Engineer
E103 – MK1		Boat Engineer			Boarding Team 2
E104 – MK1	EOW	Boat Engineer			Boat Engineer
E105 – MK2		Boat Engineer			Boat Engineer
E106 – EM1	EOW	Boat Engineer			Boat Engineer
E107 – MK2		Chock & Chain	Chock & Chain		
E108 – MK3		Boat Engineer			Boarding Team 2
O101 – ETC	OOD	HCO	HCO	Boat Deck Crane	
O102 – FS1					
O103 – QM1	NOW				Boarding Team 2
O104 – HS1	COMMS	HCO	HCO		
T102 – ITC	NOW		CIC		Boarding Team 2
T103 – ET1	NOW	Hot Suit			
T104 – IT2	COMMS	Hot Suit			
T105 – OS3	COMMS	Chock & Chain	Chock & Chain		
W101 – BMC		LSE	LSE	Boat Deck Safety	
W102 – BM1	OOD	Coxswain			Coxswain
W103 – GM2		Boat Deck Crane			Boarding Team 2
W108 – BM2	COMMS	Boat Deck Crane	Chock & Chain	Boat Deck Crane	
BM1		Coxswain			Coxswain
BM2		Boat Deck Crane	Chock & Chain	Boat Deck Crane	
Det – LEDet1					Boarding Officer
Det – LEDet2					Boarding Team 1
Det – LEDet3					Boarding Team 1
Det – LEDet4					Boarding Team 1
Det – LEDet5					Boarding Team 1
Det – LEDet6					Boarding Team 1

Optimal Crew Results

The scenario used as the criterion for the optimal crew was largely the same as the original scenario for the 26-person crew with one exception. The flight operations schedule was modified in order to reduce fatigue. It was found that the original schedule, where the first and last flight operations of the day were both helo ops, tended to substantially increase fatigue. Therefore, the flight operations were rearranged with the VUAV performing the early and late flight operations. This new flight operations schedule was not rerun with the 26-person crew, since that crew was unable to perform the full flight operations schedule without exceeding severe fatigue thresholds. The new scenario which substituted in VUAV flights would not have improved the fatigue issues.

When the optimized 28+6 crew was run against the scenario described above, they were able to successfully execute all evolutions while continuously manning all Condition-3 watches. In addition, fatigue levels across the crew were acceptable, as shown in the Table 5 for the engineering department.

In summary, the optimized 28+6 man crew is able to successfully sustain the required OPTEMPO that includes an average of three boardings a day with instances of two simultaneous boardings and all VUAV and helo flight operations. It also appears that from a fatigue standpoint, this OPTEMPO could be sustained indefinitely.

4. CREW INSIGHTS

Objectives and Approach

Sea Fighter's CG and Navy crew combined have more than 200 years of seagoing experience. They transformed an experimental vessel into a fully operational vessel during the 13 months they were on-board. They have the most comprehensive knowledge of the vessel, and given their seagoing experience, they offer invaluable insight into Sea Fighter's capabilities (good and bad) relative to traditional CG and Navy ships. It was critical that the overall evaluation of Sea Fighter capture the wealth of knowledge gained by the cutter's crew. In addition, the valuable insights of air station and specialty team (MSST) personnel that operated on Sea Fighter was also captured and incorporated.

The design capabilities of new vessels are often different from the actual capabilities of the vessel as witnessed by those who sail on-board. Since Sea Fighter is an experimental vessel, the combined CG/USN crew afforded an opportunity to obtain firsthand information on the vessel's unique capabilities. Crew and shipriders' (R&DC representatives and CG MSST personnel and helicopter pilots) insights are used to complement the information gained from OT&E and M&S activities.

Summary insights focus on crew and shiprider observations relative to the unique capabilities of Sea Fighter: *High-speed, Multiple Deployable Assets, Small Crew Size,* and mission payload *Modularity*. Additional insights are provided in Appendix D.

Summary Insights

Summary insights are based on a consensus of written surveys completed by the crew, face-to-face interviews of the crew, and shipriders' observations.

High-speed

<u>50 kts</u>

Sea Fighter accelerated to 50 kts in less than five minutes and was highly maneuverable at top speed; it could turn tightly and stops in a very short distance. The crew believed high-speed capability would be a great asset in accomplishing any law enforcement mission and especially effective at intercepting fast, evasive, and uncooperative targets.

