Defense Acquisition Guidebook

Chapter 6 - Human Systems Integration (HSI)

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DEFENSE ACQUISITION GUIDEBOOK
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6.0. Overview

DoD acquisition policy requires optimizing total system performance and minimizing the cost of ownership through a "total system approach" to acquisition management by applying Humans Systems Integration elements to acquisition systems. (DoD Directive 5000.01).

6.0.1. Purpose

While Chapter 4 discusses systems engineering at large, this chapter specifically addresses the human systems elements of the systems engineering process. This chapter provides the Program Manager with the necessary background and understanding to design and develop systems that effectively and affordably integrate with human capabilities and limitations. It also makes the program manager aware of the staff resources available to assist in this endeavor.

6.0.2. Contents

This chapter has six major sections:

- Section 6.1 briefly reviews the total systems approach directed by DoD Directive 5000.01.
- Section 6.2 describes the importance of integration with respect to Human Systems

Integration (HSI) implementation and its value in systems integration and risk management.

- Section 6.3 describes each of the domains of HSI: Manpower, Personnel, Training, Human Factors Engineering, Safety and Occupational Health, Survivability (Personnel), and Habitability. Each of these sub-sections contains an overview of the domain, addresses domain requirements, and a discussion of planning considerations.
- Section 6.4 follows with the implementation of HSI, to include formulation of the HSI strategy and the sequencing of expected HSI activities along the timeline of the Defense Acquisition Framework.
- Section 6.5 describes the human considerations associated with resource estimating and planning; it is the HSI complement to Chapter 3.
- Section 6.6 provides two reference lists for additional information .

6.1. Total System Approach

The total system includes not only the prime mission equipment and software, but also the people who operate, maintain, and support the system; the training and training devices; and the operational and support infrastructure. Human Systems Integration (HSI) practitioners assist program managers by focusing attention on the human part of the system and by integrating and inserting manpower, personnel, training, human factors engineering, environment, safety, occupational health hazards, and personnel survivability considerations into the Defense acquisition process. Consistent with DoD Instruction 5000.02, Enclosure 8 , when addressing HSI, the program manager must focus on each of the "domains" of HSI. These domains are outlined and explained beginning in Section 6.3 . The focus on the domains; however, should also include a comprehensive integration within and across these domains as outlined in Section 6.2 .

6.2 HSI - Integration Focus

The key to a successful HSI strategy is comprehensive integration across the HSI domains and also across other core acquisition and engineering processes. This integration is dependent on an accurate HSI plan and includes the comprehensive integration of requirements. The optimization of total system performance and determination of the most effective, efficient, and affordable design requires upfront requirements analyses. The HSI domains (manpower, personnel, training, environment, safety and occupational health, human factors engineering, survivability, and habitability) can and should be used to help determine and work the science and technology gaps to address all aspects of the system (hardware, software, and human). The program manager should integrate system requirements for the HSI domains with each other, and also with the total system. As work is done to satisfy these requirements, it is vital that each HSI domain anticipate and respond to changes made by other domains or which may be made within other processes or imposed by other program constraints. These integration efforts should be reflected in updates to the requirements, objectives, and thresholds in the Capability Development Document s .

In today's Joint environment, the integration across systems of systems is necessary to achieve a fully networked Joint war fighting capability. The warfighter requires a fully networked environment and must be able to operate efficiently and effectively across the continuum of systems from initial recognition of the opportunity to engage through to mission completion. To accomplish this, HIS domains and human capabilities and constraints, should be considered in analytic assumptions, through system-of-systems analysis, modeling, and testing. This provides opportunities for integration, synchronization, collaboration, and coordination of capabilities to meet human centered requirements. A fully integrated investment strategy with joint sponsorship from the Materiel Development Decision on through the series of incremental developments may be required.

Values for objectives and thresholds, and definitions for parameters contained in the Capabilities Documents, Manpower Estimate , Test and Evaluation Master Plan , Acquisition Plan and Acquisition Program Baseline , should be consistent. This ensures consistency and thorough integration of program interests throughout the acquisition process.

6.2.1. Integrated Product and Process Development (IPPD) and Integrated Product Teams (IPTs)

DoD acquisition policy stresses the importance of IPPD. IPPD is a management technique that integrates all acquisition activities starting with capabilities definition through systems engineering, production, fielding/deployment and operational support in order to optimize the design, manufacturing, business, and supportability processes. At the core of the IPPD technique are IPTs. Human Systems Integration (HSI) should be a key consideration during the formation of IPTs. HSI representatives should be included as members of systems engineering and design teams and other IPTs that deal with human-oriented acquisition issues or topics. The various HSI domain experts should have the opportunity to work in an integrated structure to comprehensively impact the system. Domain experts working separately and in different IPT structures may make significant changes / inputs to the system without fully appreciating effects their changes may have on other domains . Only by working closely together can the HSI practitioners bring an optimum set of human interfaces to the Systems Engineering and Systems Acquisition Processes . HSI participants assist in IPPD as part of the IPTs by ensuring the following:

- HSI parameters/requirements in the Initial Capabilities Document (ICD) , Capability Development Document , and Capability Production Document are based upon and consistent with the user representative's strategic goals and strategies. These parameters/requirements are addressed throughout the acquisition process starting in the Capabilities Based Assessment CBA and ICD and continuing throughout engineering design, trade-off analysis, testing, fielding/deployment, and operational support;

