DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
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17 Jul 03

MEMORANDUM FOR DISTRIBUTION

Sub: NAVY SHIP SYSTEMS PROGRAM MANAGER'S HUMAN SYSTEMS INTEGRATION GUIDE

Ref: (a) NAVSEANOTE 5400, Ser 10/251, 15 Oct 02
(b) NAVSEAINST 5400.97a, Ser 05BX/001, 3 Feb 03
(c) CJCSI 3170.01C, 24 Jun 03
(d) CJCSM 3170.01, 24 Jun 03
(e) DoDD 5000.1, 12 May 03
(f) DoDI 5000.2, 12 May 03

Encl: (1) Navy Ship Systems Program Manager's Human Systems Integration (HSI) Guide, Volume 1, 14 July 2003

1. Enclosure (1) is provided as guidance for program managers and those charged with the execution and design of Navy ships and ship systems to ensure NAVSEA ship and ship system acquisition programs successfully meet DoD and NAVSEA HSI requirements (references (a)-(f)). Volume 1 of the Navy Ship Systems Program Manager's Human Systems Integration Guide provides a basic overview and the rationale for HSI application in Navy ship systems. Volume 2, to be distributed by separate correspondence, will detail the HSI process in acquisition cycles, provide measurement metrics, and list HSI resources available to program managers.

2. The Navy Ship Systems Program Manager's Human Systems Integration Guide is NAVSEA official policy, and will be used for all NAVSEA Ship and Ship System acquisition.

3. If you have questions, please contact the SEA 03 Technical Director, Mr. Bob Bost, at 202-781-2053, email: BostJR@navsea.navy.mil.

P. M. BALISLE
Commander

Distribution: See Attached.

Sub: NAVY SHIP SYSTEMS PROGRAM MANAGER'S HUMAN SYSTEMS INTEGRATION GUIDE

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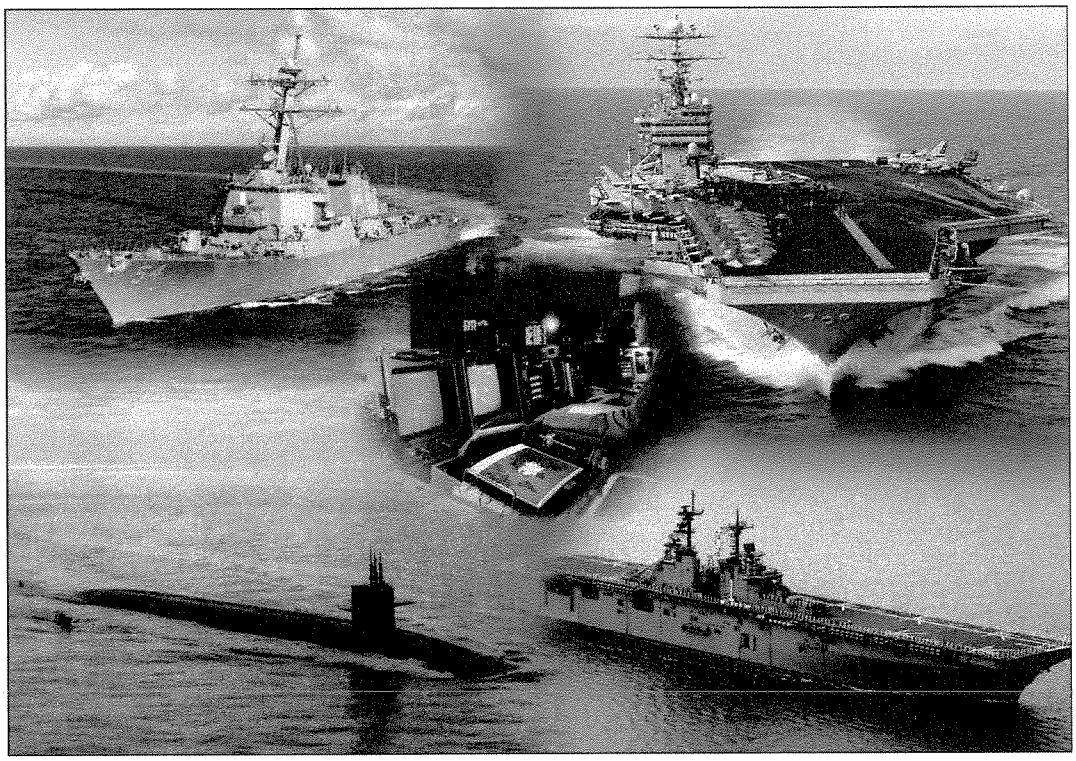
Navy Ship Systems Program Manager's Human Systems Integration Guide



Volume 1
Overview

14 July 2003

VISION

Human Systems Integration (HSI) is "the technical process of integrating the areas of human (factors) engineering, manpower, personnel, training, systems safety, and health hazards with a materiel system to ensure safe, effective operability and supportability" (NATO Defense Research Group Panel 8 Report, *Analysis Techniques for Human-Machine System Design*, 1999).

