

## U.S. DEPARTMENT OF HOMELAND SECURITY HUMAN SYSTEMS INTEGRATION APPLIED TO U.S. COAST GUARD SURFACE ASSET ACQUISITIONS

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### ABSTRACT

The US Coast Guard (USCG) established the Human Systems Integration (HSI) Technical Authority in October 2007 to provide technical expertise and disciplined advice to asset developers and acquirers in manpower, personnel, training, human factors engineering, systems safety, habitability, and personnel survivability. As a result, HSI has become the technical and management approach to the entire lifecycle of systems that integrates human related issues into the technical and operational picture within the USCG acquisition community. Specifically, the HSI human factors engineering team has made progress within both the SENTINEL Class Patrol Boat and Offshore Patrol Cutter projects by applying the Department of Homeland Security (DHS) process of defining key human performance parameters and operational requirements for the development of the assets. The HSI Technical Authority best practices throughout the Systems Engineering Life Cycle include engaging in the evaluations of gross task analyses, critical task analyses and the integration of human factors and system safety evaluations on current drawings and models for compliance with government standards.

*Keywords: Human systems integration, Human factors engineering, U.S. Coast Guard, Human performance, Acquisition, Design*

### NOMENCLATURE

DHS Department of Homeland Security  
HFE Human Factors Engineering  
HSI Human Systems Integration  
HSRE Human Systems Research & Engineering  
OPC Offshore Patrol Cutter  
USCG United States Coast Guard

### 1. INTRODUCTION

The human systems integration (HSI) Technical Authority within the United States Coast Guard (USCG) is working in conjunction with the Department of Homeland Security (DHS) Human Factors/Behavioural Sciences Division to develop and implement an HSI process to improve the planning, design, and development of system acquisitions DHS-wide. From an HSI perspective, the major concern is to maximize human performance and minimize human performance risks through the identification of gaps, which address established deficiencies in any one or more of the constituents of human performance including (a) human capability (inability to perform as required), (b) human proficiency (training is inadequate), (c) human availability (systems are understaffed or crew is overworked), (d) human utilization (personnel are assigned to work who are lacking the required knowledge and skills), (e) human accommodation (quality of life in the system

or platform is inadequate), (f) human health and safety (hazardous design features, working environments, or work practices are encountered), and human survivability (protection is inadequate for systems personnel and/or bystanders). This paper describes the results of the DHS HSI approach, specifically the application of human factors engineering principles for USCG surface assets, which can be applied to future ship acquisitions in general.

### 2. THE DHS HSI PROCESS

The DHS Science & Technology (S&T) Directorate's Human Factors /Behavioural Sciences Division established the Human Systems Research and Engineering (HSRE) Program in 2007 to ensure that HSI is incorporated and institutionalized throughout S&T's Research, Innovation, Transition, and Acquisition projects in all of the DHS component agencies.

The HSRE Program has stated that the most important determiner of mission success for the complex, high impact, technology-based, manpower-limited homeland security systems of the 21<sup>st</sup> century is *human performance*. The HSRE Program defines human performance as the demonstrated capability of the human end-user to operate, control, maintain, support, manage, and use the components of the systems under all

expected operational, environmental and tactical conditions. Human performance refers to the successful attainment of job task objectives for roles and tasks (e.g., cognitive and physical) allocated to humans. Successful attainment of job task objectives means that the outcome of the task meets time, accuracy, energy and throughput criteria, under specified operational, environmental, and tactical conditions, as performed by intended personnel. Effective performance of these systems is usually a direct function of the capabilities of the human in making accurate decisions, understanding the situation, interacting with automation, and acting decisively in collaboration with other individuals and/or units (groups of individuals) to execute the mission.

HSI is the discipline directed at addressing human performance in complex systems. HSI ensures the full integration of the human with other elements of the system, including hardware, software, firmware, webware, courseware, information, procedures, policy and doctrine, documentation, design features, technology, environments, organizations, and other humans. HSI is primarily concerned with designing the system or technology to ensure required levels of human performance, which includes human capability, proficiency, human utilization, accommodation, survivability, health and personnel safety, into the acquisition strategy. Addressing these dimensions of human performance leads to the seven domains of HSI, which include manpower (quantity and quality of personnel required), personnel (requirements for recruiting, retaining, assigning, and supporting personnel in career advancement), training (requirements and techniques for delivering needed knowledge, skills and abilities to the human), human factors engineering (requirements, concepts and criteria for design of user interfaces in accordance with the capabilities and limitations of the human), habitability (requirements for providing an adequate quality of life), personnel survivability (requirements for human protection and safeguards), and safety and health (requirements to reduce hazards to human safety and health). This engineering discipline is directed at improving the efficiency and effectiveness of technology by addressing human requirements in the analysis, design, testing and use of technology. The dimensions of technology to be improved through the application of HSI include:

- Usability – by ensuring that information is integrated, displays are understandable, controls and displays are integrated and compatible, labels are readable, decision aids are provided, awareness of the situation is maintained, automation interfaces are clear, procedures are consistent, and communications are intelligible.