- Performance and HSI domain issues, identified in legacy systems and by design capability risk reviews, are used to establish a preliminary list for risk management. These issues should be evaluated and managed throughout the systems life cycle at a management level consistent with the hazard;
- The factors, tools, methodologies, risk assessment/mitigations, and set of assumptions used by the acquisition community to assess manpower, personnel, and training requirements, measure human-in-the-loop system performance, and evaluate safety, occupational health hazards, survivability, and habitability are consistent with what the functional communities/user representatives use to evaluate performance and establish performance based metrics;
- The factors used by the acquisition community to develop cost estimates are consistent with the 1) manpower and personnel requirements reported in the Manpower Estimate ; 2) training requirements reported in the DoD Component training plans; and 3) assessments of safety and health hazards documented in the Programmatic Environment, Safety, and Occupational Health Evaluation ; and,
- The Manpower Estimates and training strategies reported during the acquisition milestone reviews are reflected in the manning documents, training plans, personnel rosters, and budget submissions when the systems are fielded.

6.2.2. HSI Strategy, Risk, and Risk Mitigation

The development of an HSI strategy should be initiated early in the acquisition process, when the need for a new capability or improvements to an existing capability is first established. To satisfy DoD Instruction 5000.02, the program manager should have a plan for HSI in place prior to entering Engineering and Manufacturing Development. The program manager should describe the technical and management approach for meeting HSI parameters in the capabilities documents, and identify and provide ways to manage any HSI-related cost, schedule, or performance issues that could adversely affect program execution.

When a defense system has complex human-systems interfaces; significant manpower or training costs; personnel concerns; or safety, health hazard, habitability, survivability or human factors engineering issues; the program manager should use the HSI plan to describe the process to identify solutions. HSI risks and risk mitigation should be addressed in the program manger's risk management program.

The HSI plan should address potential readiness or performance risks and how these risks should be identified and mitigated. For example, skill degradation can impact combat capability and readiness. The HSI plan should call for studies to identify operations that pose the highest risk of skill decay. When analysis indicates that the combat capability of the system is tied to the operator's ability to perform discrete tasks that are easily degraded (such as those contained in a set of procedures), solutions such as system design, procedural changes or embedded training should be considered to address the problem. Information overload and requirements for the warfighter to dynamically integrate data from multiple sources can result in degradation of situational awareness and overall readiness. Careful consideration of common user interfaces, composable information sources, and system workload management will mitigate this risk. An on-board "performance measurements capability" can also be developed to support immediate feedback to the operators/maintainers and possibly serve as a readiness measure to the unit commander. The lack of available ranges and other training facilities, when deployed, are issues that should be addressed. The increased use of mission rehearsal, as part of mission planning, and the preparation process and alternatives supporting mission rehearsal should be addressed in the HSI plan. Team skills training and joint battlespace integration training should also be considered in the HSI plan and tied to readiness. Additionally, HSI issues should be addressed at system technical reviews and milestone decision reviews.

The program manager's Programmatic Environment, Safety, and Occupational Health (ESOH) Evaluation (PESHE) describes the strategy for integrating ESOH considerations into the systems engineering process and defines how PESHE is linked to the effort to integrate HSI considerations into systems engineering. The PESHE also describes how ESOH risks are managed and how ESOH and HSI efforts are integrated. It summarizes ESOH risk information (hazard identification, risk assessment, mitigation decisions, residual risk acceptance, and evaluation of mitigation effectiveness). The HSI Strategy should address the linkage between HSI and ESOH and how the program has been structured to avoid duplication of effort.

DoD Directive 5000.01 prescribes supportability comparable to cost, performance, and schedule in program decision-making. Program managers should establish a logistics support concept (e.g., two level, three level), training plans, and manpower and personnel concepts, that when taken together, provide for cost-effective, total, life-cycle support. MIL-HDBK-29612-1A , -2A , -3A , & -4A may be used as a guide for Instructional Systems Development/Systems Approach to the training and education process for the development of instructional materials. Manpower, personnel, training analyses should be tied to supportability analyses and should be addressed in the HSI plan.

Program risks related to cost, schedule, performance, supportability, and/or technology can negatively impact program affordability and supportability. The program manager should prepare a "fallback" position to mitigate any such negative effect on HSI objectives. For example, if the proposed system design relies heavily on new technology or software to reduce operational or support manning requirements, the program manager should be prepared with design alternatives to mitigate the impact of technology or software that is not available when expected.

6.3. Human Systems Integration Domains

6.3.1. Manpower

6.3.1.1. Manpower Overview

6.3.1.2. Manpower Parameters/Requirements

6.3.1.3. Manpower Planning

6.3. Human Systems Integration Domains

6.3.1. Manpower

6.3.1.1. Manpower Overview

Manpower factors are those job tasks, operation/maintenance rates, associated workload, and operational conditions (e.g., risk of hostile fire) that are used to determine the number and mix of military and DoD civilian manpower and contract support necessary to operate, maintain, support, and provide training for the system. Manpower officials contribute to the Defense acquisition process by ensuring that the program manager pursues engineering designs that optimize manpower and keep human resource costs at affordable levels (i.e., consistent with strategic manpower plans). Technology-based approaches used to reduce manpower requirements and control life-cycle costs should be identified in the capabilities documents early in the process. For example, material-handling equipment can be used to reduce labor-intensive material-handling operations and embedded training can be used to reduce the number of instructors.