<u>Ride Quality</u>

Ride quality was better at higher speeds than at lower speeds in both low- and high-period waves, independent of wave height (sea state). At high speeds, the vessel skimmed over the tops of low-period waves and followed the surface of long-period waves. In medium-period waves, high-speed ride quality was degraded due to wave slamming on the wet deck. Wave slamming could usually be mitigated by course and speed changes.

At speeds below 15 kts, ride quality degraded. Vessel roll, pitch, and heave increased, with "jerky" motions rather than "slow" motions typically associated with a monohull. The ride control system (T-foils, active skegs, and interceptor control surfaces) did not have a significant impact on dampening roll, pitch, and heave below 15 kts, probably due to the reduced flow over those control surfaces. Vessel motions at low speeds (5 kts) often adversely affected the launch and recovery of deployable surface assets RHIBs.

Noise Levels

The vessel was noisy at high-speeds due to a combination of wind on the superstructure and water noise on the hulls and T-foils, in addition to the noise generated by the gas turbines. Little (to no) insulation was installed on the vessel, which would dampen some of the noise. For several crewmembers, the noise resulted in fatigue and headaches. Hearing protection must be worn to prevent hearing damage while in the aft portion of the Mission bay during turbine operations.

Training Weapons on Targets

The Sea Fighter successfully demonstrated the crews' ability to track and train its weapons (small arms) on targets of interest while operating at high-speeds (50 kts). However, apparent wind speed across the flight deck in excess of 80 kts would preclude personnel from manning the weapons on the flight deck. A weapons station can be seen in Figure 13.

Figure 13. Sea Fighter .50 caliber machine gun on port amidship's gun mount.

Multiple Deployable Assets

Surface Deployable Assets

Sea Fighter was outfitted with one 11 m RHIB, which restricts the ability of the ship to conduct multiple boardings. The vessel was capable of carrying up to three 11 m RHIBs or five-plus 7 m RHIBs; however, the X-Y crane in the mission bay cannot be used underway to move the RHIBs onto the stern ramp.

Stern Ramp

The stern ramp was used to launch and recover surface deployable assets. The existing stern ramp was poorly designed with a 17-degree incline as seen in Figure 14. The steep angle required the coxswain in the 11 m RHIB to use full throttle upon entering the ramp. This was both unsafe for the RHIB and put excessive stress on the RHIB's propulsion system (engine and waterjet). A missed approach to the ramp could result in the RHIB being trapped under Sea Fighter's waterjet guards. Sea Fighter's RHIB launch and recovery speed was limited to 5 kts, due to safety interlock positioning defaults on the waterjets (all four water jets were pitched full out). At speeds less than 5 kts, Sea Fighter's ride quality is degraded, resulting in increased roll, pitch, and heave, which adversely affects the launch and recovery of the RHIB.

Figure 14. 7 m RHIB on Sea Fighter stern ramp pier side.

SOLAS Boat

Another deployable asset, the Safety of Life at Sea (SOLAS) boat was designed to be used for man overboard recovery operations. The launch and recovery equipment was poorly designed, resulting in an awkward and potentially dangerous operation. When the SOLAS boat was swung out and lowered, it rotates excessively (even with bow and stern tending lines). An image of the boat being boomed out over the water jets can be seen in Figure 15. Once the boat was in the water, there was a concern that it could be caught under the flare of Sea Fighter's hull. Based on safety concerns, man overboard recovery was performed by the 11 m RHIB via the stern ramp.

Figure 15. SOLAS boat launch from Sea Fighter off San Diego.

Air Deployable Assets

Sea Fighter could accommodate two manned helicopters on deck simultaneously (including HH-60s), two-plus VUAVs, or a combination of manned and unmanned aircraft. There is currently no hangar on Sea Fighter; however, there is an elevator from the flight deck to the Mission bay. The elevator can accommodate helicopter parts or VUAVs similar to the Eagle Eye (or smaller). If Sea Fighter operates at high-speeds with helicopters on deck, rotor blade boots must be applied to prevent blade rotation.

Flight Deck Operations

The flight deck size easily accommodated two HH-65Cs for simultaneous flight operations during OT&E scenarios. The flight deck, seen in Figure 16, was significantly better than most Coast Guard flight decks due to "clean air" across the flight deck (reduced eddies caused by ship superstructures), excellent visibility of the forward horizon, and an outstanding flight deck lighting system for night operations.

Sea Fighter does not have a hangar to protect an embarked helicopter from salt spray; however, it does have a high-capacity freshwater washdown capability. The aviation gasoline (AVGAS) refueling station was conveniently located on the flight deck. The helicopter support kit (HSK) can easily be stored in the mission bay, and the elevator can be used to transport maintenance equipment between the mission bay and flight deck.

