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An American National Standard

Standard Practice for Human Systems Integration Program Requirements for Ships and Marine Systems, Equipment, and Facilities[1]

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1. Scope

1.1 *Objectives*—This practice establishes and defines the processes and associated requirements for incorporating Human Systems Integration (HSI) into all phases of government and commercial ship, offshore structure, and marine system and equipment (hereafter referred to as marine system) acquisition life cycle. HSI must be integrated fully with the engineering processes applied to the design, acquisition, and operations of marine systems. This application includes the following:

1.1.1 Ships and offshore structures.

1.1.2 Marine systems, machinery, and equipment developed to be deployed on a ship or offshore structure where their design, once integrated into the ship or offshore structure, will potentially impact human performance, safety and health hazards, survivability, morale, quality of life, and fitness for duty.

1.1.3 Integration of marine systems and equipment into ships and offshore structures including arrangements, facility layout, installations, communications, and data links.

1.1.4 Modernization and retrofitting ships and offshore structures.

1.2 *Target Audience*—The intended audience for this document consists of individuals with HSI training and experience representing the procuring activity, contractor or vendor personnel with HSI experience, and engineers and management personnel familiar with HSI methods, processes, and objectives. See 5.2.3 for guidance on qualifications of HSI specialists.

1.3 *Contents*—This document is divided into the following sections and subsections.

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2. Human Systems Integration

2.1 *Definition of Human Systems Integration*—HSI is a systematic life-cycle engineering process that identifies and integrates human considerations into the design, acquisition, and support of marine systems through the application of knowledge of human behavior, capabilities, and limitations. The goal is to optimize human performance, including human capability, proficiency, availability, utilization, accommodation, survivability, health and safety by influencing design, construction, and operations through the integration of requirements that rely on the expertise found in the following HSI domains:

2.1.1 *Manpower*—Establishing the number and type of personnel needed to operate and maintain the marine system.

2.1.2 *Personnel*—Determining where the people with the required knowledge, skill, and abilities (KSAs) required to fill marine system billets will be drawn.

2.1.3 *Training*—Establishing and providing the training requirements for the personnel selected.

2.1.4 *Human Factors Engineering*—Designing and assessing user interfaces between humans and hardware, software, firmware, Webware, courseware, information, procedures, policy and doctrine, documentation, design features, technology, environments, organizations, and other humans.

2.1.5 *Safety and Occupational Health*—Providing a safe and healthy working environment.

2.1.6 *Personal Survivability*—Providing a platform that maximizes crew survivability.

2.1.7 *Habitability*—Providing the characteristics of systems, facilities, personal services, and living and working conditions that result in high levels of crew morale, quality of life, safety, health, and comfort.

2.1.8 Government-oriented definitions of the HSI domains are provided in Table 1.

2.1.9 It is understood that not all HSI domains will be involved in every marine system design project. For example, in the commercial maritime setting, design requirements affecting several HSI domains (for example, manpower, personnel selection, and training requirements) are set by entities other than the procuring organization. This does not diminish the fact that inattention to these HSI domains can lead to the increased likelihood of human error and accidents and incidents. Therefore, the procuring organization must exert maximum effort to ensure that all HSI domains are considered in the design, construction, and operation of any maritime system.

2.1.10 HSI fundamentally involves engineering processes and program management efforts that provide integrated and comprehensive analyses, design and assessment of requirements, operational and maintenance concepts, and resources for system manpower, personnel, training, human factors engineering (HFE), safety and occupational health (SOH), personnel survivability, and habitability. These seven HSI domains are interrelated and interdependent, and they are primary drivers of effective, affordable, and safe design concepts and deployed systems. HSI relies on a concurrent engineering process to perform co-operative trade-offs among the seven HSI domains to achieve effective system performance levels and affordable life-cycle costs, but does not replace individual domain activities, responsibilities, or reporting channels.

2.1.11 The HSI framework for organizing and integrating of human considerations into marine system design represents a system-level engineering approach. HSI uses the results of its technical domain analyses and tradeoffs to integrate them into the systems engineering and design processes. In the government environment, other HSI domains provide insights, data, and design considerations that HFE translates into hardware, software, workspace, and task design. This is a more formal government process. In the commercial environment, HSI relies heavily on HFE, assigning it responsibility of being aware of considerations associated with manpower, personnel, training, safety, and habitability and representing those as part of a human-centric design process.

TABLE 1 Description of Government-Oriented HSI Domains

Domain	Description
Manpower	Manpower is the number of personnel (military, civilian, and contractor) required, authorized, and potentially available to operate, maintain, train, administer, and support each ship, offshore structure, system, or combination thereof.
Personnel	Personnel is the source, in terms of people, for the human knowledge, skills, abilities, aptitudes, competencies, characteristics, and capabilities required to operate, maintain, train, and support each ship, offshore structure, marine system, or combination thereof, in peacetime and war.
Training	Training is the instruction, education, assessment, resources required to provide ship and marine facility personnel with requisite knowledge, skills, and abilities to operate, maintain, and support ship, offshore structure, marine systems, or combination thereof.
Human Factors Engineering	Human factors engineering is the comprehensive integration of human characteristics and capabilities and limitations into system definition, design, development, and evaluation to promote effective human-machine integration for optimal total system performance.
Safety and Occupational Health	Safety is the process for hazard identification, risk evaluation, design analysis, hazard mitigation, control, and management. The process manages the design and operational characteristics of a system to eliminate or minimize the possibilities for accidents or mishaps caused by human error. Occupational health is the systematic application of biomedical knowledge, early in the acquisition process, to identify, assess, and minimize health hazards associated with the system's operation, maintenance, repair, storage, or support.
Personnel Survivability	Personnel Survivability is the how the system design minimizes medical implications when humans are injured, provides escape and evacuation routes for crew, and minimizes human mental and physical fatigue.
Habitability	Habitability is the ship, offshore structure, and system characteristics that provide for environment control of living and working conditions (temperature, noise, vibration, and space attributes); and provides accommodations and support facilities (berthing, sanitary, food service, exercise, training, laundry, medical, dental, administrative, ship stores, and community or lounge facilities). Habitability is concerned with the level of comfort and quality of life that is conducive to maintaining optimum crew performance, readiness, and morale.

TABLE 2 Key Interactions Among HSI Domains

Domain	Interactions
Manpower	Personnel – Qualities and quantities of personnel required versus availability in inventory and pipeline Training – Qualities and quantities required versus ability to train to meet requirements HFE – Qualities and quantities of personnel required versus ability of system design or redesign to support manpower, task complexity, and workload SOH – Qualities and quantities of personnel required versus ability to safely perform tasks, particularly in a reduced manpower environment Personnel Survivability – Quantities versus availability of personnel protection equipment (PPE) and designs that support survivability Habitability – Quantities of personnel and workload required to perform tasks versus habitability support requirements such as berthing, food service, laundry, administrative, postal, ship stores, and other habitability support spaces
Personnel	Training – Availability in the inventory or in the pipeline of quantities of personnel required versus ability to train required knowledge, skills and abilities (KSAs) HFE – Availability of quantities and qualities of personnel required versus complexity of task and system design
Training	HFE – Complexity and duration of training and training system design versus task/design complexity and the ability to train KSAs versus complexity of tasks and design Personnel Survivability – Transfer of information on training requirements for PPE and other emergencies
HFE	SOH – How does design avoid or mitigate risks to safety and occupational health; Risks versus ability of design to mitigate risks Personnel Survivability – Emergency egress and personal protection versus design's ability to support Habitability – How do habitability facilities support the ability of users to safely and effectively inhabit space and perform tasks
SOH	Habitability – Reduction of safety and health risks through the design of environmental control (temperature, noise, and vibration levels) and and habitability facilities and working spaces not under habitability purview (work shops, machinery spaces, etc.)
Personnel Survivability	Habitability – Ensure that requirements for PPE and survivability are integrated with the overall design of habitability facilities and working spaces
Habitability	All HSI Domains – Ensure domain concerns are addressed in habitability facilities, e.g., address the manpower or training implications of a food service facility

2.2 *HSI Integration Process:*

2.2.1 A key HSI focus is *integration*. HSI takes a total system level view of design, acquisition, and operations. This system level view starts with the performance requirements of the total system that are translated into requirements for total system performance and total cost of ownership. The system performance and cost requirements then are integrated into the design by the application of HSI methods and standards to the design of the marine system. HSI continues as an integrated element of the operations and support activity as a mechanism to support training, maintenance, and identify system improvement opportunities.

2.2.2 HSI relies on the individual technical HSI domains, but also the integration of these domains among themselves and with the other systems engineering and logistics requirements and processes. The domains of HSI must work in concert among themselves and with other systems engineering processes to address human design issues and trade-offs that optimize overall system performance and reduce life cycle costs. Table 2 provides a high-level view of some of the types of interactions and tradeoffs that occur among HSI domains.

2.2.3 Integration between HSI domains occurs through the following activities:

2.2.3.1 Developing and maintaining a Human Systems Integration Plan (HSIP) that includes all HSI domains and discusses interactions required among these domains. The key here is to maintain the HSIP over the marine system life cycle through updates as design issues and considerations change. See 5.3 for more information on the HSIP. The HSIP should be integrated with the Systems Engineering Plan (SEP) and other engineering plans.

2.2.3.2 Close coordination and communication among HSI domains. This occurs through informal and formal meetings, design reviews, and other communications such as email, telephone conversations, list serves, and bulletin boards.

2.2.3.3 Use of an HSI Integrated Product Team. See 5.4 for more information.

2.2.3.4 Performing a unified front-end analysis that addresses requirements and concepts for each domain, the interactions among HSI domains, and the integration with systems engineering. A unified front-end analysis represents one analysis that accepts input and provides output to all the HSI domains and other engineering areas.

2.2.3.5 Maintaining a consolidated database of HSI issues and design decisions. This database should include all HSI issues identified during the design effort, suggested HSI inputs from all the HSI domains, a description as to whether or not each HSI recommendation was incorporated in the marine system design; and if not accepted, provide the reason for rejection along with the risk assessment. The database is created and maintained by the HSI specialists from the procuring organization. This database should be maintained through the marine system life cycle to support the documentation of HSI issues that arise during training, operation, and maintenance. The consolidated database of HSI issues should include lessons learned from the design process, feedback from in-service ships and offshore structures on marine systems, machinery, and equipment.

2.2.3.6 Defining and empowering an integrator role that has responsibility for facilitating and managing the information flow among HSI domains and with systems engineering. This individual must be someone with an understanding of HSI, preferably possess an engineering background, and be a senior member of the organization. The HSI integrator should not be responsible for performing the HSI activities, rather should focus on ensuring communication between the various HSI domains and with the engineering program.

2.2.3.7 Collecting and tracking information on operator or maintainer feedback and lessons-learned from legacy or similar operational systems concerning human performance, workload, health and safety, and accommodation. This provides information on how well a design approach has worked in meeting objectives, and what problems or issues have been identified regarding human performance, behavior, availability, productivity, competence, health and safety, and accommodation.

2.2.3.8 Conducting user-centered design of user interfaces that emphasizes requirements for human performance, including human capability, behavior, availability, productivity, competence, health and safety, and accommodation.