- Reliability - potential and consequences of human errors are identified, predicted and reduced; tolerance of errors is enhanced.
- Supportability - human performance is addressed in the design for maintainability, and for supply and support.
- Safety and Survivability - hazards are eliminated or guarded (e.g., alarms, warning labels, etc.).
- Affordability – total ownership costs associated with system/technology redesign, manpower, training, human support, errors and accidents are reduced.
- Acceptability - technology is accepted by users, by other persons affected by its use, and by the general public.

The DHS HSRE HSI principles constitute a set of seven overarching or guiding fundamental rules or assumptions that provide an overview of the subject matter of HSI and that are directed at the primary goals, objectives, and mechanisms for the application of HSI. These principles are summarized as follows:

1. HSI considers the human to be an essential element of the system. Thus, to the extent that human involvement is important for successful system performance and that costs of human support constitute a significant portion of life-cycle costs, then system acquisition must address requirements for human performance.
2. HSI is concerned with ensuring successful and affordable total system performance (hardware, software, and human) as a direct function of the design of system user interfaces to effectively meet customer/user requirements and needs.
3. HSI is directed at reducing total-ownership costs (TOC), i.e., those costs associated with acquiring, assigning, preparing, manning, supporting, informing, training, sustaining, and protecting the human in the system and enhancing human safety and occupational health, well-being and fitness for duty. The costs of supporting and sustaining the human in the system represent a major contribution to system life-cycle costs. Costs associated with human errors and accidents also contribute a major portion of life-cycle costs for most systems. To the extent that significant reductions can be made in manpower requirements, training, incidence of errors, time to perform, and accident rates, the life-cycle costs of the system will be reduced, contributing to the affordability and competitiveness of the system.
4. The extent to which HSI can influence design is reflected not only in how early in the systems engineering process that HSI is addressed but also to what degree program management has accepted

the involvement of HSI in the acquisition of the system. HSI can enter the process early by (1) relying on lessons learned from predecessor systems to identify potential HSI risks high drivers, (2) conducting early modeling and simulation, including top-down requirements analyses, and (3) developing HSI requirements to be included in system requirements documents. HSI can acquire management support by demonstrating success in meeting objectives and by having a positive impact on system risk and affordability.

5. HSI in system acquisition is concerned with identifying, prioritizing, and mitigating risks to human performance, workload, safety and occupational health, and well being. HSI risks should be included in the risks being tracked by the acquisition program. HSI should have representation on the Risk Management Board, chartered to track the status of efforts to mitigate identified risks. In addition, risks identified by other program elements should be reviewed to identify risks that are truly HSI risks, or that pertain to other program elements but with implications for human performance, workload, and safety (i.e., HSI-related risks). The integration of HSI risks extends beyond merely tracking the HSI or HSI-related risks to address planning of HSI mitigation efforts to include the cooperation of other program elements and the application of HSI effort to assist in mitigating HSI-related risks.

6. HSI is a systems engineering discipline. As such it should be constituted in the systems engineering organization with identifiable management, organization, objectives, technical processes, metrics, methods, tools, and data.

7. HSI requirements must be addressed both in system requirements documents and life cycle documents and in all acquisition documents that address the roles, requirements, and constraints to be placed on the human element of the system.

It is the intent of the DHS HSRE Program to implement these governing principles, through HSI Policy, Processes and Best Practices, into systems acquisition in DHS. System acquisition in DHS is governed by the Acquisition Review Process (ARP) and the System Engineering Lifecycle (SELC), both of which are documented in the DHS Acquisition Directive 102-01, augmented by the Acquisition Management Guidebook [DHS, 2008]. The application of HSI, as directed by the HSRE Program Management, is currently being standardized through the use of a systematic process based on research and best practices. This standardization will be documented in written HSI processes and is intended for inclusion throughout all phases of the ARP and SELC as a formalized, standardized process for applying HSI to the

development, evaluation and fielding of DHS technology and systems.

The DHS HSRE Program has been working very closely with the U.S. Coast Guard Acquisition Directorate HSI representatives to define and develop an approach to implementing the HSI processes and best practices. These efforts and successes are described in the following sections.