6.3.1.2. Manpower Parameters/Requirements

DoD Directive 5000.01 directs the DoD Components to plan programs based on realistic projections of the dollars and manpower likely to be available in future years. Manpower goals and parameters should be based on manpower studies and analysis. These studies and analyses should ensure that design options that reduce workload and ensure program affordability are pursued, and that lower-priority design features do not take precedence. Throughout the system life cycle, program managers should strive to keep manpower and the associated ownership costs at desired/targeted levels. Program managers should also preserve future-year resources rather than attempting to compete for additional funding later to address Manpower, Personnel or associated Training issues.

When there are Congressional or Administrative caps placed on military end strengths, the introduction of a new system or capability will require compensating reductions (trade-offs) elsewhere in the force structure or in the Individuals Account. Manpower officials should identify areas for offsets, or "bill-payers," for the new system and establish constraints based on available resources. If the new system replaces a system in the inventory, manpower officials should determine whether the constraints placed on the predecessor system also apply to the new system. They should consider the priority of the new system and determine if either additional resources will be provided, or if more stringent constraints will apply. Manpower authorities should consider the availability of resources over the life of the program and weigh competing priorities when establishing manpower constraints for acquisition programs. Reviews should account for all military and civilian manpower and contract support needed to operate, maintain, support, and provide training for the system over the entire life of the program.

Manpower can be a major determinant of program cost and affordability. In translating user requirements into a Defense Acquisition Program and its associated program documents, both the Program Managers and HSI practitioners should ensure that the requirements documents provide sufficient guidance to accurately move forward. The capability documents should identify any manpower constraints that, if exceeded, would require the Department to reconsider the utility of the program. The capability documents should specify the expected location of the system on the battlefield and the expected operational conditions (e.g., a high [or low] likelihood of hostile fire or collateral damage). These specifications affect early cost, manpower mix, training, personnel, and survivability requirements. Absent this guidance, further clarification should be requested from the users.

The capability documents should establish manpower parameters (objectives and thresholds) consistent with existing departmental constraints. If the program is manpower intensive, it may be prudent to establish a manpower Key Performance Parameter (KPP) early in the acquisition process. Setting a KPP will ensure the system fit's within manpower parameters established by the Department, that agreed-upon resource thresholds are not exceeded, and that the system will not require additional resources from higher priority programs later in the acquisition process. A KPP should only be established if the adverse manpower effect of exceeding the KPP outweighs the overall benefits of the new capability. In all cases, manpower constraints and KPPs must be defendable and commensurate with the priority and utility of the new capability. Program Managers and HSI practitioners should work closely with the users and the sponsoring organization to ensure agreement on the appropriate parameters.

The capability documents should also address specific, scenario-based, factors that affect manpower, such as surge requirements, environmental conditions (e.g., arctic or desert conditions), and expected duration of the conflict. These factors are capability-related and directly affect the ability of the commander to sustain operations in a protracted conflict.

6.3.1.3. Manpower Planning

Manpower analysts determine the number of people required, authorized, and available to operate, maintain, support, and provide training for the system. Manpower requirements are based on the range of operations during peacetime, low intensity conflict, and wartime. They should consider continuous, sustained operations and required surge capability. The resulting Manpower Estimate accounts for all military (Active Reserve, and Guard), DoD civilian (U.S. and foreign national), and contract support manpower.

DoD Instruction 5000.02 requires the program manager to work with the manpower community to determine the most efficient and cost-effective mix of DoD manpower and contract support, and identify any issues (e.g., resource shortfalls) that could impact the program manager's ability to execute the program. This collaboration must be conducted within the Human Systems Integration (HSI) framework to ensure integration with the other HSI domains. The HSI lead for a program / project should be able to draw expertise from the manpower community to provide program assistance. Generally, the decision to use DoD civilians and contract labor in theater during a conflict where there is a high likelihood of hostile fire or collateral damage is made on an exception basis. In all cases, risk reduction should take precedence over cost savings. Additionally, the program manager should consult with the manpower community in advance of contracting for operational support services to ensure that sufficient workload is retained in-house to adequately provide for career progression, sea-to-shore and overseas rotation, and combat augmentation. The program manager should also ensure that inherently governmental and exempted commercial functions are not contracted. These determinations should be based on current Workforce Mix Guidance (DoD Instruction 1100.22).

Consistent with sections E1.1.4 and E1.1.29 of DoD Directive 5000.01, the program manager must evaluate the manpower required and/or available to support a new system and consider manpower constraints when establishing contract specifications to ensure that the human resource demands of the system do not exceed the projected supply. The assessment must determine whether the new system will require a higher, lower, or equal number of personnel than the predecessor system, and whether the distribution of ranks/grade will change. Critical manpower constraints must be identified in the capability document s to ensure that manpower requirements remain within DoD Component end-strength constraints. If sufficient end-strength is not available, a request for an increase in authorizations should be submitted and approved as part of the trade-off process.

When assessing manpower, the system designers should look at labor-intensive (high-driver) tasks. These tasks might result from accessibility or hardware/ software interface design problems. These high-driver tasks can sometimes be eliminated during engineering design by increasing equipment or software performance. Based on a top-down functional analysis, an assessment should be conducted to determine which functions should be automated, eliminated, consolidated, or simplified to keep the manpower numbers within constraints.