2.2.3.9 Conducting Test and Evaluation (T&E) activities that assess all HSI domains and the efficacy of any tradeoffs that have occurred. The T&E activities should focus on the human performance aspects of total system performance, behavior, availability, productivity, competence, health and safety, and accommodation.

2.3 *HSI Program Requirements*—HSI is required for government system acquisition programs. For the commercial marine industry, there is no policy requirement for HSI, but this document serves as a best practice that can be required through contract language by the procuring organization.

2.3.1 The decision as to whether to invoke this practice as a mandatory provision for design, development, and operational programs for government or commercial industry marine systems is dependent on three key factors:

2.3.1.1 The potential influence of human performance on mission and task success.

2.3.1.2 The existence of any overarching HSI drivers for the acquisition, such as reduced manpower or training burden, or both, enhanced safety, or increased human and total system performance requirements.

2.3.1.3 The potential to significantly reduce total ownership costs for systems by reducing costs associated with manpower, training, human errors and accidents.

2.3.2 Fig. 1 provides a high-level decision process for

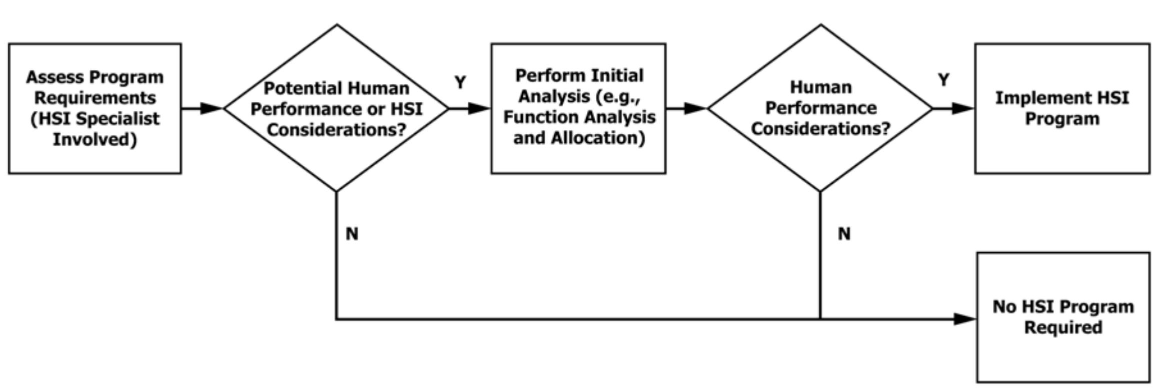

FIG. 1 Process for Determining the Need for an HSI Program

determining the requirement for an HSI Program. This process is performed as a precursor to any front-end analysis to make judgments about human involvement with the marine system. These judgments will be detailed, refined, and validated in the early phases of the marine system design and acquisition process. The size and significance of any required HSI program will depend on a number of factors, including those associated with the answers to the questions in 2.3.3.

2.3.3 Once the HSI program decision has been made, key considerations that should be looked at to scope the level of the HSI program effort include the following:

2.3.3.1 Will the type of personnel involvement or the approaches related to operation or maintenance of the marine system differ substantially from what is the current practice of the organization?

2.3.3.2 Will the marine system introduce new technologies or impose new tasks and skill requirements on the operators/maintainers not previously not supported to acceptable levels?

2.3.3.3 Are there opportunities to increase operator/maintainer levels of efficiency through improved design?

2.3.3.4 Will the marine system be operated and maintained by individuals not normally assigned to work on the facility?

2.3.3.5 Is one objective of the marine system to reduce manpower?

2.3.3.6 Will the marine system be used by personnel from a culture or geographic part of the world different from the individuals doing the design and construction? If so, what HSI requirements need to be modified to meet the target user population?

2.3.3.7 Will the marine system be operated or maintained by both males and females?

2.3.3.8 Will the marine system provide equipment with which the personnel have had little or no previous experience?

2.3.3.9 Is one goal of the marine system to reduce accidents or incidents that have occurred on other marine systems?

2.3.3.10 Will the new marine system be more complex than, or different from, any previous system?

2.3.3.11 Does the procuring organization lack any previous HSI experience on previous design projects that could be transferable to the new marine system?

2.3.3.12 Is one goal of the new project to reduce operating and maintenance costs?

2.3.3.13 Does the procuring organization have a specific mission to enhance safety and quality of the work environment for its employees?

2.3.3.14 Has the procuring organization had previous unfavorable rulings from regulatory agencies on issues of safety, pollution control, or system design based on HSI issues?

2.3.4 Where a HSI program is required, decisions to implement or comply with this practice by tailoring the HSI activities to be performed should be made by HSI specialists and include detailed justification for the decision. The procuring organization has final approval of any tailoring.

3. Referenced Documents

3.1 *Introduction*—The following documents, where appropriate, should be used in conjunction with this practice in implementing a HSI program. These documents should be considered for use by both the government and the commercial industry.

3.2 *ASTM Standards:*[2]

F1166 Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities

3.3 *Commercial Standards and Documents:*

ABS Guidance Notes on the Application of Ergonomics to Marine Systems, 2003

ABS Guidance Notes on the Ergonomic Design of Navigation Bridges, 2003

ABS Guide for Crew Habitability on Offshore Installations, 2002

ABS Guide for Crew Habitability on Ships, 2001

Human Factors Design Handbook Woodson, W., Tillman, B. and Tillman, P., 1992

ANSI/ITAA GEIA-STD-0010 Standard Best Practices for System Safety Program Development and Execution, 1 October 2008

3.4 *Government Standards and Documents:*

NAVSEA Human Systems Engineering Best Practices Guide Beaton, R., Bost, R., and Malone, T., 2008

CNO P-751-1-9-97 Navy Training Requirements Documentation Manual, 21 July 1998

CNO P-751-2-97 Training Planning Process Methodology Guide, 21 July 1998

CNO P-751-3-9-97 Training Planning Process Methodology Manual, 21 July 1998

DOD Directive 1100.4 Guidance for Manpower Programs, 12 February 2005

MIL-HDBK-46855A Human Engineering Process and Procedures, 17 May 1999

MIL-STD 882D DOD Standard Practice for System Safety, 10 February 2000

ABS Guide for Building and Classing Naval Vessels Part 0 General Provisions, Chapter 7 "Human Systems Integration," Chapter 8 "System Safety," Chapter 9 "General Arrangements," and Chapter 10 "Margins;" Part 4 Control, Automation, and Navigation Systems; Part 6 Habitability and Outfit, January 2009

NAVSEA Standard 03-01 Common Presentation Layer Guide, September 2006

NAVSEAINST 5100.12A Requirements for Naval Sea Systems Command System Safety Program for Ships, Shipborne Systems and Equipment, 20 January 2005

OPNAVINST 1000.16 Manual of Navy Total Force Manpower Policies and Procedures, 17 June 2002

OPNAVINST 1000.16K Navy Total Force Manpower Policies and Procedures, 22 August 2007

OPNAVINST 5100.23G Navy Safety and Occupational Health Program Manual, 30 December 2005

OPNAVINST 5100.24B Navy System Safety Program, 6 February 2007

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

OPNAVINST 9640.1A Shipboard Habitability Program, 3 September 1996

SECNAVINST 5100.10H Navy Policy for Safety, Mishap Prevention, Occupational Health and Fire Protection Program, 15 June 1999

4. Terminology

4.1 *Definitions:*

4.1.1 *arrangement drawing*—engineering design drawings that provide plan, sectional, and elevation views of (*1*) the configuration and arrangement of major items of equipment for manned compartments, spaces, or individual workstations, and (*2*) within the workstation, such as in a modular rack.

4.1.2 *contractor*—the organization or company with the contractual responsibility for designing the ship, offshore structure, or marine system. For ships or offshore structures, this is typically a shipyard.

4.1.3 *critical activity*—any human activity that, if not accomplished in accordance with system requirements (for example, time limits, specific sequence, necessary accuracy), would have adverse effects on system or equipment cost, reliability, efficiency, effectiveness, or safety.

4.1.4 *cultural expectation*—the cause and effect relationships and use conditions (for example, red means stop or danger, moving a toggle switch up to activate) that humans learn from their culture and form the bases for design conventions. Also referred to as population stereotype.

4.1.5 *function*—a higher-level activity performed by a system or human (for example, provide electric power) to meet mission objectives usually decomposed into sub functions and tasks.

4.1.6 *human systems integration*—modern systems engineering that addresses optimization of manpower, personnel and training, and enhancement of human performance affecting total system performance and life cycle costs, including human capability, availability, safety, survivability and fitness for duty.

4.1.7 *high drivers*—high drivers for HSI include functions that impose high demands on manpower, are labor intensive, are expected to impose high risks, workloads, and performance complexities, are error prone, require excessive training, or are unsafe.

4.1.8 *human error*—inappropriate or undesirable human decision or behavior. Human errors can be categorized into errors of omission where the human forgets or does not perform a task or step and commission where the human unintentionally performs a task or step incorrectly. In addition, there are intentional errors where the human consciously and purposefully omits or performs a task incorrectly. Another way to classify human error is by slips, where errors are due to incorrect automated/unconscious behavior, and mistakes, where errors are due to incorrect conscious decision making.

4.1.9 *manning*—represents the personnel assigned to, or required for, a marine system in terms of whether people are currently in the personnel inventory, are in the recruitment pipeline, or need to be recruited. Manning also deals with how the personnel need to be trained to meet KSA requirements.

4.1.10 *manpower*—the requirements for the number and types of people needed to perform the required workload associated with the tasks defined for a marine system as expressed in the number and characterization of the billets approved for a marine system crew.

4.1.11 *marine system*—ships, offshore facilities, equipment, and software used in a marine environment.

4.1.12 *mission*—a specific performance requirement imposed on one or more systems (for example, unload cargo) within the operational requirements.

4.1.13 *offshore structure or facility*—fixed and floating installations, offshore supply vessels (OSVs), offshore terminals, or any other offshore facility created for exploration, production, distribution, and/or transportation of natural gas and oil.

4.1.14 *operational requirements*—requirements under which the platform, system, equipment, or software are expected to operate and be maintained (for example, day/night, all weather operation, sea state, speed, endurance) while completing a specific mission or missions.

4.1.15 *panel layout drawings*—detailed drawings include scale layouts (for example, controls and displays on each panel), items of equipment (for example, shipboard command console), descriptions of all symbols used, identification of the color coding used for displays and controls, the labeling used on each control or display, identification of control type (for example, rotary or pushbutton), and screen layouts for software generated displays.

4.1.16 *procuring organization*—the organization that purchases a ship, offshore structure, marine equipment, or marine system. For commercial shipping and offshore structures, this is a ship or offshore structure owner.

4.1.17 *system*—a combination of components that interact together to achieve a common goal. Systems can be machine-to-machine, human-to-machine, and human-to-human. The term *system* can be used for individual components that are integrated into a ship or offshore structure, as well as the complete ship or offshore structure.

4.1.18 *task*—a lower level activity, compared to a function, which is the unit of human performance. A task represents a composite of related activities (for example, perceptions, decisions, and responses) performed by a human for an immediate purpose under specified conditions (for example, environmental, operational and/or tactical) with a definite beginning and end.