### **3. DHS HSI IN USCG SURFACE ACQUISITIONS**

In October 2007, the United States Coast Guard (USCG) Commandant established a technical authority pertaining to Human Systems Integration (HSI) within the CG-1B3 organization, to include manpower, personnel, training (MPT), human factors engineering (HFE), occupational health and safety, habitability, and personnel survivability, for the design, construction, support and sustainment of Coast Guard systems and assets.

The USCG recognizes three fundamental components of every major system that are subject to the system engineering process: the hardware, the software, and the human. All three components must be integrated and balanced for maximum effectiveness and efficiency of the total system. It is essential throughout the design and construction of Coast Guard assets and systems that key technical and production issues related to each of these three components be addressed concurrently, properly, and adequately. For the human component, the Commandant (CG-1) has the personnel and expertise to develop and employ consistent, disciplined, collaborative HSI processes essential to safe, reliable, effective, integration, timely, and affordable assets for the Coast Guard. The offices within Commandant (CG-1B3) are aligned by technical areas and empowered to provide disciplined advice and decisions consistent with their expertise in integrating the disciplines of human factors engineering, manpower, personnel, training, habitability, personnel survivability, and occupational health and safety into the systems engineering of a materiel system to ensure safe, effective operability and supportability. This alignment, in combination with the technical authorities for the hardware and software components, is essential to an agile, effective, and efficient systems engineering workforce. The independence of technical authority is an essential aspect of the USCG human resources community because it (1) ensures that the human element, the most valuable resource, is incorporated into all stages, especially the early stages, of system design, and (2) provides the checks and balances necessary to ensure assets and systems meet the changing needs of the Coast Guard.

The USCG HSI Technical Authority understands that, to the extent that human performance is

important for mission success, and/or that life cycle costs are driven by costs of acquiring, training, and supporting personnel in the operation and maintenance of products (systems and technology), HSI must be addressed in the development or procurement of their products. The USCG HSI approach is defined as the systems engineering discipline that considers the human a critical component of the system and strives to integrate the human component with other system elements. The principal objective of HSI is to influence product design with requirements for human performance. Successful human performance is a direct function of the capabilities, competence, proficiency, skills, knowledge, attitudes, aptitudes, workloads, fitness for duty, and health and safety of individual operators and maintainers, small units, teams, and total crews. Human performance is also a direct function of the design of the adequacy of user interfaces, which support and enable effective and efficient job and task accomplishment. Applying a user-centered systems engineering approach such as HSI results in safe and effective user interfaces and the development of products that reduce the incidence and impact of human error, optimize manpower, provide cost-effective training, allow efficient operation and maintenance, and are operationally suitable to successfully conduct assigned missions within the intended operating environment by the anticipated user population.

Since the establishment of the HSI Technical Authority, the Human Factors Engineering (HFE) team within CG-1 has begun to develop a strong collaborative relationship with the DHS HSRE Program to identify best practices within the USCG acquisition community that can help define the DHS HSI processes and best practices. The systematic application of HFE principles in two particular USCG surface assets, the SENTINEL Class Patrol Boat and the Offshore Patrol Cutter, are being used as testbeds for the development and implementation of standardized HSI efforts that can be applied to future DHS systems and ship acquisitions in general.

#### **4. HFE EVALUATION OF THE SENTINEL CLASS PATROL BOAT**

##### **4.1 THE SENTINEL PROJECT OVERVIEW**

The U.S. Coast Guard SENTINEL Class Patrol Boat project is a Department of Homeland Security Level 1 Investment and United States Coast Guard Major Systems Acquisition project. The primary objective of the project is to quickly procure patrol boats to reduce or eliminate the USCG's patrol boat capability gaps. The SENTINEL will use a Non-Developmental Item (NDI) hull form that will be modified as needed to accommodate Coast Guard missions. The assumption is that the cutter must support a crew of two (2) officers and twenty (20)

enlisted personnel in accordance with the preliminary manning estimate conducted by the USCG HSI for Acquisitions Division (CG-1B3).

The SENTINEL Class Patrol Boat Project will deliver vital capability to the Coast Guard, helping to meet the service's need for additional patrol boats. The current patrol boat gap hinders the Coast Guard's ability to most successfully and efficiently complete all potential missions, and this critical acquisition will help address these identified needs. The C4ISR systems on the SENTINEL Class patrol boat will be fully interoperable with not only the Coast Guard's existing and future assets, but those of our partners in the Department of Defense and the Department of Homeland Security.