Manpower requirements should be based on task analyses that are conducted during the functional allocation process and consider all factors including fatigue; cognitive, physical, sensory overload; environmental conditions (e.g., heat/cold), and reduced visibility.

Additionally, manpower must be considered in conjunction with personnel capabilities, training, and human factors engineering trade-offs.

Tasks and workload for individual systems, systems-of-systems, and families-of-systems should be reviewed together to identify commonalities, merge operations, and avoid duplication. The cumulative effects of system-of-system, family-of-systems and related system integration should be considered when developing manpower estimates.

When reviewing support activities, the program manager should work with manpower and functional representatives to identify process improvements, design options, or other initiatives to reduce manpower requirements, improve the efficiency or effectiveness of support services, or enhance the cross-functional integration of support activities.

The support strategy should document the approach used to provide for the most efficient and cost-effective mix of manpower and contract support and identify any cost, schedule, or performance issues, or uncompleted studies that could impact the program manager's ability to execute the program.

6.3.2. Personnel

6.3.2.1. Personnel Overview

Personnel factors are those human aptitudes (i.e., cognitive, physical, and sensory capabilities), knowledge, skills, abilities, and experience levels that are needed to properly perform job tasks. Personnel factors are used to develop the military occupational specialties (or equivalent DoD Component personnel system classifications) and civilian job series of system operators, maintainers, trainers, and support personnel. Personnel officials contribute to the Defense acquisition process by ensuring that the program manager pursues engineering designs that minimize personnel requirements, and keep the human aptitudes necessary for operation and maintenance of the equipment at levels consistent with what will be available in the user population at the time the system is fielded.

6.3.2.2. Personnel Parameters/Requirements

DoD Instruction 5000.02 requires the program manager to work with the personnel community to define the performance characteristics of the user population, or "target audience," early in the acquisition process. The program manager should work with the personnel community to establish a Target Audience Description (TAD) that identifies the cognitive, physical, and sensory abilities-i.e. capabilities and limitations, of the operators, maintainers, and support personnel expected to be in place at the time the system is fielded. When establishing the TAD, Human Systems Integration (HSI) practitioners should verify whether there are any recruitment or retention trends that could significantly alter the characteristics of the user population over the life of the system. Additionally, HSI analysts should consult with the personnel community and verify whether there are new personnel policies that could significantly alter the scope of the user population (e.g., policy changes governing women in combat significantly changed the anthropometric requirements for occupational specialties).

Per DoD Instruction 5000.02, to the extent possible--systems should not be designed to require cognitive, physical, or sensory skills beyond those found in the specified user population. During functional analysis and allocation, tasks should be allocated to the human component consistent with the human attributes (i.e., capabilities and limitations) of the user population to ensure compatibility, interoperability, and integration of all functional and physical interfaces. Personnel requirements should be established consistent with the knowledge, skills, and abilities (KSAs) of the user population expected to be in place at the time the system is fielded and over the life of the program. Personnel requirements are usually stated as a percentage of the population. For example, capability documents might require "physically accommodating the central 90% of the target audience." Setting specific, quantifiable, personnel requirements in the Capability Documents assist the establishment of test criterion in the Test and Evaluation Master Plan.

6.3.2.3. Personnel Planning

Personnel capabilities are normally reflected as knowledge, skills, abilities (KSAs), and other characteristics. The availability of personnel and their KSAs should be identified early in the acquisition process. The DoD Components have a limited inventory of personnel available, each with a finite set of cognitive, physical and psychomotor abilities. This could affect specific system thresholds.

The program manager should use the target audience description (TAD) as a baseline for personnel requirements assessment. The TAD should include information such as inventory; force structure; standards of grade authorizations; personnel classification (e.g., Military Occupational Code / Navy Enlisted Classification) description; biographical information; anthropometric data; physical qualifications; aptitude descriptions as measured by the Armed Services Vocational Aptitude Battery (ASVAB)); task performance information; skill grade authorization; Military Physical Profile Serial System (PULHES); security clearance; and reading grade level.

The program manager should assess and compare the cognitive and physical demands of the projected system against the projected personnel supply. The program manager should also determine the physical limitations of the target audience (e.g., color vision, acuity, and hearing). The program manager should identify any shortfalls highlighted by these studies.

The program manager should determine if the new system contains any aptitude-sensitive critical tasks. If so, the program manager should determine if it is likely that personnel in the target audience can perform the critical tasks of the job.

The program manager should consider personnel factors such as availability, recruitment, skill identifiers, promotion, and assignment. The program manager should consider the impact on recruiting, retention, promotions, and career progression when establishing program costs, and should assess these factors during trade-off analyses.

The program manager should use a truly representative sample of the target population during Test and Evaluation (T&E) to get an accurate measure of system performance. A representative sample during T&E will help identify aptitude constraints that affect system use.

Individual system and platform personnel requirements should be developed in close collaboration with related systems throughout the Department and in various phases of the acquisition process to identify commonalities, merge requirements, and avoid duplication. The program manager should consider the cumulative effects of system-of-systems, family-of-systems, and related systems integration in the development of personnel requirements.

Consistent with DoD Instruction 5000.02, Enclosure 8 , the program manager should summarize major personnel initiatives that are necessary to achieve readiness or rotation objectives or to reduce manpower or training costs, when developing the acquisition strategy. The Life-Cycle Sustainment Plan should address modifications to the knowledge, skills, and abilities of military occupational specialties for system operators, maintainers, or support personnel if the modifications have cost or schedule issues that could adversely impact program execution. The program manager should also address actions to combine, modify, or establish new military occupational specialties or additional skill indicators, or issues relating to hard-to-fill occupations if they impact the program manager's ability to execute the program.