4.1.19 *user interface*—all interfaces between the human and the system, including hardware, software, and workspace.

4.1.20 *vendor*—a supplier of marine systems, equipment, or machinery to the contractor.

5. Summary of Practice

5.1 *HSI Design Objectives*—Key objectives for HSI in marine system design are the following:

5.1.1 *Enhancement of Human Performance*—A critical factor underlying mission success is human performance; that is, the demonstrated capability of the intended user to operate, maintain, support, manage, and use the systems and equipment under all expected environmental and operational conditions.

5.1.2 *Manpower Optimization*—Manpower optimization is defined as determining the number of personnel and skillsets required to perform the required missions, functions, or tasks successfully given the anticipated human performance, workload, and safety requirements, as well as affordability, risk, and reliability constraints. This supports cost-effective operation of ships, offshore structures, and marine equipment.

5.1.3 *Training Requirement Reduction*—Reduction of difficult to train skills through design, which can reduce personnel requirements or reduce the overall training burden, or both, support the objectives of optimizing manpower, and enhancing human performance, as well as reducing life cycle costs associated with training.

5.1.4 *Enhancement of Safety and Survivability*—Safety consists of those system design characteristics that serve to minimize the potential for mishaps causing death or injury to operators and maintainers or threaten the survival or operation, or both, of the system.

5.1.5 *Improvement in Quality of Life*—Quality of life factors are those living and working conditions, that is, effective design of space, equipment, and environmental control in habitability facilities and work spaces, which result in levels of personnel morale, safety, health and comfort, and fitness for duty adequate to sustain maximum personnel effectiveness to support mission performance and avoid personnel retention problems. This includes avoidance of exposure to risks of adverse health and occupational health effects.

5.1.6 These key objectives are met through the application and integration of HSI within the systems engineering process throughout the life cycle of the marine system. This includes incorporating the feedback gained from lessons learned during design, development, build, and system operation (for example, operator and maintainer feedback) into updates to HSI processes and requirements. The execution of only one or more of these key objectives without requisite system integration efforts does not constitute HSI.

5.2 *Key Success Factors*—The following success factors should be part of any HSI program:

5.2.1 *Management Commitment*—Management within the procuring organization, as well as contractor and vendor organizations must be committed to the procuring organization's HSI program by emphasizing planning, providing funding, and making available appropriate resources. This commitment should be demonstrated by the following:

5.2.1.1 Identification of an HSI champion within the procuring organization or the vendor organization who has responsibility for implementation of HSI within the program, as well as the required authority to be successful.

5.2.1.2 Location of the HSI activity within the engineering organization.

5.2.1.3 Providing appropriate resources, including adequate funding and qualified personnel, to the HSI activity to ensure success.

5.2.1.4 During design and development phases, provide adequate margin for design and service life growth.

5.2.1.5 Providing HSI awareness training to other parts of the organization.

5.2.1.6 Incorporation of HSI into the systems engineering process through integration with the systems engineering plan or other master planning document.

5.2.2 *Early and Consistent Involvement of HSI*—HSI must be integrated with the engineering effort throughout the life cycle of the marine system. This integration is facilitated by HSI specialists from the procuring organization or the contractor and vendor, or both, depending on the phase of the acquisition life cycle.

5.2.3 *Involvement of Qualified HSI Personnel*—Qualified HSI specialists should be used to provide the required HSI support to the program. HSI specialists should bring to the program a broad, systems engineering orientation with a behavioral science and ergonomics background. Knowledge of the systems being designed and their operational environments also is important and can be fine tuned early in the program. HSI domain experts should provide technical supporting capabilities. Recommended minimum qualifications for HSI specialists are provided in Table 3. The HSI specialist should meet the qualifications listed for a Practitioner or Lead/Senior level HSI professional to lead HSI programs. Individuals with qualifications listed for the Junior or Entry levels should work on a project under technical supervision of senior HSI personnel.

5.2.4 *Incorporation of HSI into Program Documentation*—HSI requirements and standards must be incorporated into all program requirements documents, specifications, statements of work, requests for proposals or quotes, test and evaluation plans, and other contract documentation, where relevant. This

TABLE 3 Minimum Qualifications for HSI Specialists

Role	Minimum Education	Minimum Years Experience
Lead/Senior	Ph.D. or Master's degree in relevant field such as human factors engineering, behavioral science, industrial engineering, and systems engineering.	15 years experience applying their HSI specialty in a system design environment. Preferably, some of that experience is with marine systems. Years of applied experience may offset the educational requirements.
Practitioner	Master's or Bachelor's degree in relevant field such as human factors engineering, behavioral science, industrial engineering, and systems engineering.	8 years experience applying their HSI specialty in a system design environment. Preferably, some of that experience is with marine systems. Years of applied experience may offset the educational requirements.
Junior Level	Bachelor's degree in relevant field such as human factors engineering, behavior science, industrial engineering, and systems engineering.	4 years experience applying their HSI specialty in a system design environment. Advanced degrees may offset years of experience.
Entry Level	Bachelor's degree in relevant field such as human factors engineering, behavioral science, industrial engineering, and systems engineering.	1 year or less experience applying their HSI specialty in a system design environment.

includes all specifications provided to vendors and contractors, as well as involvement in source selection.

5.3 *HSI Plan*—The HSIP is the technical strategy and programmatic management plan to ensure that HSI is implemented as early as possible and throughout the system life cycle to affect the design, affordability, and supportability of the system. The HSIP must be integrated with the systems engineering plan or with other relevant engineering plans when a systems engineering plan is not part of the program. For government acquisitions, HSI planning may be incorporated into the systems engineering plan where possible rather than having a stand-alone HSIP.

5.3.1 The HSIP is an essential element of the HSI effort and possesses the following characteristics:

5.3.1.1 It is a dynamic document updated as the acquisition process progresses and as new information is available.

5.3.1.2 It is a planning and management guide, which ensures that HSI issues are addressed at the required time throughout the life cycle of the system. It provides a system management approach for identifying and addressing HSI issues and concerns, as well as tools and analyses that potentially provide answers for these HSI issues.

5.3.1.3 It identifies information sources, documents the results of analyses and trade-offs conducted, provides an audit trail for decisions made in each acquisition phase, and identifies when products and events were completed.

5.3.1.4 It can be a stand alone document that serves as the single source of what information is required, when the information is required, who is responsible for the information, what is the strategy for collecting the information, and what are the required resources in terms of personnel, facilities, and funding.

5.3.1.5 It integrates requirements from all the HSI domains and addresses overarching HSI considerations.

5.3.1.6 It integrates HSI requirements into the systems engineering plan.

5.3.2 The HSIP should be prepared early in the marine system acquisition process and maintained throughout.

5.3.3 Preparation of the HSIP is the responsibility of the procuring organization, whether that is the government or a commercial activity. However, the procuring organization may delegate responsibility for the HSIP to the contractor or require that the contractor also prepare a coordinated HSIP that describes the contractor and vendor HSI requirements, activities, deliverables, and schedule. The procuring organization has approving authority over the HSIP. An example outline of a typical HSIP is provided in Fig. 2.

System Name
Human Systems Integration Plan

1. Background	
a. System/Program Description	Describes the ship, offshore installation, or marine system in terms of technology, components, mission/purpose, expected operational environment, and performance goals.
b. Scope	Summarizes the objectives of the HSI program.
2. Target Audience/Users	Describes the expected operator, maintainer and other users. This description includes, but may not be limited to, their knowledge, skills, and aptitudes (KSAs), training, demographics, physical attributes, and nationalities.
3. Acquisition Strategy	Describes the acquisition approach and process for developing the system such as standard design process versus evolutionary acquisition or other approach. Describes how HSI fits into the chosen approach.
4. Organization, Responsibilities, and Coordination	Describes the HSI organization, where it fits into the overall procuring activity or contractor organization, responsibilities of each HSI participant, and how coordination among HSI participants and between HSI and engineering will occur.
5. HSI Master Schedule	Describes the master schedule for HSI activities and events, overlaid on the system engineering schedule.
6. HSI Goals and Constraints	
a. Goals by Domain	Describes the performance requirements, objectives, and success criteria for each HSI domain.
b. Constraints by Domain	Describes any constraints on the HSI goals such as specific limitations to the types of personnel available to operate the system.
7. HSI Activities	Describes the planned HSI tasks and activities that will be performed by the government as well as the contractor.
Annex A – HSI Issues	Provides a "living" list of issues and their resolution
Annex B – References	Provides relevant references for the HSI program

FIG. 2 Sample Outline of a Typical HSIP

5.3.4 For the government, the HSIP integrates information sources (see Table 2), as well as information from other HSI documents such as the HSI risk management plan and HSI T&E plans.

5.3.5 For the commercial industry, the HSIP can be synonymous with the Human Engineering Program Plan (HEPP) provided that the HEPP adopts a systems perspective. The HEPP should emphasize how HFE will integrate manpower, personnel, safety, and other domain considerations into the design and acquisition of the marine system.

5.4 *HSI Integrated Product Team*—Successful integration of HSI requires a team approach where HSI specialists work closely with other personnel from engineering, SOH, program management, logistics, and stakeholders to ensure that the HSI goals and objectives of the program are met. The formation of an Integrated Product Team (IPT) facilitates this team approach. The IPT should include representatives of the procuring organization and the contractor(s). An HSI specialist should be the chair of the IPT and coordinate all meetings and agendas. Other members should provide input in their respective areas of expertise. The IPT should address the following, at a minimum:

5.4.1 Measuring progress in meeting stated HSI goals.

5.4.2 How to deal with new HSI concerns or issues that arise during the acquisition process.

5.4.3 Coordination and communication between the acquisition and design team with respect to HSI issues, scheduling, and resources.

5.4.4 Integrating HSI into engineering.

5.5 The HSI IPT should have membership with other IPTs to ensure coordination of HSI issues and requirements with the overall engineering process.

5.6 *Quality Assurance*—Verification of compliance with the requirements of this practice and other HSI requirements specified by the contract is the responsibility of the procuring organization. HSI performed during the design and construction program by a contractor or vendor must be demonstrated to the satisfaction of the procuring organization at the scheduled design and configuration reviews and inspections throughout the design and construction period, as well as during test and evaluation inspections, demonstrations, and tests.

5.7 *Nonduplication*—The efforts performed to fulfill the HSI requirements specified herein should be coordinated with, but not duplicated by, efforts performed in accordance with other requirements. An extension of the results of other efforts for use in the HSI program is not considered duplication. Instances of duplication or conflict should be brought to the attention of the procuring activity.

5.8 *Cognizance and Coordination*—Where appropriate, the HSI program should be coordinated with maintainability, reliability, and integrated logistic support. Results of HSI analyses or lessons learned information are provided to the logistics support community. The HSI portion of any analysis, design, and development, or test and evaluation program is conducted by, or under the direct cognizance of the Lead/Senior or Practitioner HSI specialist.