In order to meet these acquisition requirements along with the specific needs of the USCG users, the USCG recognized that Human Factors Engineering (HFE) principles must be implemented. A key issue of HFE is operational suitability, or how well the design supports the required operations of the users (including maintenance and supply/support). HFE also includes operability, maintainability, ergonomics, lighting, noise, vibration, shock as it affects human performance, habitability and seakeeping characteristics such as sea sickness mitigation. In order to validate operational suitability and that HFE has been addressed in the design, the SENTINEL Project Management (PM) requested that CG-1B3 provide the required personnel to perform an assessment of the pilothouse, galley, and mess deck spaces (via the full-scale mock-ups). CG-1B3 requested that BMT Designers and Planners (D&P), through a contract with Computer Sciences Corporation (CSC), perform the assessment. This initial assessment was performed between December 28, 2009 and January 21, 2010.

##### **4.2 SCOPE OF THE HFE EFFORT**

The objective of this project was to perform a HFE technical assessment of the pilothouse, galley, and mess deck mock-ups for the SENTINEL Project Management (PM), including the SENTINEL Project Resident Office (PRO). As follow-on to the Contractor's HFE efforts in the development of the SENTINEL Class, this USCG-led HFE design validation will help provide an additional validation that the proposed design will adequately and suitably support the users required tasks. In concert with the aforementioned DHS HSRE benefits of HSI application, this USCG HFE effort during Critical Design Review was intended to evaluate the project's mock-ups for usability, reliability, supportability, safety and survivability, affordability, and acceptability based on human performance design criteria consideration.

The scope of this project was to first ensure that the design of the SENTINEL's pilothouse, galley, and mess deck mock-ups met the requirements set forth by the contractual Circular Of Requirements (COR) which state: *"The FRC-B design shall provide operational and maintenance workplaces, equipment, controls, and displays in accordance with ASTM F1166, the ABS Guide for Crew Habitability on Ships, and OPNAVINST 9640.1A" (Contract HSCG23-08-C-2FR125, Section 088-1.2).*

In addition to meeting the technical requirements of the contract, the other major area of validation undertaken within this project was to assess the usability of the design, in other words how well the users are able to perform their required duties given the configuration of the design.

Within this larger scope, the specific objectives of this HFE assessment were to review the design of the SENTINEL to 1) identify accomplishments, e.g. strengths in the design and 2) opportunities for improvement, e.g. potential weaknesses in the design, in the context of an HFE perspective. With this in mind, the ultimate goal was to obtain the data necessary to make an informed assessment of whether the proposed design of the SENTINEL's pilothouse, galley, and mess deck provide the users with the tools and capabilities required to safely and efficiently conduct their tasks, and meet mission requirements. It should be noted that the review did not include assessments of the individual GFE/COTS equipment, per se, only their placement in the spaces and integration with other equipment in the boat. In addition, the mockup of the galley and mess deck had not yet been fully completed, which limited the ability to adequately assess the proposed design and implement the method of having users walk through their required tasks as a means of HFE analysis. The completion of the galley design and final analysis is scheduled to occur in Spring 2010, after submittal of this paper.

#### 4.2 (a) HFE Mock-up Assessment

A HFE technical assessment was performed on the pilothouse, galley, and mess deck mock-ups for the SENTINEL Project Management (PM), including the SENTINEL Project Resident Office (PRO). As follow-on to the HFE efforts in the development of the SENTINEL Class, this USCG-led HFE design validation is being reviewed and considered in the proposed design changes for the galley and mess deck that will better meet the requirements of the users.

The goals of this assessment were threefold. First, the planning phase included research and background activities for the HFE subject matter experts (SMEs) to understand the missions and operational requirements of the vessel, as well as the capabilities and required missions of the current

configurations of the vessels that the FRC is intended to replace (i.e., 87' Coastal Patrol Boat (WPB), 110' Patrol Boat (WPB), or 179' Cyclone Class (WPC)). This planning included the development of scenarios and tools to be used in the assessments. Second, the data collection phase included assessments of the physical design as well as operational capabilities for both the legacy assets (as a baseline) and the FRC mockups (proposed designs). Finally, the HFE SMEs completed the data analysis and reporting to the project office. The HFE process is described in detail below.

**The Planning Phase.** The HFE SMEs from CG-1B3 developed scenarios based on the SENTINEL Concept of Operations (CONOPS) document, guidance from the FRC sponsors, comparable patrol boat SMEs, and observations made during the legacy asset reviews. Evolutions that were included in the scenario development were:

- Search and Rescue (SAR),
- Counter Narcotics / Go-Fast,
- Alien Migrant Interdiction Operations (AMIO),
- Living Marine Resources,
- Maritime Domain Awareness,
- General Defense Operations, and
- Damage Control for Main Space Fire.