6.3.3. Training

6.3.3.1. Training Overview

Training is any activity that results in enabling users, operators, maintainers, leaders and support personnel, to acquire, gain or enhance knowledge, skills, and concurrently develops their cognitive, physical, sensory, team dynamics and adaptive abilities to conduct joint operations and achieve maximized and fiscally sustainable system life cycles. The training of people as a component of material solutions, delivers the intended capability to improve or fill capability gaps.

Cost and mission effective training facilitates DoD acquisition policy that requires optimized total system performance and minimizing the cost of ownership through a "total system approach" to acquisition management (DoD Directive 5000.01).

The systems engineering concept of a purposely designed *total system* includes not only the mission system-equipment, but more critically, the people who operate, maintain, lead and support these acquired systems. Including the training, training systems; and the operational and support infrastructure.

The Human Systems Integration (HSI) Training Domain assists program managers throughout the acquired systems life cycle by focusing attention on the human interface with the acquired system, and by integrating and inserting manpower, personnel, training, human factors engineering, environment, safety, occupational health, habitability, and survivability as Systems Engineered elements into the Defense acquisition process consistent with DoD Instruction

5000.02, Enclosure 8

The Systems Engineered practice of continuous *application of human-centered methods and tools ensure* s *maximum operational and training effectiveness of the newly acquired system throughout its life cycle.* Systems Engineering in DoD Acquisition provides perspectives on the use of systems engineered/developed training approaches to translate user-defined capabilities into engineering specifications and outlines the role of the program manager in integrated system design activities.

In all cases, the paramount goal of training for new systems is to develop and sustain a ready, well-trained individual/unit, while giving strong consideration to options that can reduce life-cycle costs and provide positive contributions to the joint context of a system and provide a positive readiness outcome.

6.3.3.2. Regulatory Statutory Basis for Training

In order to achieve intended capabilities of new systems acquisition, enable joint integration, interoperability, testing and insure sustainment goals over the life-cycle of weapon systems, training of user, operator, maintainer, and leader personnel will be performed. (ref: DoDI 5000.02 Enclosure 2 & 6, Title 10 USC Sections 2433 & 2535)

To facilitate timely, cost effective and appropriate training content, development and planning of training should be performed during the earliest phases (e.g. Material Solution and Technology Development Phases) of the acquisition processes, outlined within the AoA, System Training Plans (e.g. STRAPs, NTSPs or STPs) Acquisition Strategies(AS) and Acquisition Program Baselines (APB). (ref: DoDI 5000.02 Enclosure 4, 7 & 8, Title 10 Sections 2433 & 2435)

To insure appropriate training for new systems acquisition and traceability to life cycle sustainment costs estimates, systems engineering processes should assess training impacts of material decision trades and appropriately document. New Equipment Training (NET) plans (e.g. STRAPs, NTSPs and STPs) should identify service joint warfighting training requirements. Training planning and training cost estimates should be incorporated within the Cost Analysis Requirements Description (CARD) and Life Cycle Sustainment Plans (LCSPs). (ref: DoDI 5000.02 Enclosure 7, DoDD 5000.04-M & 5141.01, Title 10 Sections 2433 & 2435)

6.3.3.3. Training Planning

Training Planning assists the Program Manager in understanding acquisition program (new or upgrade) systems training as a key performance parameter to successfully integrating DoD Decision Support Systems, e.g. the Acquisition System (DoD 5000 Series), the Joint Capabilities Integration and Development System (JCIDS) and the Planning, Programming, Budgeting & Execution (PPBE) Process, and effectively translate joint capabilities into training system design features.

Initially, the JCIDS process should address joint training requirements for military (Active, Reserve, and Guard) and civilian support personnel who will operate, maintain, lead and support the acquired system.

Training programs should employ integrated cost-effective solutions, and may consist of a blend of capabilities that use existing training program insights and introduces new performance-based training innovations. This may include requirements for school and unit training, as well as new equipment training, or sustainment training. This also may include requirements for instructor and key personnel training and new equipment training teams.

Training planning should be initiated early, by the PM in coordination with the training community within the capabilities development process beginning with the Capabilities Based Assessment and Analysis of Alternatives which support development of the Initial Capabilities Document , informing the Material Development Decision to support the Material Solutions Analysis phase, and continues with development of the Capability Development Document .

Training should also be considered in collaboration with the other Human Systems Integration (HSI) domains in order to capture the full range of human integration issues to be considered within the Systems Engineering process.

Early training planning will inform the Capability Development Document and should characterize the specific system training requirements and identify the training Key Performance Parameter :

- Allow for interactions between platforms or unit's (e.g., through advanced simulation and virtual exercises) and provide training realism to include threats (e.g., virtual and surrogate), a realistic electronic warfare environment, communications, and weapons.
- Appropriate embedded training capabilities that do not degrade system performance below threshold values nor degrade the maintainability or component life of the system are preferred.
- That Initial Operational Capability (IOC) is attained and that training capabilities are met by IOC.
- An embedded performance measurement capability to support immediate feedback to the operators/maintainers and possibly to serve as a readiness measure for the unit commander.
- Training logistics necessary to support the training concept (e.g., requirements for new or upgrades to existing training facilities).
- Provide concurrent capability with actual equipment and training devices and systems.