6. Significance and Use

6.1 *Intended Use*—Compliance with this practice provides the procuring organization with assurance that human users will be efficient, effective, and safe in the operation and maintenance of marine systems, equipment, and facilities. Specifically, it is intended to ensure the following:

6.1.1 System performance requirements are achieved reliably by appropriate use and accommodation of the human component of the system.

6.1.2 Usable design of equipment, software, and environment permits the human-equipment/software combination to meet system performance goals.

6.1.3 System features, processes, and procedures do not constitute hazards to humans.

6.1.4 Trade-offs between automated and manual operations results in effective human performance and appropriate cost control.

6.1.5 Manpower, personnel, and training requirements are met.

6.1.6 Selected HSI design standards are applied that are adequate and appropriate technically.

6.1.7 Systems and equipments are designed to facilitate required maintenance.

6.1.8 Procedures for operating and maintaining equipment are efficient, reliable, approved for maritime use, and safe.

6.1.9 Potential error-inducing equipment design features are eliminated, or at least, minimized, and systems are designed to be error-tolerant.

6.1.10 Layouts and arrangements of equipment afford efficient traffic patterns, communications, and use.

6.1.11 Habitability facilities and working spaces meet environmental control and physical environment requirements to provide the level of comfort and quality of life for the crew that is conducive to maintaining optimum personnel performance and endurance.

6.1.12 Hazards to human health are minimized.

6.1.13 Personnel survivability is maximized.

6.2 *Scope and Nature of Work*—HSI includes, but is not limited to, active participation throughout all phases in the life cycle of a marine system, including requirements definition, design, development, production, operations and decommissioning. HSI, as a systems engineering process, should be integrated fully into the larger engineering process. For the government, the HSI systems engineering process is manifested in both a more formalized, full scale system acquisition, as well as a non-developmental item acquisition. For the commercial industry, the system acquisition process is less formal and more streamlined. Each process is described below.

6.3 *Government Formalized, Full Scale Acquisition*—The U.S. Government's acquisition process is composed of six steps, as illustrated in Fig. 3. Each phase is briefly summarized below.

6.3.1 *Capabilities Requirements*—The Capabilities Requirements phase precedes the other acquisition phases and it is performed by the procuring organization. It focuses on defining operational goals and desired capabilities that will be used to guide marine system development; clarifying requirements;

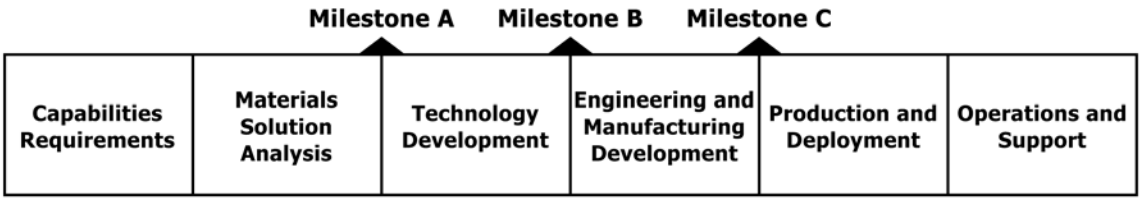

FIG. 3 Government HSI Systems Engineering Process and the System Acquisition Life Cycle

developing initial design concepts and alternatives; and assessing the feasibility and costs of development.

6.3.1.1 These are developed through the Analysis of Alternatives (AoA) process, as defined in the Joint Capabilities Integration Development System (JCIDS) , and captured in the Initial Capabilities Document (ICD). These are based on analyses of multiple concepts that consider affordability, technology maturity, and responsiveness.

6.3.1.2 Typical HSI inputs during this phase include defining human performance, habitability, and safety issues; identifying high level HSI requirements; identifying HSI risks, functions, and tasks from legacy or predecessor systems that will challenge human performance; identifying HSI lessons learned from legacy or predecessor systems, or both; and identifying opportunities for workload reduction, manpower optimization, and enhancement of human performance, safety, and survivability.

6.3.2 *Materials Solution Analysis*—The objective of the Materials Solution Analysis phase is to refine the concept(s) for marine system design developed during the previous phase and to evaluate the technical soundness of the selected concept(s), as well as to determine if the concept(s) meet requirements.

6.3.2.1 This phase is entered once the ICD has been approved, and includes the conduct of an AoA by the Government. This includes developing and evaluating initial design concepts in response to the ICD.

6.3.2.2 Typical HSI inputs in this phase include task and requirement analyses; manpower, personnel, and training analyses; trade-off studies for alternatives; iterative assessments of user interface (UI) design concepts; input to design decisions and products; identification of human performance and safety requirements; development of the HSIP; initial development of habitability and quality of life requirements; and input into test and evaluation strategies.

6.3.3 *Technology Development*—The technology development phase focuses on detailing the design to the level required for the shipbuilder or system developer to be able to have a clear understanding of required features and develop an accurate estimate for the costs to construct. Outputs should include detailed drawings, design specifications, and design standards.

6.3.3.1 This phase, which is entered after Milestone A approval, focuses on reducing risk, selection of a final concept, if not already determined, and determining the technologies to be integrated into the full system design. During technology development, the government prepares the Capability Development Document (CDD) to support program initiation. The CDD builds on the ICD and provides the detailed operational performance parameters necessary to design the proposed system. During this phase of the design process, the safe disposal of the marine system should be estimated and planned, including documenting the use of hazardous materials contained in the system.

6.3.3.2 HSI activities during this phase include top down requirements analysis, human performance evaluations of technology alternatives, UI specification development, inputs to the CDD, personnel, habitability, and training requirements analysis, and developing crewing concepts. After CCD is completed, HSI activities in this phase include HSI input into the development of the preliminary design, detail or performance specification, and contract design including detailed requirements for habitability.

6.3.4 *Engineering and Manufacturing Development*—The focus of the engineering and manufacturing development phase is on performing the design and development activities required to achieve an initial operational capability, as well as demonstrating that the marine system will achieve operational requirements. In terms of ships, this might include development of the lead ship of its class.

6.3.4.1 This phase is entered after Milestone B. During this phase, the Capability Production Document (CPD) is prepared to update and extend the CDD.

6.3.5 HSI activities during this phase include development and prototyping of design concepts for UI, equipment access, maintainability, space layout, and machinery layouts; performing human performance studies and evaluations of prototypes and concepts; refining manpower estimates; developing training concepts; providing inputs to the CPD; and conducting safety and health risk assessments. Detail design is developed for compartment layout, equipment access, machinery layout, habitability facilities, and personnel access routes, etc. Human performance analysis is performed, manpower estimates are refined, and training concepts are developed.

6.3.6 *Production and Deployment*—The goal of the production and deployment phase is to achieve an operational capability that meets mission needs.

6.3.6.1 This phase is entered after Milestone C. The marine system is evaluated through Operational Test and Evaluation (OT&E) for effectiveness and suitability, and the system may go into limited production before full production is approved.

6.3.6.2 HSI activities during this phase for government development include support to OT&E, capturing lessons learned for future builds and development cycles, and implementation of training and personnel plans.

6.3.7 *Operations and Support*—The objective of the Operations and Support phase is the execution of a support program that meets operational performance requirements; sustains the system in the most cost-effective manner over its total life cycle; provides for improvements, upgrades, and modernization; allows for safe disposal at the end of the system's useful life; and provides for the elicitation of structured user feedback. Operations and Support has two major efforts: Sustainment and Disposal.

6.3.7.1 Sustainment strategies evolve and are refined throughout the life cycle, particularly during development of subsequent increments of an evolutionary strategy, modifications, upgrades, and re-procurement.

6.3.7.2 Disposal strategies at the end of the useful life of a system should focus on decommissioning in accordance with all legal and regulatory requirements and policy relating to safety (including explosives safety), security, and the environment.

6.3.7.3 HSI continues to be integrated into these stages of the life cycle through participation in all upgrades, retrofits, and modernization efforts. Emphasis is placed on understanding the potential impacts on manpower, personnel, training, human performance, habitability, quality of life, safety and occupational health, as well as on capturing lessons-learned for influencing future designs, training systems, and support of new technologies.

6.4 *Commercial Acquisition Process*—As indicated earlier, the commercial marine system acquisition process is more streamlined and less formal than the government process, but it follows a logical systems engineering like process. This process is illustrated in Fig. 4.

6.4.1 *Identify Components*—During the identify components phase, which is analogous to the capabilities requirements phase in the government process, basic requirements for the acquisition are defined. This includes, but is not necessarily limited to, operating specifications, applicable laws, human and marine system performance expectations, and estimated crew size. These requirements are used to determine the types of ships/offshore facility equipment, systems, structures, and other components that will be needed.

6.4.1.1 HSI activities during this phase include identification of the HSI team, identification of appropriate HSI specifications, analysis of human performance requirements, development of HSI lessons learned, HSI risk analysis, and development of any planned HSI training for engineers and others on the acquisition team.

6.4.2 *Assess*—During the assess phase, trade-offs between design alternatives are performed. This is analogous to the materials solutions analysis phase in the government acquisition process. The trade-off process focuses on comparing various alternatives for the equipment and other components identified during the previous phase, as well as exploring alternatives for the design for considerations such as space arrangements.

6.4.2.1 HSI activities during this phase include preparing the procuring organization's HSIP, participation in trade-off studies including performing human performance studies and evaluations, and preparation of HSI input to specifications and statements of work.

6.4.3 *Select*—During the select phase, which is analogous to the government technology development and engineering and manufacturing development phases, the results of the Assess phase are used to "select" the design, in essence to develop the detailed design of the marine system. The design is developed with computer-aided design (CAD) drawings and specifications. Trade-offs continue to be made as the design is detailed out. A final design solution is defined in the design specification or specifications.

6.4.3.1 HSI activities during this phase include the development of HSI input to design specifications; performance of any front-end analyses that support the evolution of the design such as task analysis, link analysis, critical valve analysis, and Hazardous Operations (HAZOPS); design reviews using CAD tools; and assessment of vendor HSIPs. Any planned training of engineers and other members of the acquisition team should occur during this phase as well. During this phase, the HSI specialist should consider how the design impacts planned manpower levels, crew complements, training requirements, and safety and occupational health considerations.

6.4.4 *Execute*—During the execute phase, which is analogous to the government production and deployment phase, the marine system is built in accordance with the specifications developed during the Select phase. This phase also includes testing, commissioning, and, for offshore facilities, installation where it will be used. Where appropriate, the marine system is classified by appropriate classification societies.

6.4.4.1 HSI activities during the phase focus primarily on monitoring the execution of the design to ensure that HSI issues and design considerations identified during the previous phases are incorporated into the finished marine system. This includes participation in testing activities, on-site visits, and reviews of any design modifications or engineering change orders.

6.4.5 *Operate*—During the Operate phase, which is analogous to the government Operations and Support phase, the marine system is operated as designed.

6.4.5.1 The primary HSI activity during this phase is to perform follow-on evaluations of the design to develop lessons learned for future acquisition efforts, as well as providing HSI input to any modernization efforts.

6.5 *Non-Developmental Item Acquisition*—Both the government and commercial industries sometimes use a Non-Developmental Item (NDI) acquisition process.