Department of Defense (DoD) Instruction 5000.2, *Operation of the Defense Acquisition System, 12 May 2003*, adds habitability, survivability, and the environment to the definition of HSI listed above.

For the Navy, this translates into the systems engineering discipline dedicated to providing Navy systems *with the best total system performance at the lowest total ownership cost (TOC)*. In addition to hardware and software considerations, HSI designs, produces, supports, fields, and modernizes systems by a complete and careful integration of the human into the system. Specifically, requirements for human performance, human availability, human utilization, health and safety, and human accommodation are addressed.

About This Guide:

The purpose of the Navy Ship Systems Program Manager's HSI Guide is to inform Navy program managers (PMs) and acquisition specialists about the Navy's need for HSI; what the HSI process entails for their programs; and most importantly from the PM's standpoint, the benefits that the HSI process will have for the success of their programs. It also provides the design and engineering community with the details required to support the PM in carrying out a successful HSI program. The primary objective of HSI is to influence system design, starting at the earliest phase of acquisition, to ensure that the resulting system will have the highest performance at the lowest TOC through consideration of human limitations and capabilities. The Navy Sailor ***is*** part of the system, and as such, human performance and design requirements need to be addressed concurrently with other system performance and design requirements.

The Program Manager's Guide is divided into multiple volumes that address all potential phases of a program from User Needs and Technology Opportunities to Operations and Support. In these volumes, PMs and designers will find what they need to do to successfully implement HSI at any stage of their program for the four different acquisition scenarios:

- New Systems
- Legacy System Modernization and Upgrade
- Direct Prototypes to Production
- Commercial Off-the-Shelf (COTS) / Non-Developmental Item (NDI)

Volume 1 is an overview of HSI. It gives program managers a brief overview of HSI, the key paragraphs in DoD acquisition directives mandating application of HSI, and its benefits to the success of their programs.

Volume 2 is targeted to the individuals responsible for implementing the HSI process in the acquisition program. It contains the activities and guidelines for applying HSI for each of the acquisition scenarios listed above. It also includes the criteria for evaluating HSI processes, products, and progress within each phase of the acquisition, for each acquisition scenario. It also lists resources that provide comprehensive details of the HSI process and how to apply it to actual designs.

Why HSI? The Navy's Requirement

Recent affordability initiatives at the DoD and Department of the Navy (DoN) levels have re-emphasized the importance of recognizing cost reduction opportunities across the entire life cycle of a weapons system, from development to disposal. The DoN has directed the implementation of formal TOC reduction efforts for all DoN programs regardless of Acquisition Category (ACAT) designation, program dollar value or life cycle stage. TOC reduction plans require the establishment of a cost baseline, identification of cost drivers within the baseline, developing specific reduction initiatives and developing metrics, which measure progress toward achieving stated goals. Each Navy ACAT program has now been directed to revise their current approved Acquisition Program Baseline and establish a TOC objective and threshold.

The trained Sailors that will operate and maintain a new ship or system over the course of its useful life are by far the most expensive component of TOC, which in turn, has been predetermined by the decisions made very early in acquisition development. If PMs are now required to demonstrate their respective systems as providing the lowest cost of ownership to the DoN, and if the best time to reduce TOC is early in systems design, then HSI provides both the processes and the tools for PMs to successfully meet TOC program requirements.

That said, Navy ships constitute some of the most intricate weapon systems in the U.S. defense arsenal, and the HSI challenges are legion. Ships have complex human-machine interfaces, which support simultaneous operations in multi-warfare environments, frequently in harm's way, and in all weather and climates. They can operate as independent combatants, components of squadrons, or as elements of a battle force. The demands placed on Sailors by Navy ship systems are unique in the breadth of their scope and the depth of their complexity. Navy ship systems employed by the fleet today, and those being designed for tomorrow, make severe demands on the readiness, performance effectiveness, and mental and physical capabilities of personnel who man them. These complex systems are extremely demanding on the senses, motor skills, cognitive skills, and decision-making capabilities of assigned personnel. Add the highly varied nature of the threat, the need to conduct multi-warfare scenarios, and the need to integrate, coordinate,

and interpret information from multiple sources; and, it becomes evident we are rapidly approaching the limits of un-aided human capacity and capability.