The training community should be specific in translating capabilities into system requirements. They should also set training resource constraints. These capabilities and constraints can be facilitated and worked through system integration efforts in several of the other HSI domains. Examples are:

- The training community should consider whether the system be designed with a mode of operation that allows operators to train interactively on a continuous basis, even when deployed in remote / austere locations.
- The training community should consider whether the system be capable of exhibiting

fault conditions for a specified set of failures to allow rehearsal of repair procedures for isolating faults or require that the system be capable of interconnecting with other (specific) embedded trainers in both static and employed conditions.
- The training community should consider whether embedded training capabilities allow enhancements to live maneuvers such that a realistic spectrum of threats is encountered (e.g., synthetic radar warnings generated during flight).
- The training community should consider whether the integrated training system be fully tested, validated, verified, and ready for training at the training base as criteria for declaring Initial Operational Capability.

From the earliest stages of development and as the system matures, the program manager should emphasize training requirements that enhance the users capabilities, improve readiness, and reduce individual and collective training costs over the life of the system. This may include requirements for expert systems, intelligent tutors, embedded diagnostics, virtual environments, and embedded training capabilities. Examples of training that enhances users capabilities include:

- Interactive electronic technical manuals provide a training forum that can significantly reduce schoolhouse training and may require lower skill levels for maintenance personnel while actually improving their capability to maintain an operational system;
- Requirements for an embedded just-in-time mission rehearsal capability supported by the latest intelligence information and an integrated global training system/network that allows team training and participation in large scale mission rehearsal exercises can be used to improve readiness.

In all cases, the paramount goal of the training/instructional system should be to develop and sustain a ready, well-trained individual/unit/theater/joint, while giving strong consideration to options that can reduce life-cycle costs and provide positive contributions to the joint context of a system, where appropriate.

Training devices and simulators are systems that, in some cases, may qualify for their own set of HSI requirements. For instance, the training community may require the following attributes of a training simulator:

- Accommodate "the central 90 percent of the male and female population on critical body dimensions;"
- Not increase manpower requirements and considerations of reductions in manpower requirements;
- Consider reduced skill sets to maintain because of embedded instrumentation;
- Be High Level Architecture compliant;
- Be Sharable Content Object Reference Model (as in DoDI 13322.26) compliant;
- Be Test and Training Enabling Architecture (overview) compliant;
- Use reusable modeling and simulation devices and architectures.

The acquisition program will be specific in translating new system capabilities into the system and its inherent training requirements.

From the earliest stages of development and as the future system design matures, the program manager should emphasize training requirements that enhance the users capabilities, interoperability, improve readiness, and reduce individual and collective training costs over the life of the system. This may include requirements for expert systems, intelligent tutors, embedded diagnostics, virtual environments, and embedded training capabilities.

6.3.3.4. Development of Training Requirements

When developing the training system, the program manager shall employ transformational training concepts, strategies, and tools such as computer based and interactive courseware, simulators, and embedded training consistent with the programs acquisition strategy, goals and objectives and reflect the tenants outlined in the next generation training strategy.

In addition, the program should address the requirement for a systems training key performance parameter as described in the JCIDS Manual .

The USD (P&R), as a member of the Defense Acquisition Board (DAB), assesses the ability of the acquisition process to support the Military Departments, COCOMs, and other DoD Components acquisition programs from a manpower, personnel, and training readiness perspective.

The acquisition program will characterize training planning, development and execution within the Cost Analysis Requirements Description. Life Cycle Support Plans and Manpower Estimate Reports tailored to each document-type. These training summaries will capture - support traceability of planned training across acquisition and capability documents, and will include logistics support planning for training, training equipment and training device acquisitions and installations

A Special Note on Embedded Training. Both the sponsor and the program manager will provide analysis that demonstrates careful consideration to the use of embedded training as defined in DoD Directive 1322.18 : The sponsor's decisions to use embedded training will be determined very early in the capabilities assessment process. Analysis will be conducted to compare the embedded training with more traditional training media (e.g., simulator based training, traditional classroom instruction, and/or maneuver training) for consideration of a systems Total Operating Cost. The analysis will compare the costs and the impact of embedded training (e.g., training operators and maintenance personnel on site compared to off station travel to a temporary duty location for training).

6.3.4. Human Factors Engineering (HFE)

6.3.4.1. Mandatory Guidance

6.3.4.2. Overview

6.3.4. Human Factors Engineering (HFE)

6.3.4.1. Mandatory Guidance

The program manager employs human factors engineering to design systems that require minimal manpower; provide effective training; can be operated, maintained and supported by users; and are suitable (habitable and safe with minimal environmental and occupational health hazards) and survivable (for both the crew and equipment). In accordance with DoD Instruction 5000.02,

> *"The PM shall take steps (e.g., contract deliverables and Government/contractor IPT teams) to ensure ergonomics, human factors engineering, and cognitive engineering is employed during systems engineering over the life of the program to provide for effective human-systems interfaces and to meet HSI requirements. Where practicable and cost effective, system designs shall minimize or eliminate system characteristics that require excessive cognitive, physical, or sensory skills; entail extensive training or workload-intensive tasks; result in mission-critical errors; or produce safety or health hazards."*

The human factors that need to be considered in the integration are discussed below:

6.3.4.2. Overview

Human factors are the end-user cognitive, physical, sensory, and team dynamic abilities required to perform system operational, maintenance, and support job tasks. Human factors engineers contribute to the acquisition process by ensuring that the program manager provides for the effective utilization of personnel by designing systems that capitalize on and do not exceed the abilities (cognitive, physical, sensory, and team dynamic) of the user population. The human factors engineering community works to integrate the human characteristics of the user population into the system definition, design, development, and evaluation processes to optimize human-machine performance for operation, maintenance, and sustainment of the system.