The capability to operate two HH-60s simultaneously permits an entire MSRT or MSST (16 people) to rapidly board a target of interest.

Figure 16. Sea Fighter's flight deck as seen from HH-65C during flight operation off Los Angeles.

Crew Size

Too Small

A 26-person crew size was adequate for standing underway watches but significantly limits sustained underway operations such as flight operations and boardings via surface deployable assets. The crew felt the Sea Fighter was undermanned, and the crew composition and cross-training adversely impact flexibility. Crew fatigue is discussed in Section 3.

Automation Helps

The Sperry integrated bridge and navigation system (IBNS) provided the OOD and NOW with excellent situational awareness and full control over multifunction display consoles from a seated or standing position. This significantly reduced the number of underway watchstanders on the bridge and provides the OOD hands-on control of vessel operations. Figure 17 shows the OOD in front of his control station. The OOD was standing at his position in front of and to the right of his chair. The NOW is located to the OOD's far left. The Commanding Officer is in the middle seat.

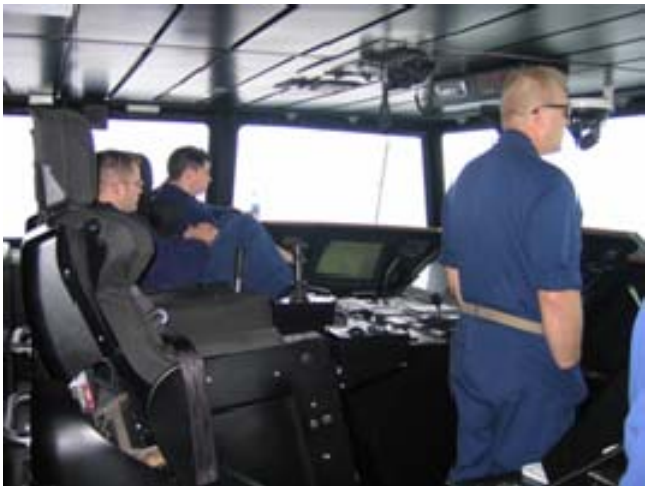

Figure 17. Sea Fighter bridge watch team (with CO) at integrated bridge console underway.

The installed aqueous film forming foam (AFFF) total flooding system on the flight deck facilitated a minimal flight deck crew of six persons (two chock-and-chain men, three hot suit men, and one landing signal enlisted (LSE)).

The machinery spaces on Sea Fighter were unmanned. The machinery control system (MCS-5) permited the EOW to control and monitor the main propulsion engines and all auxiliary machinery from the engineer's watchstation on the bridge. Most EOWs remarked favorably about the MCS-5 system's design and recommended it for future ships. An engineering rover made routine rounds of machinery spaces. An alternative to further reduce the number of underway watchstanders was to allow the EOW to make routine rounds (as opposed to using the Rover for routine rounds). The OOD has duplicate control of all EOW console functions at his console.

Modularity

Mission Payload Flexibility

Sea Fighter has a large reconfigurable mission bay that was capable of accommodating up to 12 ISO Containers (see Figure 18), multiple surface and air deployable assets, or large numbers of detainees (400+) in the middle and forward portion of the space.

Figure 18. ISO container in Sea Fighter mission bay.

Deployable Teams

Modularity could have permitted the MSRT or MSST to deploy with its entire pre-outfitted modules, and to use the mission bay for pre-staging/pre-briefs before the boardings. The wide passageways and ladders and the elevator would have enabled the MSRTs and MSSTs to move easily about the ship with full gear.

Mission Bay Operations

Underway the mission bay was excessively noisy, often collected engine exhaust fumes, and stern wash spray. Two isolation doors were installed to divide the mission bay into three sections; however, the doors were often inoperative. The climate-controlled forward section accommodated mission modules and the elevator to the flight deck. It was an excellent location for specialty teams to lay out equipment and prep for boardings. The midsection was ventilated and provides an outstanding containment area for holding detainees. The aft section was not ventilated and provided open access to the stern, the SOLAS boat, the deployable surface asset stern ramp, an area to prep additional deployable surface assets, and exterior access to the flight deck.

There was an overhead crane (the X-Y crane) in the mission bay that is used to move mission modules. The X-Y crane was vital to mission bay operations. However, it was not designed for shipboard use and cannot be used underway, which potentially could inhibit mission operations. Without this capability, Sea Fighter was only able to launch and recover one 11 m RHIB (or 7 m RHIB).