The HFE team developed data collection tools for the following areas of assessment and analysis, using HFE design standards and best practices. In order to assess the static physical design's ability to meet relevant accepted standards and best practices (both required by the contract and not), a checklist was developed. Using data from the ASTM F1166 [2007], applicable sections of the ABS Habitability Guidance Notes [2003], which are in the specification as well as IACS Recommendation for Application of SOLAS Regulation V/15 [2007], Bridge Design, Equipment Arrangement, and Procedures, the checklist provides a means to easily ensure compliance with HFE principles. The usability assessments focused on the observation of users performing missions and tasks. Data collection tools included task descriptions and human performance-related characteristics and parameters to be observed. Interview and questionnaire materials were also developed and administered. A link analysis was used to create a means to assess work and communication flow. Tools to conduct the link analysis were researched and developed so that aspects of the tasks conducted that focus on the types, strengths, and other characteristics of relationships between people or people and equipment can be collected from a demonstrated scenario and then analyzed.

**The Data Collection Phase.** During the data collection phase, the CG-1B3 HFE SMEs were

asked to conduct an HFE observation and review of the pilothouse and galley spaces of a mission-comparable legacy asset (87' Coastal Patrol Boat (WPB), 110' Patrol Boat (WPB), or 179' Cyclone Class (WPC)) to provide a baseline in terms of asset capability; mission, evolution, and scenario familiarity, as well as a general assessment of the asset's ability to conduct the required tasks from a human performance and safety perspective. The focus of the review was to understand the required functions and highlight the challenges associated with the current designs.

In addition, the SMEs conducted a three-stage assessment of the current design (as represented by full-scale mockups of the SENTINEL pilothouse and galley). System aspects of interest include ergonomics, lighting, ingress/egress accessibility, maintenance accessibility, communications, graphical user interfaces, climate, usability, workflow/group interactions, suitability, operator workload, and situation awareness quality/availability of data. These assessments were compared to lessons learned from the review of the legacy asset in the previous task. The stages of the assessment were defined as follows:

1. Heuristic Review - A form of inspection where human factors engineers evaluate whether elements of a design followed established user-centered design methods, standards, and/or processes (e.g., ASTM F1166-2007, ABS Guide for Habitability on Ships). This type of review serves to indicate or point out areas of interest as a means to further investigate potential human performance-related risks and challenges.

2. Usability Assessment – Through the observation of required tasks and activities, further evaluation of human performance-related risks and challenges can be evaluated to include those activities which involve active crew participation and engagement with the asset's equipment and compartments. The focus was on the crew's level of performance or effectiveness of execution of the required tasks. The SMEs conducted walk-throughs, interviews, surveys, and video taped the walk-throughs for evaluation.

3. Link Analysis – Link analysis is a powerful tool that uses the capture of relationships amongst people and equipment in terms of location, frequency and type of relationship (verbal communication required or physical/visual access) to examine the efficiency and criticality of links and can drive repositioning of the nodes accordingly. The SMEs performed a link analysis in the pilothouse during the initial assessment and will follow-up at the USCG's request to complete the link analysis in the galley spaces as the mock-up design matures.

The data collection activities consisted of two major thrusts: legacy familiarization and SENTINEL Class validation. Each of the two thrusts is described below.

Legacy familiarization, which was proposed to provide a baseline to the assessment team, consisted of performing a heuristic assessment and a usability assessment on an existing legacy asset, the USCG Cutter (USCGC) GANNET, an 87' Coastal Patrol Boat.

- Heuristic Assessment - A heuristic assessment of the 87' USCGC GANNET (which is a more recent acquisition with requirements closest to the SENTINEL class) was performed, focusing on the design of the pilothouse and galley spaces. The legacy boat assessment was used to provide a baseline for comparing the design of the SENTINEL as well as to help the reviewers become familiar with mission tasks. This heuristic assessment consisted of HFE experts identifying aspects of the design that are inconsistent with principles of HFE design as specified in accepted HF standards and best practices. HFE experts boarded the legacy boat USCGC GANNET located at USCG Station Fort Lauderdale, Florida for an underway period. The HFE experts examined the design of the boat in a static sense, focusing on the design of the pilothouse, galley, and mess deck noting instances of good design attributes as well as areas that may cause potential human performance issues. These findings were analyzed following the method discussed below.

- Usability Assessment - Usability assessments were conducted concurrent with the heuristic reviews. While underway, HFE experts observed crew members performing actual or simulated selected tasks including towing, small boat launch and recovery, anchoring, go-fast investigation, main space fire emergency drill during dockside demonstrations as well as when the boats were underway. At the conclusion of each task, the HFE experts interviewed the USCG personnel to fully understand each task and step within the task as well as any issues or difficulties observed. The focus of the assessment was to understand the required functions and highlighted challenges associated with the current designs. These findings were then analyzed using the methods discussed in the Analysis and Reporting Phase.