Human factors engineering is primarily concerned with designing human-system interfaces consistent with the physical, cognitive, and sensory abilities of the user population. Human-system interfaces include:

- Functional interfaces (functions and tasks, and allocation of functions to human performance or automation);
- Informational interfaces (information and characteristics of information that provide the human with the knowledge, understanding and awareness of what is happening in the tactical environment and in the system);
- Environmental interfaces (the natural and artificial environments, environmental controls,

and facility design);

- Cooperational interfaces (provisions for team performance, cooperation, collaboration, and communication among team members and with other personnel);
- Organizational interfaces (job design, management structure, command authority, policies and regulations that impact behavior);
- Operational interfaces (aspects of a system that support successful operation of the system such as procedures, documentation, workloads, job aids);
- Cognitive interfaces (decision rules, decision support systems, provision for maintaining situational awareness, mental models of the tactical environment, provisions for knowledge generation, cognitive skills and attitudes, memory aids); and,
- Physical interfaces (hardware and software elements designed to enable and facilitate effective and safe human performance such as controls, displays, workstations, worksites, accesses, labels and markings, structures, steps and ladders, handholds, maintenance provisions, etc.).

6.3.4.3. Parameters/Requirements

Human factors requirements, objectives, and thresholds should be derived from each of the Human Systems Integration (HSI) domains and should provide for the effective utilization of personnel through the accommodation of the cognitive, physical, and sensory characteristics that directly enhance or constrain system performance. In many cases, the interface design limitation may require tradeoffs in several of the other domains and vice, versa.

Cognitive requirements address the human's capability to evaluate and process information. Requirements are typically stated in terms of response times and are typically established to avoid excessive cognitive workload. Operations that entail a high number of complex tasks in a short time period can result in cognitive overload and safety hazards. The capability document s should specify whether there are human-in-the-loop requirements. This could include requirements for "human in control," "manual override," or "completely autonomous operations." Knowledge, skills and abilities for operators, maintainers and other support personnel continuously change with the increasing complexity of emerging systems. These requirements should be cross correlated with each of the HSI domains.

Physical requirements are typically stated as anthropometric (measurements of the human body), strength, and weight factors. Physical requirements are often tied to human performance, safety, and occupational health concerns. To ensure the users can operate, maintain, and support the system, requirements should be stated in terms of the user population. For instance, when the user requires a weapon that is "one-man portable," weight thresholds and objectives should be based on strength limitations of the user population and other related factors (e.g., the weight of other gear and equipment and the operational environment). For example, it may be appropriate to require that "the system be capable of being physically maintained by central 90% of both the male and female population, inclusive of battle dress, or arctic and Mission Oriented Protective Postures-Level 4 protective garments inside the cab," or that "the crew station physically accommodate 90% of the female/male population, defined by current anthropometric data, for accomplishment of the full range of mission functions."

Sensory requirements are typically stated as visual, olfactory (smell), or hearing factors. The Capability Development Document should identify operational considerations that affect sensory processes. For example, systems may need to operate in noisy environments where weapons are being fired or on an overcast moonless night with no auxiliary illumination. Visual acuity or other sensory requirements may limit the target audience for certain specialties.

6.3.4.4. Application of Human Factors Engineering (HFE)

HFE plays an important role in each phase of the acquisition cycle, to include requirements development, system definition, design, development, evaluation, and system support for reliability and maintainability in the field. To realize the potential of HFE contributions, HFE must be incorporated into the design process at the earliest stages of the acquisition process (i.e., during the Materiel Solution Analysis and Technology Development phases). It should be supported by inputs from the other Human Systems Integration (HSI) domains as well as the other Systems Engineering processes . The right decisions about the human-machine interfaces early in the design process will optimize human and hence, total systems performance. HFE participation continues to each succeeding acquisition phase, continuing to work tradeoffs based on inputs from the other HSI domains and the hardware and software designs / adaptations. The HFE practitioners provide expertise that includes design criteria, analysis and modeling tools, and measurement methods that will help the program office design systems that are operationally suitable, safe, survivable, effective, usable, and cost-effective. In any system acquisition process, it is important to recognize the differences between the competencies (skills and knowledge) required for the various warfighters. Application of HFE processes will lead to an understanding of the competencies needed for the job, and help identify if requirements for knowledge, skills, and abilities (KSAs) exceed what the user can provide and whether the deficiency will lead to a training or operational problem. HFE tools and techniques can be used to identify the KSAs of the target audience and account for different classes and levels of users and the need for various types of information products, training, training systems and other aids. While it is critical to understand the information processing and net-centric requirements of the system, it is equally important to understand the factors affecting format and display of the data presented to the user to avoid cognitive overload. This applies equally to the system being designed as well as to the systems which will interface with the system. The system should not place undue workload or other stress on systems with which it must interface.