A negative effect of ship systems becoming more sophisticated without taking into account proper HSI has been the degradation of the capability of ship personnel. The International Maritime Organization, the U.S. Coast Guard, and the Navy have estimated that human error is the root cause of 80% of ship accidents. Liabilities from accidents and high operating costs on offshore oil platforms have forced that industry to implement HSI in their system designs. The loss of the North Sea platform PIPER ALPHA and the drilling rig OCEAN RANGER due to a lack of HSI resulted in the deaths of 250 people and the loss of hundreds of millions of dollars of physical assets. The Navy faces many of the same issues as the offshore industry.

Significantly, command environment experiments at Naval Surface Warfare Center, Dahlgren, involving state-of-the-art HSI showed a 10:1 reduction in training time and a 2:1 reduction in crew size with sustained mission performance.

These are but a few examples that underscore the need for HSI to reduce manpower, personnel, training (MPT), and operating costs, decrease the potential for human error and accidents, and dramatically improve the performance capability of Sailors.

Human Systems Integration

HSI resulted from the need to consolidate the various disciplines of system engineering and acquisition that address the roles, requirements, provisions, and accommodations for humans in complex systems. Aspects of ship systems acquisition that concern humans include: MPT; human factors engineering (HFE); habitability; survivability; and environment, safety and occupational health (ESOH). Table 1 shows the seven domains of HSI and some of the human related challenges confronting the PM.

Directives Mandating HSI

There are several mandates for HSI in both DoD and DoN directives and instructions. For example, CJCSI 3170.01C, dated 24 June 2003, includes HSI elements when determining the operational suitability of a proposed system during the analysis of alternatives (AoA). DoDD 5000.1, dated 12 May 2003, Sections E.1.27 (Systems Engineering) and E1.29 (Total Systems Approach), require the PM to pursue HSI and systems engineering initiatives that optimize total system performance and minimize TOC. The PM shall integrate manpower, personnel, training, safety and occupational health, habitability, human factors engineering, and survivability considerations into the acquisition process. The PM's acquisition strategy is required to identify HSI responsibilities, describe the technical and management approach for meeting these HSI requirements, and summarize the major elements of the associated training system. Specific

considerations for each HSI domain follow DoDI 5000.2, dated 12 May 2003, Enclosure 7.

DoDD 5000.1, Sections E1.27 and E1.29 and DoDI 5000.2, Enclosure 7, relate to all programs regardless of ACAT, and require the PM to initiate a comprehensive strategy for HSI early in the acquisition process to minimize ownership costs and ensure that the system is built to accommodate the human performance characteristics of users who will operate, maintain, and support the system. The PM shall work with the manpower, personnel, training, safety and occupational health, habitability, survivability, and HFE communities to establish quantifiable and measurable system performance requirements.

Human Systems Integration						
Human Factors Engineering	**Manpower**	**Personnel**	**Training**	**Habitability**	**Survivability**	**Environment, Safety and Occupational Health**
Human Performance Human Interfaces Human Error Avoidance Top Down Analysis Design for Usability Design for Maintainability	Workload Wartime Requirements (Quality/Quantity) Peacetime Requirements (Quality/Quantity) Officer, Enlisted and Civilian Force Structure Operating Strength	Personnel Classification Selection Recruiting Retention Career Progression Skill Mix Special Skills Occupational Standards Distribution Manning Concepts	Knowledge, Skills and Attitudes Initial Skill Skill Progression Functional Individual and Team Training Concepts Initial & Follow-on Delivery Systems Organic Training Embedded Training Distance Learning Virtual Environment Intelligent Tutoring	Quality of Life Quality of Work Environmental Limits and Controls Personnel Services	Anti-Fratricide Personnel Protection Damage Control Performance Effects of Ensembles	Accident Avoidance Safety Hazard Avoidance Health Hazard Avoidance Risk Mitigation Medical

Table 1.

HSI Objectives in Navy Ship Systems Acquisition

The primary objective of HSI is to provide Navy systems with the highest total system performance at the lowest TOC. This is accomplished through several initiatives:

- Achieve optimal manning, defined as the minimum number of personnel consistent with human performance, workload, and safety requirements, and affordability, risk, and reliability constraints;
- Reduce total program TOC costs
- Addressing HSI issues and concerns early in system acquisition;

- Conducting top down requirements analysis (TDRA) early in system design;
- Identifying deficiencies and lessons learned in baseline comparison systems;
- Applying simulation and prototyping early in system development;
- Defining the roles of humans in system operations and maintenance early in system design;
- Applying human-centered design (HCD) throughout the development;
- Applying human-centered test and evaluation.
- Reduce the incidence and impact of human errors (the direct cause of 80%of ship accidents);
- Enhance human performance, specifically situational awareness and decision making;
- Enhance ship space habitability, quality of life, and quality of work at sea;
- Enhance the maintainability of shipboard equipment and maintainer's performance capability;
- Improve training and personnel management.