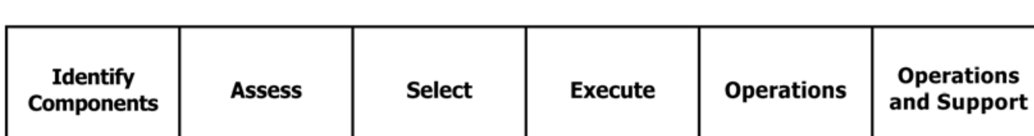

FIG. 4 Phases of the Commercial Ship Acquisition Process

6.5.1 *Government NDI*—In the government, NDIs are commercial-off-the-shelf (COTS) technologies and systems that may provide the required capabilities and provide opportunities for quicker deployment at reduced development costs. NDI acquisitions normally follow a spiral acquisition process, but they can also be part of a standard acquisition strategy. In spiral development, the capability for each increment is pre-planned with a specific capability delivered at the increment's conclusion. During each increment, there are a number of "spirals" that involve the developer, the user, and the tester with continuous feedback and experimentation.

6.5.1.1 A NDI can be defined as a product or system that is available in the commercial marketplace; has been previously developed and is in use by federal, state, or local agencies of the U.S. or a government with which the U.S. has a mutual defense cooperation agreement; requires only minor modifications to meet the requirements; is being produced but does not meet the requirements above solely because it has not yet fully transitioned to deployment; or is not yet available in the commercial marketplace.

6.5.1.2 HSI activities for a NDI acquisition focus on determining suitability of the NDI product for the intended user population and environment. This includes providing input to acquisition documents and addressing questions such as those listed in Table 4.

6.5.1.3 HSI assists in the verification of the operational suitability and effectiveness of the NDI capability used to help selection through task analysis and usability testing. HSI also participates in market surveys where performance and suitability are compared, test and evaluation activities, and any required design modifications.

6.5.2 *Commercial Ship NDI*—Commercial ship and offshore facility acquisitions frequently rely on a NDI approach that re-uses existing ship or platform designs with modifications or upgrades. The procuring organization provides the detailed specifications for the ship or platform to the shipyard. The shipyard comes back with a list of alternatives (products, systems, and components) for each aspect of the design. The procuring organization selects the alternatives that are integrated into the ship or installation. Each alternative offered to the procuring organization should have been developed in accordance with the requirements stipulated in this document. The integration process for the alternatives also should be in accordance with this practice.

6.5.2.1 HSI activities include providing HSI input into the specifications, assessing alternatives from an HSI perspective, and evaluating the design during its construction. This includes the application of requirements contained in ASTM F1166 to the design, development and production of the system. The design should accommodate the fifth percentile (female) to the 95th percentile (male) dimensions with respect to anthropometric and biomechanical factors. Engineering change proposals, waivers and deviations should be subject to review by HSI specialists.

TABLE 4 Typical HSI Questions for NDI Acquisitions

Will the NDI product meet human performance requirements?
Will it be safe to operate in the expected environment by the expected user population?
How will it impact manpower, KSA, and training requirements?
How supportable is the NDI product in the short and long term?
Does maintenance require special training, special tools, or difficult to find parts?
How reliable is the NDI product?
What are the issues or considerations with integration of the NDI product into a larger system or with other systems?

6.6 *Modernization*—One key part of operations and support is modernization. In many cases in both government and commercial marine system development, existing designs are modified, retrofitted, or modernized to meet new mission requirements or to implement new technology. In these cases, design activities are focused on the modifications and their integration with the existing design rather than the complete marine system. These design activities follow a systems engineering process, much like new design.

6.6.1 HSI activities during modernization may include any of those listed in the following sections but scaled to focus on the modifications and their integration with the existing design. HSI activities should focus on determining the impact of the modifications on existing manpower, personnel, and training (MPT) requirements and identifying how MPT considerations may need to be modified for successful integration. HSI activities also focus on ensuring that modifications are integrated into the existing marine system without any negative implications to human performance, safety, occupational health, survivability or habitability.

7. HSI Activities

7.1 *Overview*—The HSI program for marine system acquisition and design includes all appropriate HSI activities, as determined by the procuring organization. HSI activities consist of those methods and technical approaches that serve to integrate human performance considerations into the design of marine systems. The following sections present a comprehensive, though not exhaustive, list of typical HSI activities used in the design and acquisition of marine systems. Table 5 represents HSI activities performed in Government marine system acquisition. Table 6 represents HSI activities performed in commercial marine system acquisition.

7.2 *HSI Lessons Learned*—Lessons learned from precursor and legacy ships, offshore structures, and marine systems should be used to guide design where applicable.

7.2.1 Lessons learned data include problems and difficulties experienced by operators and maintainers in the operational environment, insights associated with previous design efforts that may improve the design process, and positive aspects of design which should be continued into the future. Identification of HSI lessons learned places emphasis on identification of HSI high drivers in legacy systems. HSI high drivers include functions in legacy systems that impose high demands on manpower; are labor intensive; are expected to impose high

TABLE 5 HSI Activities by Government Acquisition Phase

HSI Activity	Paragraph Reference	Acquisition Phase (Shaded Areas Indicate When the Activity is Performed)					
		Capabilities Requirements	Material Solution Analysis	Technology Development	Engineering and Manufacturing Development	Production and Deployment	Operations and Support
HSI Lessons Learned	7.2	■				■	■
Early Marine Systems Analysis	7.3	■	■				
Front End Analysis	7.4		■	■			
HSI Risk Analysis	7.5	■	■	■	■	■	■
Manpower Analyses	7.6		■	■			
Personnel Analyses	7.7		■	■			
Training Analyses	7.8		■	■			
Workload Analysis	7.9		■	■	■		
HSI Input to Documents and Specifications	7.10	■	■	■	■		
Safety and Occupational Health Hazards Analyses	7.11		■	■	■		
Personnel Survivability Analyses	7.12		■	■			
Habitability Analyses (includes afloat medical analyses)	7.13 and 7.14		■	■	■		
Modeling and Simulation	7.15	■	■	■	■		
User Interface Design	7.16		■	■	■		
Usability Evaluations and UI Concept Exploration	7.17		■	■	■		
Valve Criticality Analysis	7.18			■			
Link Analysis	7.19			■	■		
Design Reviews	7.20			■	■	■	■
Drawings/CAD Model Reviews	7.21		■	■	■		
Inspections	7.22				■	■	
Developmental T&E	7.23			■	■		
Operational T&E	7.24				■	■	■

risks, workloads, and performance complexities; are human error prone; require excessive training; or are unsafe. The identification of HSI high drivers serves to focus the effort to optimize human performance by emphasizing the functions that were challenging to HSI considerations in the legacy system. Analyzing lessons learned is typically performed by the procuring organization.

7.2.2 The steps in developing lessons learned include the following:

7.2.2.1 Acquire lessons learned data from documentation, interviews, observations and measurements. Lessons learned also can be identified from HSI specialists who are familiar with marine system design.

TABLE 6 HSI Activities by Commercial Industry Acquisition Phase

HSI Activity	Paragraph Reference	Acquisition Phase (Shaded Areas Indicate When the Activity is Performed)				
		Identify Components	Assess	Select	Execute	Operate
HSI Lessons Learned	7.2	■				■
Early Marine Systems Analysis	7.3	■	■			
Front End Analysis	7.4		■	■		
HSI Risk Analysis	7.5	■	■	■	■	■
Manpower Analyses[1]	7.6		■			
Personnel Analyses[1]	7.7		■			
Training Analyses[1]	7.8		■			
Workload Analysis	7.9		■	■		
HSI Input to Documents and Specifications	7.10		■	■		
Safety and Occupational Health Hazards Analyses	7.11		■	■		
Personnel Survivability Analyses[1]	7.12		■	■		
Habitability Analyses[1]	7.13		■	■		
Modeling and Simulation	7.15		■	■		
User Interface Design	7.16		■	■		
Usability Evaluations and UI Concept Exploration	7.17		■	■		
Valve Criticality Analysis	7.18			■		
Link Analysis	7.19			■	■	
Design Reviews	7.20			■	■	■
Drawings/CAD Model Reviews	7.21			■	■	
Inspections	7.22			■	■	

[1]Typically done as part of the HFE analysis and design activities

7.2.2.2 Analyze lessons learned data to define strengths and weaknesses of the design.

7.2.2.3 Validate lessons learned data, to the extent possible, and identify the source.

7.2.2.4 Identify potential solutions to HSI problems.

7.2.2.5 Integrate the lessons learned into the design process using the HSIP or other feedback mechanisms such as the HSI IPT.

7.2.3 Acquiring and applying HSI lessons learned, while primarily performed very early in the acquisition process and after a marine system has been deployed, can be a continuous process throughout the marine system life cycle, including determining the HSI implications of lessons learned gathered from other technical disciplines.

7.3 *Early Marine Systems Analyses*—HSI specialists for the procuring organization should participate in early marine system analyses to ensure that human considerations are incorporated into the analyses and develop an understanding of system requirements to guide subsequent HSI analyses. This participation should include the identification of human performance gaps between current capabilities and what is desired or needed for the future that can be addressed by new technology or other means. These should be included in early requirements documents.

7.3.1 Early system analyses include the following:

7.3.1.1 *Operational Requirements*—Operational requirements (ORs) define parameters within which the marine system, and its components, is expected to perform. This includes weather conditions, duration of operational profile, anticipated maximum crewing, and types and size of cargo to be carried. HSI should provide input on manpower, personnel, training, and human performance considerations.

7.3.1.2 *Mission Requirements*—Mission requirements define the marine system performance requirements in more details than the ORs. Mission requirements describe specific activities or outcomes that the equipment and system is to accomplish. HSI should provide input on mission requirements where human capabilities and limitations may be a controlling factor on whether the mission requirements can be met.

7.3.1.3 *System Requirements*—System requirements define the specific systems, subsystems, and components required to complete each mission. HSI input should include, but not be limited to, human performance, safety, manpower, personnel and KSA considerations.

7.4 *Front End Analysis*—Front end analyses consist of a set of tools used in HSI to identify human requirements and provide data for other analyses. Front end analyses should be performed by the procuring organization as part of HSI programs on all marine system acquisitions.

7.4.1 *Top-Down Requirements Analysis*—One approach for doing a front end analysis is the Top-Down Requirements Analysis (TDRA), which should be used primarily for new marine system design. The TDRA is an integrated analysis that encompasses functional analysis, functional allocation, task analysis, and other formal processes. TDRA represents a systems engineering approach to specifying the requirements, constraints, and concepts for including the human component in systems. The objectives of the HSI TDRA are as follows:

7.4.1.1 Integrate HSI within the systems engineering process.

7.4.1.2 Derive, as part of the TDRA, the analyzed requirements, functional allocation concepts, workload estimates, human task models, system and human performance metrics, and manpower models necessary for influencing design with human requirements.

7.4.2 *Function Analysis*—Function analysis should be performed to define marine system functions, determine how each system function can be performed, and explore alternatives that lead to mission success. These functional definitions will be used as the basis for the functional allocation.