Upon completion of the familiarization and assessment on the legacy boat, a three-stage assessment of the current proposed design of the SENTINEL (as represented by full-scale mock-ups of the pilothouse, galley, and mess deck) was performed as the SENTINEL Class Validation effort. Particular areas of interest included: ergonomics, lighting (including glare), ingress/egress accessibility, maintenance accessibility, communications, climate, usability, workflow/group

interactions, suitability, operator workload, and situation awareness quality/availability of data. These assessments were compared to lessons learned from the review of the legacy asset in the previous task. The activities associated with this thrust included:

- **Heuristic Review** – Before incorporating the users into the assessment, the HFE experts evaluated whether elements of a design followed established human-centered design methods, standards, and/or processes (e.g., ASTM F1166-2007, ABS Guide for Habitability on Ships). This review served to indicate or point out areas of interest as a means to further investigate potential human performance-related risks and challenges that could be salient in the usability analysis that followed. The checklists developed in the Planning Phase were used to facilitate this review. Areas of focus were: controls, displays, alarms, anthropometrics, access for maintenance, access aids, and environmental controls to include lighting to the extent possible given the status of the mockups.
- **Usability Assessments** – Through the observation of required tasks and activities, further evaluation of human performance-related issues and challenges were evaluated to include those activities which involve active crew participation and engagement with the cutter’s equipment and compartments. The focus was on the crew’s level of performance or effectiveness of execution of the required tasks. The key to this activity was having users talk or walk through the required tasks in the developed scenarios either physically or verbally to highlight the ability for the system to support these tasks or perhaps present limitations to performance and even safety hazards. Task performance challenges during the scenarios were documented. Additionally, users were interviewed at the conclusion of each task to better understand strengths and weaknesses of the design in terms of supporting task performance. Crew performance of the scenarios was videotaped for later review to further identify potential issues as well as to provide inputs into the following task.
- **Link Analysis** – In the pilothouse, galley, and mess deck spaces, the equipment location and relationships with personnel in the context of the required tasks was collected, significant issues were reported, but a more in-depth analysis of the links will follow after the final analysis is completed.

**The Analysis and Reporting Phase.** Data collected during the Data Collection Phase was then analyzed to understand how well the design supported the optimization of human performance and quality of life. The results of the data collection activities of the boat and mock-ups included pictures, checklists, notes and observations which were and will continue to be analyzed. All data was documented as “issues”, but not necessarily negative as the goal was also to highlight areas

where the design supports the required tasks and is designed in accordance with the technical requirements of the contract.

Identified issues were then tied to specific SENTINEL requirements. This traceability is key to provide the HFE Team with a means to determine the ability for the SENTINEL Class Patrol Boat to meet its human performance and safety goals. Assessments of the design’s ability to support the users’ required tasks were developed, and potential recommendations were provided to the SENTINEL Project Management (PM), including the SENTINEL Project Resident Office (PRO) for the proposed design of the spaces as reflected in the mock-ups.

#### 4.2 (b) HFE Mock-up Assessment Findings

The goal of this assessment was to determine whether the pilothouse, galley, and mess deck spaces, as designed, will be able to support the users in their ability to achieve the performance required to meet the missions. Table 1. SENTINEL HFE Opportunities for Improvement describes the results of the observations made by the HFE team in the context of the HFE requirements. The HFE requirements are derived from the contract specifications, and the high level findings included mostly minor ergonomic design level compliance issues, such as hand grabs needed overhead and on bridge consoles.

**Table 1. SENTINEL HFE Opportunities for Improvement**

HFE Design Category	Items Noted in Pilothouse	Items Noted in Galley / Mess	Total Items Noted
General Design	3	17	20
Communications	4	0	4
Accessibility	10	10	20
Maintainability	1	4	5
Controls, Displays, and Alarms	2	0	2
Error-Tolerant Design	1	1	2
Workstation Design	21	15	36
Labeling	2	0	2
<b>Total Items Noted By Mockup Location</b>	<b>44</b>	<b>47</b>	<b>91</b>

The next steps for this project include working with the SENTINEL Project Office to conduct another galley mock-up evaluation and design validation with the assistance of USCG operational Food Service SMEs once the mock-up is further constructed. In addition, CG-1B3 would like to further evaluate maintenance access issues in the pilothouse and complete formal link analyses for both the galley and pilothouse.

The USCG HFE analysis and data collection process used for the SENTINEL Class Patrol Boat project is complementary to the DHS HSRE process for HSI implementation in Acquisitions and the lessons learned will contribute to the best practices.