HSI in New Ship Systems Acquisition

New systems, from an HSI perspective, require the "clean-sheet-of-paper" approach to the system's manning, training, and human-machine interface design. This approach starts with zero manning until the manpower requirements are justified based on task analysis and workload assigned to the Sailors. The HSI process features TDRA and HCD to identify relevant functions, allocate these functions to humans or automation, derive tasks from the functions, and define the roles and requirements of humans and automation in conducting these tasks. The HSI process develops and verifies human-machine interface design concepts through modeling and simulation (M&S), develops techniques for human-automation interaction, specifies human performance competencies and training concepts, and assesses human performance, workload and safety through HSI test and evaluation.

For new acquisitions, HSI requirements and activities must be identified for each acquisition phase, including User Needs and Technology Opportunities; the Concept Refinement and Technology Development phase; the System Development and Demonstration Phase; the Production and Deployment phase; and the Operations and Support phase. HSI applications for each of these phases are described in Volume 2 of this manual.

A new ship systems acquisition strategy shall define not only the approach to be followed in System Development and Demonstration, but also how the program is structured to achieve full capability. There are two such approaches—evolutionary (the Navy's preferred approach) and single step. Evolutionary acquisition is an approach that fields an operationally useful and supportable capability in as short a time as possible. Evolutionary acquisition delivers an initial capability with the explicit intent of delivering improved or updated capability in the future. The ultimate capability delivered to the user is divided

into two or more blocks, with increasing increments of capability. The first block provides the initial deployment capability (a usable increment of capability called for in the Capability Development Document (CDD) or Operational Requirements Document (ORD).

In a single step to full capability approach, the full system capability is developed and demonstrated prior to Milestone C. Under this approach, any modification that is of sufficient cost and complexity that it could itself qualify as a Major Defense Acquisition Program (MDAP) shall be considered for management purposes as a separate acquisition effort. Modifications that do not cross the MDAP threshold shall be considered part of the program being modified, unless the program is no longer in production. In that case, the modification shall be considered a separate acquisition effort.

In new ship systems acquisitions, the products affected by HSI application include:

- HSI inputs to acquisition documentation, including ICD, Mission Needs Statement (MNS), CDD, ORD, Capstone Requirements Document (CRD), System Engineering Master Plan (SEMP), Test and Evaluation Master Plan (TEMP), M&S Plan, Risk Reduction Plan, and procurement documents.
- HSI Plan (HSIP)
- Navy Training System Plan
- Ship Manning Document
- Manpower Estimate
- Design concepts and criteria for human-machine interfaces
- Design concepts and criteria for ensuring Quality of Service
- Design concepts and criteria for habitability and personnel survivability
- Design concepts and criteria for safety and health

HSI in the Modernization and Upgrade of Legacy Ship Systems

HSI for modernization or upgrade of systems already fielded requires that the clean-sheet-of-paper approach be modified to account for a hard reality—the system already exists making a completely fresh design impractical. However, the limitations placed on HSI by legacy systems do not mean that the HSI process cannot improve the cost, operational performance, and success of modernization and upgrades. The key is for the PM to understand HSI and to take a long-term view of upgrades, applying HSI as much as possible to the upgrade design, with the understanding that any HSI conducted will move the whole legacy system toward higher performance, lower errors, and optimal manning.

According to DoDD 5000.1, DoD shall use performance based strategies for re-procurement of systems, subsystems, components, spares, and services whenever feasible. To the extent possible in system upgrades, PMs should address requirements for:

- Sustained human performance;
- Prevention of human error;
- Use of information approaches which reduce cognitive workload while enhancing human decision-making and warfighting capabilities;
- Improved ease of use and promotion of a corresponding reduction in training requirements.