7.4.2.1 For each top-level function identified, requirements are identified, including the information, performance capability, decision making, and support the marine system needs to complete the function. Based on these requirements, each top-level function is decomposed to lower level subfunctions in an iterative manner, with requirements identified for each sub-function as described for top-level functions. Functions should be analyzed without reference to whether the function should be performed by a human, a machine, or a combination. Functions are defined in terms of required actions, such as monitor, receive, communicate, and calibrate. The transfer and processing of information, such as verbal communications and electronic transmissions, are identified as a function without reference to specific human or machine involvement. Function definitions should be as detailed as necessary to facilitate the subsequent allocation of functions.

7.4.3 *Function Allocation*—Function allocation should be performed for a marine system to define the functions and roles that humans versus machines will perform. In many cases, the human and the machine will share the performance of a function. Some general considerations for function allocation are illustrated in Table 7.

7.4.3.1 In the allocation of functions, marine system functions are allocated to human performance, automation, or to some combination of the two. The typical thrust for function allocation is to maximize the role of automation, and minimize the role of the human as long as human performance, system effectiveness, and safety are not compromised. In addition, determinations are made about which functions can be eliminated (removed entirely or moved from the ship or offshore structure to another location), which functions can be consolidated with other functions, and which functions can be simplified (to reduce workload burdens). Function analysis performed on a subsystem should be verified within the context of the total system.

7.4.4 *Task Analyses*—Task analyses should be performed to develop a model of human operator or maintainer tasks on a timeline with performance requirements for each task. Task analysis consists of defining and sequencing the tasks required of the human operator/maintainer to complete each function identified and allocated to the human during the functional allocation activity. Task analysis should present these tasks in the sequence in which they must be completed and against an established time line reference. Information flows into, or out from, the human should be included, as well as information on the context within which the human is performing the task. Human workload, including that associated with not just the primary task but all collateral tasks and duties should be defined. The task analysis becomes the basis for designing the human-machine interfaces, procedures, and training, as well as helping define required manpower levels. There are a number of methods for performing task analysis including operational sequence diagrams, hierarchical task analysis, and cognitive task analysis. There are two typical levels of task analysis that can be performed, particularly for government acquisitions.

7.4.4.1 *Gross Task Analysis*—A gross task analysis is performed by the procuring organization, though it can be delegated to the contractor. Gross task analysis consists of defining the major tasks required to complete each function allocated to the human. The gross task analysis is used to determine whether the system performance requirements can be met with the function allocations, backup facilities, and equipment selections that have been previously made. These analyses can also be used as basic information for developing

TABLE 7 Function Allocation Considerations

Humans are better at:	Detecting signals (for example, auditory, visual) in the presence of high background noise (for example, visual or auditory)
	Recognizing objects under varying degrees of perception
	Handling unexpected occurrences or low-probability events
	Reasoning inductively
	Profiting from experience (for example, learning)
Machines are better at:	Responding quickly to signals
	Performing precise routine, repetitive operations
	Computing and handling large amounts of stored information quickly and accurately

preliminary manpower levels; equipment procedures; personnel skill, training, and communication requirements; and as logistic support analysis inputs.

7.4.4.2 *Critical Task Analysis*—A critical task analysis is performed by the contractor but can also be performed by the procuring organization. In a critical task analysis, tasks identified during the gross task analysis that require critical human performance, reflect possible unsafe practices, or are subject to promising improvements in operating efficiency are further analyzed. Critical task analysis requires detail to the subtask or even task element level.

7.4.4.3 Task analysis should include specific task performance requirements for each task. The types of information included in a task analysis may vary, depending on its purpose. For example, a task analysis done for training may have different outputs than one done for human factors engineering. Typical types of information which may be included in a task analysis are illustrated in Table 8.

7.5 *HSI Risk Analysis*—HSI risk analysis should be performed on marine systems. The HSI risk analysis involves identification of critical human-system factors in the design that may have a significant impact on readiness, life cycle costs, schedule, or performance. These include tasks, task sequences, task complexity estimates; environments and environmental controls; equipment design features; maintenance requirements; information requirements; UI features; manpower requirements; workloads; personnel skill levels; training requirements; and hazards.

7.5.1 HSI risks should be assessed in terms of the following:

7.5.1.1 Impact on human performance, safety, and health.

7.5.1.2 Impact on overall system effectiveness.

TABLE 8 Typical Task Analysis Information

Information required by the operator/maintainer for task initiation
Information available to the operator/maintainer
Cognitive functions required of the operator/maintainer to process or act on the information
Actions required by the human based on the cognitive processes
Workspace envelope (reach envelope and visual envelope) required by the actions
Workspace available
Frequency and accuracy required of tasks
Feedback required to the operator/maintainer regarding the adequacy of his/her actions
Tools or equipment required by the human
Job aids or references required
Number of personnel required or provided, as well as their specialty and experience
Required knowledge, skills, and abilities
Communications required, and the types of communications
Safety hazards involved
Operational requirements of the human (for example, hours on duty, number of repetitive motions)
Performance shaping factors such as ship motion, vibration, noise, and fatigue
Backup facilities available
Operator interaction where more than one person is involved
Time estimates for task performance
Duties
Steps required to accomplish each task
Conditions such as tools and equipment required
Standards of proficiency/performance objectives for each task

7.5.1.3 Impact on program costs and schedule. HSI risk analyses are performed by both the procuring organization and the contractor, depending on the acquisition phase. HSI specialists should also perform an HSI risk analysis of deficiencies found in designs through HSI analyses and test and evaluation in order to more fully characterize their impacts on human performance.

7.5.2 HSI risks should be subjected to an analysis to define their potential of occurrence (likelihood or probability), and their expected consequences (impact or severity). This analysis results in a rating of each risk such as High (unacceptable, major disruption or human death likely, different approach required, priority management attention required), Serious (unacceptable, major disruption or human injury likely, different approach required, additional management attention required), Medium (some disruption, different approach may be required, additional management attention may be needed), and Low (minimum impact, minimum oversight needed to ensure risk remains low). Example HSI risk analysis tables are illustrated in Tables 9-11. Risk mitigation strategies should be defined along with determinations of acceptable levels of risk (residual risk).

7.5.3 HSI risks should be integrated into the marine system programmatic risk management process when appropriate, as well as coordinated with the system safety risk analysis process.

7.6 *Manpower Analyses*—Manpower analyses define the number of people required to perform the expected workload which allows estimates of the number of crew required for marine systems. Manpower levels include manpower by category of crew (for example, officer, licensed, unlicensed, specific role, military, civilian), as well as quantities of each category. Manpower analysis should take into account workload imposed by primary responsibilities, as well as collateral duties that each person must perform. Manpower analyses consider the number of people required for the marine system and the number required to provide total support ashore and afloat. Manpower analyses should be informed by the results of an integrated task analysis that addresses all HSI requirements including manpower, personnel and training requirements.

7.6.1 For commercial marine systems, manpower requirements typically are determined by outside agencies or international standards. As such, the goal of HSI is to ensure that the design of the marine system is appropriate for the manpower requirements.

7.6.2 For government marine system acquisition, early manpower concepts are developed by the procuring organization. Manpower concepts should be refined and finalized by the procuring organization over the course of the design process. Initial manpower requirements, typically captured in an initial Manpower Estimate Report (MER), are used to develop the Preliminary Ship Manpower Document (PSMD). Later in the acquisition process, the initial MER is refined and documented in a preliminary manpower document that provides estimates of the numbers and KSAs of the personnel required to support the marine system operation and human tasks. The final MER is developed by the procuring organization. This estimate builds on the initial MER and is documented in a final

TABLE 9 Example HSI Risk Probability Ratings

Probability Rating	Category	Probability of Occurrence
A	Extremely Likely	Likely to be experienced almost continuously
B	Likely	Likely to be experienced frequently
C	Occasional	Likely to occur sporadically
D	Unlikely	Unlikely, but can reasonably be expected to occur
E	Extremely Unlikely	Extremely unlikely but possible to occur

TABLE 10 Example HSI Risk Severity Ratings

Impact Rating	Category	Impact
I	Catastrophic	Inability to execute the mission which leads to a catastrophic mission failure due to inadequate human performance; death or permanent total disability; program or technology initiative will not meet costs or performance goals due to HSI considerations
II	Critical	Mission and human performance are significantly compromised leading to inability to perform part or all of a mission, permanent partially disabling injury, injuries or occupational illness that may result in hospitalization of at least 3 people; program or technology initiative will experience difficulty meeting cost and performance goals due to HSI considerations
III	Marginal	Mission and human performance are difficult to accomplish leading to some risk to mission success; temporary disabling injury or occupational illness resulting in one or more lost workdays; program or technology initiative will experience minimal to no difficulty meeting cost and performance goals due to HSI considerations
IV	Negligible	Mission and human performance are degraded slightly but can be accomplished without any impact on mission success, minor injury or injury not resulting in a lost workday; program or technology initiative will experience no difficulty meeting cost and performance goals due to HSI considerations

TABLE 11 Example Human System Integration Risk Index

		Impact Levels (S)			
		I Catastrophic	Ii Critical	Iii Marginal	Iv Negligible
Probability of Occurrence	A – Extremely Likely	1 (High)	3 (High)	7 (Serious)	13 (Medium)
	B – Likely	2 (High)	5 (High)	9 (Serious)	16 (Medium)
	C – Occasional	4 (High)	6 (Serious)	11 (Serious)	18 (Low)
	D – Unlikely	8 (Serious)	10 (Serious)	14 (Medium)	19 (Low)
	E – Extremely Unlikely	12 (Serious)	15 (Medium)	17 (Medium)	20 (Low)

manpower document that provides estimates of the numbers and KSAs of the personnel required to support the marine system operation.

7.7 *Personnel Analyses*—Personnel tracks and assesses the availability of the quantities and qualities of personnel required for a marine system, as well as how the personnel inventory is sustained across the personnel requirements for all marine systems.

7.7.1 Personnel is driven by manpower requirements, as well as the results of task analyses, and defines:

7.7.1.1 Current personnel inventory by position and KSAs.

7.7.1.2 Expected retention rates.

7.7.1.3 Expected recruitment rates.

7.7.1.4 How to identify, acquire, and train to meet current and future manpower requirements (that is, change the pipeline) where there is a deficiency.

7.7.2 Personnel analyses should be performed by the procuring organization to determine the availability of people to fill the required billets and KSAs, and how to train or recruit those not available. Personnel analyses are performed by the government procuring organization. In commercial marine system acquisition, personnel requirements usually are driven by external organizations, treaties and laws. The HSI specialist should take personnel requirements into consideration when performing other HSI analyses and human factors design.

7.7.3 Personnel analyses start with the quality and quantity of personnel required for a marine system. The personnel analyst compares those requirements with the existing inventory of personnel to determine whether the KSAs currently exist and if there are sufficient quantities to meet the requirements.

7.7.4 Where there are discrepancies, the analyst assesses whether and how the required personnel can be recruited. The personnel analyst works with training specialists to determine if and how the KSAs can be trained. Where the requirements for the quality and quantity of personnel cannot be met, the personnel analyst works with manpower and HFE to revise the design so that appropriate personnel can be provided out of the personnel inventory.