## **5. HSI APPLIED TO THE OFFSHORE PATROL CUTTER (OPC)**

### **5.1 THE OPC PROJECT OVERVIEW**

Another project that the USCG HSI for Acquisition Division is working that directly implements the DHS HSRE processes and best practices is the Offshore Patrol Cutter (OPC). The OPC is a major acquisition to replace the aging fleets of 270' and 210' Medium Endurance Cutter (WMEC), as well as to address the newly mandated security requirements following the terrorist attacks on September 11, 2001.

The OPC will typically conduct its primary missions in the Coast Guard deepwater environment, beyond 12 nautical miles from shore, and will be deployed anywhere around the globe where the national interests require the Coast Guard's unique blend of authorities and capabilities. To maximize efficiency the Coast Guard continues to require its assets to be of a stand alone, multi-mission nature, as well as having interoperable capabilities. This asset will be expected to perform the following Coast Guard mandated missions:

- Ports, Waterways, and Coastal Security (PWCS)
- Search and Rescue (SAR)
- Drug Interdiction (DRUG)
- Alien Migrant Interdiction Operations (AMIO)
- Living Marine Resources (LMR)
- Other Law Enforcement (OLE)
- Defense Readiness (DR)

Through its unique set of law enforcement and military capabilities, the OPC will bridge the gap between the Coast Guard's law enforcement/homeland security mission priorities and the Navy's military defense mission priorities. The OPC will implement the common vision of the Chief of Naval Operations (CNO) and the Commandant of the Coast Guard (CCG) in the National Fleet Policy. The cutter will be able to conduct assigned missions through a full-spectrum of climate and maritime weather conditions to include tropical, dry, temperate, and Arctic climates. The OPC will include the latest Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) systems to improve capability to operate in a highly complex network centric environment. The OPC's aviation capabilities will provide the versatility required to effectively perform in a multi-mission

capacity. The OPC's small boat capability will support almost every facet of the cutter's operations and will be configured to operate with small boats already in the Coast Guard inventory. The cutter will be able to operate at a broad range of speeds providing flexibility for rapid response/interception, fuel efficient patrolling/transiting, and efficient performance of mission defined tasks (e.g. launch recover aircraft/small boats, towing, etc.). The cutter will be crewed by the minimum number of personnel to optimize mission performance, human performance, affordability, safety, and survivability. The HSI considerations for this vessel are vast and are critical to the design of an operationally affordable and sustainable OPC.

The OPC project acquisition is in the early stages of the SELC, specifically the Solution Engineering Phase of Acquisition. This is a unique and crucial position for HSI within the USCG to become involved as a permanent member of the Ship Design Team, Integrated Product Teams, and contributing authors to the Request for Proposal. In line with one of the three major elements of the DHS HSRE Standard HSI Process (Requirements Analysis, Design, and T&E), the CG-1B3 HFE SMEs have been contributing to the OPC project since the Needs Validation stage of acquisition by developing interim requirements based on legacy cutter analysis and lessons learned that were directly applied to the Operational Requirements Document (ORD). The project details are described in the following sections.

### **5.2 HFE INTERIM REQUIREMENTS DEVELOPMENT PROJECT**

The approach to developing the OPC Initial Requirements Document (IRD) focused on identifying human performance issues and concerns as well as HFE design requirements based on:

- Review of technical reports and other documentation from legacy cutters and other applicable sources
- Lessons learned from previous cutter development programs such as the National Security Cutter (NSC)
- Observation of current cutter operations.

These potential issues, concerns, and HFE design requirements were systematically reviewed and analyzed in order to develop HFE and human performance requirements to include in OPC acquisition documentation. To facilitate this effort, the HFE Team developed a data collection process and set of tools. The team then reviewed and refined the process and tools through discussions with SMEs at USCG Headquarters (HQ). The data collection as well as the analysis focused on documenting issues and requirements as they



apply to anticipated OPC evolutions, tasks, and spaces.

**Documentation Review.** The HFE SMEs started the first step in the Requirements Analysis process by reviewing the OPC Preliminary-Operational Requirements Document (P-ORD), the Preliminary-Specification, the Technical-Specification, a U.S. Navy Board of Inspection and Survey (INSURV) team report on an existing 270' cutter, and a Weapon System Explosive Safety Review Board (WSESRB) report regarding the same 270' cutter to gain an understanding of existing issues in the operational environment on assets of similar mission and function.

**Mission Decomposition.** In order to develop a better understanding of USCG cutter operational requirements, the HFE Team identified the missions shared by similar platforms and the proposed OPC. The team then began decomposing these missions into subsequent evolutions and tasks. Getting down to the task level allowed the team to understand crew individual roles and responsibilities, how the ship equipment should support the task and mission, and what level of human performance is required for mission success.