HSI issues in modernization of systems are primarily derived from lessons learned from the predecessor system, evolving concept of operation (CONOPS) and doctrine, and the impact of adding new capabilities. Decision makers at all levels should encourage and facilitate the documentation and institutionalization of lessons learned—both good and bad—from past experience. The objective is to generate a learning culture that embraces change and continuously adapts to new challenges. The HSI issues in system modernization include identification of:

- Areas in fielded systems where HSI has a significant impact on system performance, affordability, and risk;
- Opportunities for insertion of advanced technology in existing systems to significantly impact HSI;
- The extent to which design directions taken in existing systems constrain the degrees of freedom in making improvements;
- How a reengineering and modernization approach can be taken to design for human performance, safety, health and quality of life;
- How changes in requirements impact requirements for improving human performance, MPT, survivability and habitability, and ESOH.

HSI in Prototype to Production Acquisition

Another acquisition method emphasizes acquiring a system by proceeding directly from prototype to production. This method applies the spiral development process (iterative build-test-fix-test-deploy) within the evolutionary acquisition strategy. In this approach, spiral development defines a set of capabilities for one evolutionary increment (or block), with each increment providing a militarily useful capability. Application of HSI is still compatible with this approach. TDRA, simulation-based design, and performance specification that include HSI considerations are still required. Prototype to production is an attempt to reduce cycle time to produce a system. It is not a different design approach. In the application of simulation-based design, the major HSI M&S approaches are: (a) task network simulation to determine the effectiveness of task sequence performance with time constraints; and (b) human-in-the-loop simulation to assess human performance with alternate levels of automation control and support.

Through the TDRA, HSI inputs to the Prototype Performance Specification, regarding the human roles and requirements impact on what the system will be capable of doing, specify the performance tolerances required for successful

performance and risk reduction. In the system performance specification, human performance requirements must address:

- Information management approaches that will reduce cognitive workload while enhancing human decision making and system warfighting capabilities;
- Design concepts for human-machine interfaces and shipboard communications systems that address human capabilities and requirements;
- Capability for sustained performance; and
- Provision of information products and effective integration of information so as to prevent or minimize the probability of human error.

HSI in COTS/NDI Acquisition

DoDI 5000.2 encourages PMs to consider and use COTS solutions. In this context, integration may assimilate a single COTS product or encompass multiple COTS components integrated into one deployable system, or system block. In either case, the PM shall ensure that the system, including the human component, co-evolves with essential changes to doctrine or reengineered business processes (for combat support and IT systems). The PM shall apply commercial item best practices. HSI is considered a commercial item best practice in commercial standards, such as the IEEE Standard for Application and Management of the Systems Engineering Process (IEEE STD 1220-1998). Regardless of COTS use, the PM is ultimately responsible for the engineering, development, integration, test and evaluation, delivery, sustainment, and management of the overall system.

Determining the HSI requirements for NDI begins by identifying the HSI inputs to NDI concepts and issues. The extent to which NDI meets the users' and environmental needs must be determined. HSI issues in NDI operational requirements are then identified and include:

- Human performance issues;
- Human safety and health issues;
- Human quality of life – habitability issues;
- Personnel management issues;
- Workload and manning issues; and
- Training issues.

The HSI effort provides inputs to ensure the developer is responsive to legitimate needs, but is also conscious of technical and logistic risks and affordability constraints. The HSI effort also provides inputs to TOC determinations, including the determination of which NDI approach has the:

- Lowest projected TOC, within acceptable risks, and meets essential requirements, including human performance and safety requirements;
- Lowest human workload and manning requirements for operations and maintenance;
- Most effective training program;

- Fewest safety and health hazards;
- Best mean time to repair;
- Best overall availability; and
- Best overall supportability.

Benefits

As noted in the section entitled "Why HSI? The Navy Requirement," there are clear cost, safety, and system performance benefits for the PM who uses solid HSI procedures and practices. The payoffs of applying HSI to Navy system acquisition are as follows:

- Affordable systems
- Acceptable workloads that encourage crew retention
- Manning that is optimal
- Efficient personnel utilization
- Reduced error and accident rates
- Effective human performance
- Highly capable teams
- Productive crew
- Safe environments
- Habitable facilities
- Information and knowledge that is readily understood
- Meaningful communications
- Highly usable human computer interfaces
- Readable, well organized displays
- Integrated workstations
- Accessible components and reduced maintenance costs
- Responsive and effective training
- Consistent procedures
- Enriching jobs
- Satisfying duty cycles

Summary

Summing up, the primary objective of HSI is to influence system design to ensure that the resulting system will have the highest performance at the lowest TOC through consideration of human limitations and capabilities. Whether a completely new system or an upgrade to an existing, in-service system, HSI is a critical element in ensuring that operational readiness and manpower requirements will be satisfied. More to the point, DoD and DoN directives require that PMs actively embrace HSI in their programs.