7.8 *Training Analyses*—Training is concerned with providing the skills and knowledge necessary for effective human performance. Analysis of training requirements and developing the training concepts should be performed by the procuring organization which provides general guidance. This analysis is informed by the results of task analysis, manpower analysis, and personnel analysis. Training analyses should focus on identifying options for individual, team, and joint training of operators, maintainers, support personnel, and crews.

7.8.1 The training analysis should identify tasks for which minimal training is required, job performance aides that maximize human performance, or where task performance can be designed into the system to reduce the requirement for training. Training requirements should be refined over the course of the acquisition process to better represent the planned manpower, identified personnel requirements, missions and tasks to be performed, and emerging design. These requirements should address tasks to be trained, performance measures for the tasks, the anticipated instructional setting (for example, classroom versus on-the-job versus self study), and estimated costs for training.

7.8.2 In commercial marine system acquisition, training requirements may be defined external to the acquisition process through international agreements, regulations, and treaties. The HSI specialist should include training considerations in developing the marine system design.

7.9 *Workload Analysis*—Workload analysis should be performed by the procuring organization to estimate individual and crew workload associated with task performance. Workload can be assessed in a number of ways including measured performance or accumulated task performance times. This allows the analyst to assess the capability of an individual or crew to perform all their assigned tasks over the period of time anticipated for a function or mission. The results of this analysis should be used to explore design concepts; refine hardware, software, and task design; assess required manpower and staffing levels; assess assignment of tasks across crew; explore communications requirements; and examine and refine function allocations.

7.9.1 Key factors that should be considered when performing a workload analysis include the following:

7.9.1.1 *Perceptual-Motor Channels*—One mechanism for estimating human workload is to break the task down into the perceptual-motor channels through which the human will be processing information. These perceptual-motor channels include visual, auditory, cognitive, verbal, olfactory, and touch.

7.9.1.2 *Percentage Acceptable Total Workload Across All Channels*—Typically, workloads over 100 percent are not acceptable, between 75 and 100 percent are not desirable, and less than 75 percent are acceptable. Workloads that are too low are also undesirable because as they may reduce arousal and vigilance levels and degrade overall performance.

7.9.1.3 *Concurrent Individual Tasks*—In analyzing workload, consideration should be given to concurrent tasks that the human may need to perform. Workload can be acceptable for an individual task but when other tasks must be performed during the same time interval, overall human workload may be unacceptable.

7.10 *HSI Input to Procurement Documents and Specifications*—A critical part of marine system design is the development of HSI specifications to communicate the design to contractors and vendors. HSI specifications, or HSI input to other marine system specifications, should be developed by the procuring organization to provide detailed HSI design criteria for the design of marine systems. These specifications should include appropriate HFE standards such as ASTM F1166. HSI specifications for contractors should be prepared by the procuring organization and focus on the design of the total marine system. Guidance for vendor HSI specifications to be prepared by the contractor also should be provided by the procuring organization. This should include specifications on machinery, equipment, subsystem and component design.

7.10.1 Specifications should be developed iteratively with input from critical stakeholders including HSI specialists, engineers, and users. Specifications for marine system design should include definitions of the user population in terms of expected KSAs and physical characteristics (5^{th} through 95^{th} percentile, geographic population, etc.), as well as the expected training levels and required analyses, such as task, and TDRA. Any special studies or analytical tasks required for the marine system also should be defined in the design specification, statement of work, or contract.

7.11 *SOH Hazards Analyses*—SOH, also referred to as Health, Safety, and Environment in the commercial industry, analyses should focus on ensuring that the design does not compromise human safety during operation, maintenance, or support.

7.11.1 SOH strives to reduce the likelihood of mishap risk (that is, injury to humans) through either acute (sudden trauma) or chronic (cumulative exposures to noise, vibration, or repetitive motion tasks) causes.

7.11.2 SOH considers the full marine system life cycle from concept through decommissioning. Key issues during operations include mishap risk during maintenance and exposure to hazardous substances contained in components or used to dispose of components. SOH risk management must be incorporated into the larger programmatic risk management process. Key documents developed for SOH include;

7.11.2.1 Preliminary hazard analysis, which identifies initial safety and occupational health issues. This analysis is typically performed by the procuring organization. Issues include: hazards such as noise, radiation (ionizing and non-ionizing), vibration, exposure to gases, exposure to chemicals and other substances; and physical injury. These should be developed by reviewing data from predecessor systems, as well as expert opinion and previous experience. The preliminary hazard analysis should address acceptable levels of risk (residual risk) for identified SOH issues.

7.11.2.2 Safety and Occupational Health Management Plan (SOHMP), which is a living document that identifies the processes by which SOH considerations are incorporated into the design. The SOHMP also tracks safety and occupational health issues and their resolution. Initially, the SOHMP should be developed by the procuring organization. In later acquisition phases maintenance of the SOHMP is the responsibility of the contractor. For the government, the Programmatic Environment Safety and Occupational Health Evaluation (PESHE) may be used in lieu of the SOHMP as the management plan.

7.11.2.3 For government and commercial acquisition programs, SOH input should be provided to the systems engineering plan by the procuring organization. For the government, SOH input should also be provided for the PESHE.

7.12 *Personnel Survivability Analyses*—Personnel survivability analyses should be performed by the procuring organization on the design of each marine system, starting in the material solutions analysis phase of the acquisition and design process. These analyses also should explore the impact of modernization programs on personnel survivability.

7.12.1 Personnel survivability assumes that the human is an integral part of the system and damage to the system or equipment, or both, comprising that system can endanger the human. It focuses on designing the marine system to provide for crew protection during and after exposure to hostile environments induced by factors such as severe weather conditions, accidents, hostile action, and damage to the ship and equipment. The design should minimize the likelihood of crew suffering acute or chronic illness, disability, or death, as well as improve human survival rates through the following:

7.12.1.1 Physical integrity of ship and offshore structure compartments.

7.12.1.2 Ability for personnel to rapidly and safely egress.

7.12.1.3 Efficient access to equipment such as lifeboats, immersion suites, fire extinguishers, fire and damage control equipment, life saving gear, life vests, and self-contained breathing apparatus.

7.12.1.4 Availability of emergency systems for contingency management, escape, and rescue.

7.12.1.5 Easy to access on-board medical facilities.

7.13 *Habitability Analysis*—Habitability analyses should be performed on ship and offshore structure design. For the commercial industry, habitability typically is part of the human factors engineering analysis. For the government, analysis for the habitability domain is conducted by habitability design specialists.

7.13.1 Habitability focuses on the environmental control of living and working spaces, accommodations, and personnel service spaces, which result in levels of personnel morale, safety, health and comfort that are adequate to sustain maximum personnel effectiveness and personnel retention. This includes, but is not limited to, compartment color coordination, approved bedding and outfitting materials, furniture and equipment, distillation and stowage of water for habitability functions, drinking fountains, emergency wash facilities, sheathing for bulkheads and overhead, deck coverings, berthing, sanitation, food service spaces, laundry, leisure and community spaces, workspaces, and medical spaces.

7.13.2 Habitability requirements are developed by the procuring organization based on established habitability criteria. Sizing of habitable facilities should be based on approved manpower estimates for marine system crew, detachments, and visitors. Review of the ship or offshore structure compartment volume should be performed (in the government, hull volume is in the Advanced Surface Ship Evaluation Tool Program or other design plans) to ensure adequate area and volume allocation for habitability spaces. These requirements should be included in ship and offshore structure design specifications and Requests for Proposals (RFPs).

7.13.3 Habitability design reviews (including noise, vibration, climate, and lighting) should be performed by the procuring organization using early design drawings, CAD models, or other design documentation. The goal is to identify issues or concerns associated with the living and working environment that might impact human performance, health or safety. Redesign recommendations should be developed and integrated into the overall systems engineering process.

7.14 *Health Service Analysis*—Shipboard health care facilities, equipment, supplies, and personnel should support providing quality, timely casualty care and management of sick, injured, and wounded personnel. Shipboard or facility healthcare service should be designed to provide essential care to the injured and ill for return to duty or stabilization for rapid evacuation to definitive care external to the marine system. For government ship acquisitions, Afloat Medical Program (AMP) design specialists are responsible for medical and dental spaces and ensure that the spaces and supporting medical equipment are appropriate for the health service missions of the ship. Close cooperation and coordination between the AMP design specialist, the habitability design specialist, and military medical authorities (for example, Bureau of Medicine and Surgery, Army Medical Department, Naval Medical Logistics Command, and Fleet Health Services) personnel are vital to developing successful health service facilities.

7.15 *Modeling and Simulation*—Modeling and simulation (M&S) should be used by the procuring organization for identifying or resolving issues or problems with human integration into the system, as well as assessing crew concepts and the ability of the crew to meet all mission functions.

7.15.1 The objectives of HSI M&S are as follows:

7.15.1.1 Assess alternative system design concepts in terms of human performance, productivity, workload, and safety using a logical, physical or virtual representation of the system, equipment, and environment before finalizing design decisions and directions.

7.15.1.2 Provide human performance inputs to system level modeling and simulation, and determine the impact of system design on human performance and safety.

7.15.1.3 Quantify relationships among human capabilities, operational variables, and design concepts for factors such as workload, visual fields, physical arrangements, traffic patterns, personnel interactions, display, and maintenance access.

7.15.1.4 Visualize and quantify spatial relationships among humans and workstations, worksites, spaces, equipment, and environments.

7.15.2 M&S uses a model of the real-world system or situation, as well as a scenario of the mission to be conducted by the real-world system. Where appropriate, HSI M&S should be integrated with larger M&S for the marine system.

7.16 *User Interface (UI) Design*—User Interface (UI) design refers to the process for developing UIs that meet human capabilities and limitations. UI refers to all interfaces between the human and the system including hardware, software, and workspace. HSI UI design principles and standards should be applied to the design of all compartments, spaces, systems, individual equipment, workstations, and facilities where there is a human interface. The goal of UI design is to reduce the potential for human error and accidents, thereby improving total system effectiveness.

7.16.1 UI design is iterative and includes user input throughout the process. UI design moves from high level concepts and alternatives to a more detailed and refined design through the design process. Critical to the success of UI design is integration of UI designers with the rest of the design team.

7.16.2 Throughout the UI design process, inputs should include those activities specified in this document, as well as those identified in standards and best practices such as MIL-HDBK-46855 and Woodson et al., 1992. Drawings, specifications, analyses, and other documentation should reflect the incorporation of human engineering principles and standards. Design criteria, where required, should conform to ASTM F1166, ABS guides and guidance notes, or other appropriate UI design standards. The design standard(s) to be used must be spelled out in the marine system specification.

7.16.3 UI design should include the following:

7.16.3.1 *Workstation*—Workstation design includes control and display integration, ergonomics of consoles and furniture for standing and seated operations, reach and visibility envelopes, communications with other crew, and lighting to support task performance.

7.16.3.2 *Human-Machine Interface (HMI)*—HMI design includes the design of information displayed to support decision making and situation awareness, and machinery and equipment controls and displays.

7.16.3.3 *Human Computer Interface (HCI)*—HCI design includes the design of software displays including, but not limited to menus, screen design, navigation, forms, and dialog between the user and the computer, as well as the hardware that supports the input and output of information from a computer system.