In order to develop a better understanding of USCG operations, cutter missions, and crew tasks, operational procedures were developed for several USCG Medium Endurance Cutter (WMEC) evolutions. The basic approach taken to develop these operational procedures was to identify the evolutions to observe, identify and review available relevant operational task data, refine task data by talking to USCG SMEs, then develop the operational procedures as conducted on WMEC's based on all input. Operational procedures for the following evolutions were developed:

- Launch Rigid Hull Inflatable Boat (RHIB) using Davit,
- Recover Boat (RHIB) using Davit RHIB,
- Helicopter Operations,
- Towing,
- Alien Migrant Interdiction Operations (AMIO),
- Vertical Replenishment (VertRep),
- Fuelling At Sea (FAS),
- Stern Recover – RHIB (NSC), and
- Stern Launch – RHIB (NSC).

**Cutter Visits.** The specific objectives of conducting cutter visits were to: develop better insights into how evolutions and tasks are performed on USCG Cutters; understand the potential impact of the work environment on task performance; and to identify HFE design and human performance requirements. The SME Team worked with CG-1B3 personnel to identify the most appropriate types of cutters to include in the visits, where they were based, and

when key evolutions would be conducted by the targeted cutters. The appropriate cutters primarily included representatives of the 270' WMEC, and maybe the 210' WMEC and 87', 110' and 170' WPB classes. The D&P Team also identified key information required and tasks and evolutions to be observed. The basic approach to collecting data was to review spaces (e.g., to assess HF related issues, such as layout, lighting, noise levels, etc.), to conduct interviews of cutter crew members (e.g., to review lessons learned through their experience), and to observe tasks being performed while the cutter is at sea (e.g., to assess workflow, layout, communications issues, etc.). A Task Inventory Database (described previously) was then developed as a guide for underway data collection. The D&P Team then coordinated, through CG-1B3, access and final schedules for each cutter visit.

## 5.2 (a) HFE Applied to the OPC Project

Through the holistic approach of gleaning information from all available sources and synthesizing that information into usable and needed requirements, as well as verifying draft requirements already developed, the team discovered systemic and recurring deficiencies in accommodating human requirements in the shipboard environment. A few of these deficiencies in the realms of maintenance, storage, and physiological accommodation are well known and were merely confirmed by this effort. A few more were suspected deficiencies exacerbated by reduced manning, changes in maintenance strategies, changes in mission requirements, and insertion of technology and equipment over a given ship's lifecycle. The final group of deficiencies (mostly encompassing the categories of communications and situation awareness) revealed themselves as singular concerns by SMEs at various levels, as minor inconveniences during drills and evolutions, and as increased training, logging, and reporting requirements. This effort, having been correctly executed at the earliest SELC stages of OPC development, has provided valuable insight into these problematic areas.

Table 2. OPC HFE Findings details the areas within the project that the HFE SMEs recommend follow up for verification and validation of requirements against human performance best practices and guidance documents. These findings have begun to be addressed as the OPC project matures through the acquisition process. The findings have been incorporated into the ORD development, and are being addressed throughout the development of the system design specifications.

The next steps for HSI in this project include continued involvement in the SELC acquisition process and close working relationships with the OPC Ship Design Team and IPTs. This will allow

for continued explicit identification of human performance requirement deficiencies and validation of the design approach in accordance with the DHS HSRE HSI Process and existing guidance and standards. In addition, the CG-1 Technical Authority will continue to use the OPC project as a testbed for identifying where the HSI process is both successful and unsuccessful in terms of requirements analysis, compliance with standards, trade-off analyses, and shipyard compliance and HSI level of effort. Based on the success of the SENTINEL Class Patrol Boat HFE mock-up evaluation, the HSI Technical Authority will continue to push for mock-ups, prototyping, usability analyses, and link analyses as recommended HSI best practices.

Directive 102-01 Interim Version 1.9, Department of Homeland Security, Washington, DC.  
 International Association of Classification Societies, (2007). Recommendation for the Application of SOLAS Regulation V/15 Bridge Design Equipment Arrangement and Procedures (BDEAP). London, United Kingdom.

**Table 2. OPC HFE Findings**

HFE Finding	Number of results
Presented new requirements	90
Verified P-ORD requirements	20
Suggested guidance verification	9
Identified issues outside HFE	8
Suggested P-ORD revisions	3
<b>Total issues presented to OPC</b>	<b>130</b>

## 6. CONCLUSIONS

The USCG HSI technical authority process and policies exist to ensure the Coast Guard has the best value engineering and technical products as well as to ensure assets, new and existing, are designed with the most effective, efficient, and affordable crew composition, workforce management support, job performance preparation, human performance reliability, and a habitable and safe work environment. Through the close partnership with the DHS HSRE Program, the USCG HSI Technical Authority can continue to ensure continued mission readiness.

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