The elevator from the flight deck to the mission bay was not flush with the deck of the mission bay when fully lowered. The elevator platform was approximately 1.5 feet above the mission bay deck, which made it very difficult to move heavy material on and off the elevator platform.

5. CONCLUSIONS

A Sea Fighter-like cutter (i.e., ModCAT hullform) offers superior High Endurance Cutter (WHEC) mission capabilities with the crew size and performance characteristics of a patrol boat.

The ModCAT hullform provides excellent flexibility for Coast Guard missions currently performed by a patrol boat or a WHEC. As a patrol boat, the vessel can operate for 14 continuous underway days, execute an average of three boardings per day, intercept targets at 50 kts, and conduct VUAV flight operations with just a 26-person crew. As a WHEC, the vessel can operate 14 continuous underway days, execute an average of three boardings per day, intercept targets at 50 kts, and conduct both helicopter and VUAV flight operations with a crew of 28 plus a 6-person boarding detachment (LEDET, MSST, MSRT).

The mission payload capacity of Sea Fighter could provide the Coast Guard tremendous mission flexibility. Multiple deployable teams (MSRTs, MSSTs) with modularized mission packages can deploy for extended periods. Secure and environmentally controlled detainment capability provides for surge AMIO operations. The large Mission bay can readily accommodate up to 12 C4ISR and/or habitability modules to perform extended on-scene command and control. Sea Fighter is not weight critical with respect to stability and has ample top side area to install any required antennas or sensors. The two-pad flight deck permits simultaneous flight operations for two manned helicopters, multiple VUAVs, or a combination of both.

The conclusions from the four main Sea Fighter capabilities can be summarized as follows:

- High-speed (50 kts) capability would prove useful in areas where high-speed targets are the major concern, or in a situation where rapid response (transit) is a priority such as natural disasters. This speed advantage becomes especially effective when combined with wide-area, off-board sensing capability.
- The ability to operate multiple deployable assets (greater than 2) appears to be the most vital capability that Sea Fighter possesses. Both OT&E and M&S demonstrated that the abilities to execute multiple boardings and assist in target detection is of the utmost importance (regardless of intercept speed). The addition of untethered HH-60 helicopters (boarding range of 300 nm) was the performance driver in the M&S scenarios.
- The tradeoff of a small crew size for automation can be achieved for pure vessel operation. Augmentation of the ship's core crew prior to periods of high OPTEMPO is a necessity.
- Modularity (while not fully evaluated) proved to be one of the more useful capabilities of Sea Fighter in that crew augmentation units and other ship riders could easily be accommodated. Additionally, modular ship design provides the ability to support multiple deployed assets (i.e., UAVs/USVs/USSVs) and conduct other missions with minimal operational interruption.

A highly automated Sea Fighter-like cutter provides more mission capability, albeit for a shorter duration, than a WHEC with the crew size of a patrol boat. The ModCAT hullform and large mission bay provides excellent flexibility for emerging Coast Guard missions and demands. Its speed and multiple deployable asset capability offer outstanding performance improvement potential for the Coast Guard; however, a critical enabler is improving awareness of vessel traffic

within the oparea – an element of maritime domain awareness. As MDA improves, a 50 kt patrol cutter capable of deploying four deployable assets (i.e. helos, RHIBs, UAVs) could provide a tremendous improvement in end-game capability over current and future 30 kt cutters.

6. RECOMMENDATIONS

The CG needs to continue to evaluate non-standard hull forms such as ModCAT-type vessels for both speed and modularity purposes. High-speed vessels normally have endurance problems based on their fuel consumption rates. This has been one of the perceived shortcomings of this hullform type. However, the ModCAT hullform (i.e. Sea Fighter) provides very good fuel economy and, given the typical patrol profile (12 kt patrol speed, 20 kt transit speed, and 50 kt intercept speed), the vessel is capable of remaining within the patrol area for an entire patrol period. Opportunities exist for the CG to further evaluate other Navy/DOD high-speed vessels (HSV) such as the M88 Stiletto for MSRT type missions and the HSV platforms, HSV Swift and HSV Joint Venture, for extended duration missions.