7.16.3.4 *Communications Systems*—Communications system design includes appropriateness of communication modes given criticality, design of supporting HMI and equipment, message format and syntax, and speech intelligibility.

7.16.3.5 *Arrangements*—Arrangements include design of workspace and living space to support safe task performance, accessibility of equipment, evacuation routes, design of deck systems and compartments, equipment removal processes and routes, passageways, cargo stowage routes, and visibility from bridges and bridge wings.

7.16.3.6 *Habitability*—Habitability includes the establishment of design limits for environmental factors, that is, noise, lighting, vibration, temperature, ventilation, humidity, and fumes. Habitability also includes the establishment of design limits for space requirements, furniture, and equipment in accommodations, food service, sanitary, recreation spaces, offices, workshops, laundries, and other spaces that support crewmembers in their work or leisure. In commercial acquisition, habitability usually is the responsibility of the human factors engineering group. In the government, habitability is usually is a shared responsibility between the domains of human factors engineering and habitability.

7.16.3.7 *Maintainability*—Maintainability includes, but is not limited to, space for access around equipment requiring maintenance, ability to easily remove and install assemblages and parts, ability to monitor status of equipment, troubleshooting, and fault diagnosis and isolation.

7.16.4 During the early phases of the acquisition process, UI design should be performed by the procuring organization and focus on identifying design requirements based on results of front end analyses, defining appropriate HFE standards for use, determining human performance considerations, providing input into overall design concepts, and developing preliminary concepts for the design of the UI.

7.16.5 In later stages of the acquisition process, human performance requirements should be refined. UI design should be conducted using a human-centered design process with the design evolving iteratively. Input from users and other stakeholders, such as systems engineering and other HSI domains, should be solicited to refine and begin to detail the concepts. Prototypes should be used to help designers and other stakeholders visualize the design, as well as perform studies and user assessments. Prototypes can include drawings, interactive computer-aided models, and physical mockups. UI designers should integrate with other HSI domain activities and with the larger systems engineering process, providing input into design specifications and design concepts.

7.17 *Usability Evaluations and UI Concept Exploration*—Early in the design and acquisition process, design concepts and prototypes should be evaluated to assess and explore human performance considerations associated with early UI design concepts, help evolve designs that facilitate human performance, and help select appropriate technologies from an HSI perspective. These evaluations may consist of usability studies, comparative analyses between potential technology solutions or concepts, expert inspection of design concepts, and user reviews. Representative users should be included, where feasible.

7.18 *Valve Criticality Analysis*—One of the most frequent human-machine interactions on a ship or an offshore facility is the operation or maintenance, or both, of valves. A valve criticality analysis allows for the classification and location of all valves used on a marine system based on their criticality. This formalizes the decision process for determining the location and accessibility of all valves and provides clear guidance to designers. A valve criticality analysis also ensures that operational and maintenance requirements are addressed when deciding on the location of a valve.

7.18.1 The analysis is based on a formal set of criteria for classifying valves agreed upon by all members (disciplines) of the Engineering, Design, Operations, and Maintenance teams. ASTM F1166 (2007) provides guidance on valve criticality and location including the establishment of three levels of criticality, as well as design criteria for placement of each level of valve criticality. For example, the most critical valves (Level 1) require direct access from a normal walking surface for operation and maintenance, while the least critical (Level 3) can be accessed by staging such as movable platforms or even a vertical ladder.

7.19 *Link Analysis*—Link analysis is an HFE methodology that can be used to provide information for design, as well as evaluation. It focuses on understanding the relationships among elements such as equipment and people within a workspace, workstation, and working environment. It is used to develop the optimum arrangement of elements within control and display panels, workstations, and workspaces, as well as to explore communication and work flow. Its focus is on both human-to-machine interactions and human-to-human interactions. Link analysis can be performed by the procuring organization and the contractor.

7.20 *Design Reviews*—HSI design reviews should be conducted as part of total system design reviews to identify HSI risks, assess human performance implications of design concepts, and help integrate HSI design considerations into the design process. HSI specialists should review design documents, drawings, CAD files, and mockups and prototypes, as well as participate in design review meetings. HSI considerations also should be addressed within program, system and subsystem reviews.

7.20.1 The design should be reviewed to identify how well it supports human task performance and is in accordance with applicable HSI standards (ASTM F1166).

7.21 *Drawings and CAD Model Reviews*—Drawing and CAD review should be used to incorporate HFE, habitability, and SOH into the design, as well as to compare design alternatives without having to build mock-ups or prototypes. The reviews should be cooperative efforts between HSI specialists and engineering personnel. HSI specialists should coordinate with engineering to ensure that there is appropriate engineering staff available to walk through the design with the HSI specialists. The engineering staff will provide design rationale and engineering input. Formal drawing and CAD reviews that involve HSI, designers and other members of the engineering team should occur at the 30 percent, 60 percent, and 90 percent design completion stages. Informal drawing and CAD reviews between the designer and HSI specialist should occur as necessary.

7.21.1 The process for reviewing drawings and CAD files is similar. The HSI specialists and engineering should work together to identify HSI risks associated with any identified design issues and approaches for mitigating those risks.

7.21.2 Drawings or CAD that are reviewed by HSI specialist should include, but not be limited to, the following:

7.21.2.1 General arrangements.

7.21.2.2 Deck arrangements.

7.21.2.3 Machinery arrangements.

7.21.2.4 Workstation arrangements.

7.21.2.5 Control and display arrangements.

7.21.2.6 HCI screen designs.

7.21.3 The reviewer should have a good knowledge of what tasks are required for the operator/maintenance personnel for each piece of equipment in the space. The reviewer also should have an understanding of the operating environment including physical environment, anticipated noise and vibration levels, temperature, and expected sea levels. Standards that should be used as technical references during the review include the following:

7.21.3.1 ASTM F1166.

7.21.3.2 ABS Guidance Notes on the Ergonomic Design of Bridges.

7.21.3.3 ABS Guidance Notes on the Application of Ergonomics to Marine Systems.

7.21.3.4 ABS Guide for Crew Habitability on Ships.

7.21.3.5 ABS Guide for Crew Habitability on Offshore Installations.

7.21.3.6 ABS rules for shipbuilding (Navy Vessel Rules, Steel Vessels rules).

7.21.3.7 HCI standards like the NAVSEA Standard 03-01, Common Presentation Layer Guide.

7.21.3.8 HSI specialists and engineering should work together to identify HSI risks associated with any identified design issues and approaches for mitigating those risks.

7.22 *Inspections*—Inspections of marine systems under production should be performed at the shipyard or contractors facility by HSI specialists. Vendor provided equipment and machinery also should be inspected by HSI specialists to verify that they comply with HSI requirements. Checklists derived from standards (for example, ASTM F1166) should be used for these inspections. Equipment should be inspected before and after installation.

7.23 *Developmental Test and Evaluation*—For the government, Developmental Test and Evaluation (DT&E) activities should begin during the Technology Development phase. DT&E during this phase is performed by the procuring organization. DT&E focuses on compliance with standards, specifications, and requirements as they relate to human factors, safety, habitability, occupational health, and personnel survivability. DT&E also focuses on risk reduction for the program by identifying human performance risks and mitigation approaches. DT&E should be performed systematically, starting with components and moving through subsystems, systems, and the fully integrated marine system.

7.23.1 Data collection approaches should include, but not necessarily be limited to, the following:

7.23.1.1 Expert reviews where experienced and trained HSI specialists review the component, subsystem, or system. These reviews can be performed on drawings, mockups and prototypes, or early production items. Checklists containing criteria drawn from appropriate standards and specifications may be used as a guide to the evaluation. How well the test item design complies with the HSI requirements and criteria should be documented and any issues assessed in terms of human performance and programmatic risks.

7.23.1.2 Walkthroughs where HSI specialists observe a typical user performing their tasks on the equipment, component, or system. The HSI specialist interacts with the user during the walkthrough to note difficulties being experienced by the user, as well as capture user observations and comments.

7.23.1.3 Usability testing involving formal and controlled evaluations are performed with the test item using typical users. Usability testing focuses on capturing quantitative human performance data, such as error rates and task performance times, as well as qualitative data in the form of observations, user comments, and results of the administration of questionnaires and interviews.

7.23.1.4 Surveys of users to elicit positive and negative aspects of the design from the user's observations, experiences, and opinions. These surveys can include questionnaires, interviews or focus groups.

7.23.2 Information, data, and results contained in DT&E test reports should be used by designers to refine and evolve designs early in the design process, develop lessons learned for future design, monitor progress against HSI program goals, and develop issues for operational test and evaluation in subsequent phases.

7.24 *Operational Test and Evaluation*—HSI OT&E should be used to evaluate operational readiness, suitability, and effectiveness with respect to human performance. HSI OT&E should focus on manpower levels, personnel, training, operability, maintainability, environment, safety and occupational health, habitability, and personnel survivability in an operationally realistic environment. HSI OT&E also should assess the adequacy of individual and team performance where possible. HSI OT&E should be performed by the procuring activity and be fully integrated with the overall marine system OT&E program. Where possible OT&E should utilize data from DT&E to perform evaluations. Limited OT&E also can be conducted using prototypes.

7.24.1 Data collection should include, but not necessarily be limited to, the following:

7.24.1.1 Observation of human performance.

7.24.1.2 Questionnaires and interviews.

7.24.1.3 Measures of human performance including, but not limited to, task performance times and error rates.

7.24.2 Once a marine system is operational, follow-on operational test and evaluation should be conducted by the procuring organization to understand how well the marine system meets its operational requirements under actual use. Data can be collected through observation, interviews and questionnaires, and other reporting mechanisms. Data collected on operational suitability and effectiveness will be used in HSI lessons learned and HSI risk analysis activities.

8. Documentation

8.1 *Data Requirements*—Human system integration data requirements are as specified in the contract.

8.1.1 *Government Data Requirements*—For government procurements, in which the use of a Contract Data Requirements List (DD 1423) is a requirement, the Data Item Descriptions (DID) is used when applicable.

8.1.2 *Commercial Data Requirements*—For commercial procurements, the data requirements are included in the contract in the manner commonly used for other data requirements.

8.2 *Traceability*—The procuring activity and the contractor/vendor document the HSI effort to provide traceability from the initial identification of HSI requirements during analysis or systems engineering through design and development to the verification of these requirements during testing and evaluation of approved design, software, and procedures. Each HSI input made during design, construction, and test is recorded, along with status, to indicate that the input was included in the finished product or rationale for exclusion. Requirements traceability assists in the following ways:

8.2.1 Assessing compliance

8.2.2 Developing and tracking lessons learned

8.2.3 Managing change and evolution of the design.

8.2.4 Prioritizing and justifying requirements.

8.3 *Access to Data*—All HSI data, such as plans, analyses, design review results, checklists, design and test notes, and other supporting background documents, must be maintained in either hardcopy or electronic format and made available to the procuring activity.

9. Keywords

9.1 design; ergonomics; habitability; human system integration; human engineering; human factors engineering; manpower; marine equipment; marine structures; marine systems; occupational health; offshore facilities; offshore structures; oil rigs and platforms; personnel; personnel survivability; safety; ships; test and evaluation; training