Additionally, the CG should look at ways to optimize the number and type of deployable and off-board assets through a more detailed M&S analysis. A 50 kt Sea Fighter-like cutter with four deployable assets (e.g., two 11 m OTH RHIBs and two HH-60 helicopters) can provide significant mission performance improvement compared to a standard 30 kt cutter. To maximize the benefit from embarking four deployable assets (two 11 m OTH RHIBs and two HH-60s), a revised approach to boardings would need to be established. Currently, boardings are to be conducted within two hours from the WHEC (at the WHEC's maximum speed). Under the MSRT CONOPs, the boarding teams would need to be trained similar to MSRTs which are able to defend themselves while conducting a boarding at greater distances from the patrol vessel.

The CG needs to continue to incorporate more automated systems on-board cutters, but have contingency plans (both personnel and equipment) in place for changes in operational requirements or causalities. In order to derive optimal mission effectiveness, the patrol cutter must be able to safely navigate and operate deployable assets in varying sea states and at a reasonable speed. Sea Fighter's automated systems allow for these evolutions to be conducted with fewer crew members and with an acceptable margin for safety.

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APPENDIX A. GLOSSARY OF TERMS

Glossary of Terms

Term	Definition
Bridge Resource Management	Bridge Resource Management, or Bridge Team Management, is the effective management and utilization of all resources, human and technical, available to the Bridge Team to ensure the safe completion of the vessel's voyage.
Characteristics	Any property or attribute of an item, process, or service that is distinct, describable, and measurable. Features or attributes of the Sea Fighter that define its operational capabilities and that distinguish this vessel from other vessels.
Crew Interviews	Structured crew interviews conducted in April and May 2006 of every crewmember by a team of interviewers in port in San Diego, CA. Follow-up interviews of primarily the Coast Guard crewmembers are scheduled in July 2006 before they are scheduled to depart the Sea Fighter for their next duty station.
Crew Surveys	A crew survey in the form of a written questionnaire was developed by the R&DC and completed by all crewmembers except for the Commanding Officer in January 2006. The questions allowed five different answers, ranging from "Strongly Disagree" to "Strongly Agree." Comments could also be written in for each question.
Experiment Plan	Developed for the Engagement and HSI modeling effort. The Experiment Plan describes the requirements for the development and execution of the models and includes the inputs, outputs, variables, and number of replications that were planned.
Implementation Plan	Developed for the engagement and HSI modeling effort. The Implementation Plan describes the selection of the appropriate model, development of the approach and assumptions, and the validation and verification of the approach to execute the scenario.
Joint Experiment Plan	The Joint Experiment Plan presents the strategy and framework for evaluating the Sea Fighter through coordinated OT&E and M&S. It was developed as a living document with content that evolved over the life of the project. It is available as a companion document to this report (Reference 3)
OASIS Program	The Operations Analysis Simulation Information Support (OASIS) program at the R&DC is designed to serve the needs of all programs at the R&DC for operations analysis and modeling and simulation. The Sea Fighter program at the R&DC is leveraging support through OASIS for their program.
Observations of Operations	Observations of Sea Fighter operations while the ship was conducting dedicated Coast Guard tests and evolutions such as Drug Enforcement operations, Maritime Domain Awareness Exercises, Alien Migrant Interdiction Operations, and main space fire drill. During this period the Sea Fighter conducted day and night helicopter operations, including vertical insertion of a Marine Safety and Security Team (MSST) on-board Sea Fighter and landing two HH-65 helicopters simultaneously on the Sea Fighter's flight deck. Telephone interviews of the helicopter pilots and senior members of the MSST were conducted and included in these observations.
OT&E Test Plan	Provides the details and schedule for conducting Operational Test and Evaluation (OT&E) on the Sea Fighter. This Plan focused on the tests and trials that would be conducted during the underway periods dedicated to Coast Guard testing and provided the Measures of Effectiveness for each test.
Scenario	Scenarios provide the operational description of the supported mission and the measures of system effectiveness, defines the data or assumptions to be used in the modeling, and identifies data requirements that may be provided from the OT&E efforts.
Sea Fighter Development Team	The Development Team comprises representatives from the R&DC as well as members of the OASIS Support Team that are directly supporting the Sea Fighter Analysis Support Project.

Term	Definition
Stakeholders	The stakeholders consist of representatives from the Coast Guard, the U.S. Navy, and shipbuilders who are involved in the future of the Sea Fighter.
Steering Committee	The Steering Committee comprises key stakeholders from selected organizational elements in the Coast Guard, U.S. Navy, and Sea Fighter.

APPENDIX B. ENGAGEMENT MODELING

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APPENDIX C. HUMAN SYSTEMS INTEGRATION MODELING

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APPENDIX D. CREW INSIGHTS

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APPENDIX E. SEA FIGHTER PICTURES

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