6.3.4.5. General Guidelines

Human Factors Engineering (HFE) principles, guidelines, and criteria should be applied during development and acquisition of military systems, equipment, and facilities to integrate personnel effectively into the design of the system. An HFE effort should be provided to: (a) develop or improve all human interfaces of the system; (b) achieve required effectiveness of human performance during system operation, maintenance, support, control, and transport; and (c) make economical demands upon personnel resources, skills, training, and costs. The HFE effort should be well integrated with the other Human Systems Integration domain participation, and should include, but not necessarily be limited to, active participation in the following three major interrelated areas of system development.

6.3.4.5.1. Analysis

Identify the functions that must be performed by the system in achieving its mission objectives and analyze them to determine the best allocation to personnel, equipment, software, or combinations thereof. Allocated functions should be further dissected to define the specific tasks that must be performed to accomplish the functions. Each task should be analyzed to determine the human performance parameters; the system, equipment, and software capabilities; and the operational / environmental conditions under which the tasks will be conducted. Task parameters should be quantified where possible, and should be expressed in a form that permit's effectiveness studies of the human-system interfaces in relation to the total system operation. Human Factors Engineering high-risk areas should be identified as part of the analysis. Task analysis should include maintenance and sustainment functions performed by crew and support facilities. Analyses should be updated as required to remain current with the design effort.

6.3.4.5.2. Design and Development

Human Factors Engineering (HFE) should be applied to the design and development of the system equipment, software, procedures, work environments, and facilities associated with all functions requiring personnel interaction. This HFE effort should convert the mission, system, and task analysis data into a detailed design and development plan to create a human-system interfaces that will operate within human performance capabilities, facilitate / optimize human performance in meeting system functional requirements, and accomplish the mission objectives.

6.3.4.5.3. Test and Evaluation (T&E)

Human Factors Engineering (HFE) and the evaluation of all human interfaces should be integrated into engineering design and development tests, contractor demonstrations, flight tests, acceptance tests, other development tests and operational testing. Compliance with human interface requirements should be tested as early as possible. T&E should include evaluation of maintenance and sustainment activities and evaluation of the dimensions and configuration of the environment relative to criteria for HFE and each of the other Human Systems Integration domains . Findings, analyses, evaluations, design reviews, modeling, simulations, demonstrations, and other early engineering tests should be used in planning and conducting later tests. Test planning should be directed toward verifying that the system can be operated, maintained, supported, and controlled by user personnel in its intended operational environment with the intended training. Test planning should also consider data needed or provided by operational test and evaluation. (See section 9.5.2).

6.3.4.6. Life-Cycle Sustainment Plan

The program manager should summarize the steps planned to be taken (e.g., government and contract deliverables) to ensure human factors engineering (HFE) is employed during systems engineering over the life of the program to provide for effective human-system interfaces and meet HFE and other Human Systems Integration requirements.

6.3.5. Environment, Safety and Occupational Health (ESOH)

6.3.5.1. Environment, Safety and Occupational Health (ESOH) Overview

Each of the various military departments / services treat the three Human Systems Integration (HSI) domains of Environment, Safety, and Occupational Health differently, based on oversight and reporting responsibility within each of the services. DoD ESOH Guidance for systems acquisition programs can be found in Chapter 4, Systems Engineering, section 4.3.18.9 , and in the ESOH Special Interest Area on the Acquisition Community Connection . What is important to the HSI practitioner and the systems engineer is that these three domains are of vital importance to the HSI effort and must be integrated within the HSI effort. While the ESOH communities have unique reporting requirements that trace to National level mandates, the importance of integrating these domains in the HSI construct cannot be overemphasized. The human aspect brings a host of issues to a system that must be accommodated in each of these three areas and they must each be considered in consonance with the other HSI domains . How they are considered in an integrated manner is left to the Program Manager and Systems Engineering .

Environment includes the natural and manmade conditions in and around the system and the operational context within which the system will be operated and supported. This "environment" affects the human's ability to function as a part of the system.

Safety factors consist of those system design characteristics that serve to minimize the potential for mishaps causing death or injury to operators, maintainers and supporters or threaten the survival and/or operation of the system. Prevalent issues include factors that threaten the safe operation and/or survival of the platform; walking and working surfaces including work at heights; pressure extremes; and control of hazardous energy releases such as mechanical, electrical, fluids under pressure, ionizing or non-ionizing radiation (often referred to as "lock-out/tag-out"), fire, and explosions.

Occupational health factors are those system design features that serve to minimize the risk of injury, acute or chronic illness, or disability; and/or reduce job performance of personnel who operate, maintain, or support the system. Prevalent issues include noise, chemical safety, atmospheric hazards (including those associated with confined space entry and oxygen deficiency), vibration, ionizing and non-ionizing radiation, and human factors issues that can create chronic disease and discomfort such as repetitive motion diseases. Many occupational health problems, particularly noise and chemical management, overlap with environmental impacts. Human factors stresses that create risk of chronic disease and discomfort overlap with occupational health considerations.

6.3.5.2. Environment, Safety and Occupational Health (ESOH) Hazard

Parameters/Requirements

Environment, safety and health hazard parameters should address all activities inherent to the life cycle of the system, including test activity, operations, support, maintenance, and final demilitarization and disposal. Environment, safety and health hazard requirements should be stated in measurable terms, whenever possible. For example, it may be appropriate to establish thresholds for the maximum level of acoustic noise, vibration, acceleration shock, blast, temperature or humidity, or impact forces etc., or "safeguards against uncontrolled variability beyond specified safe limit's," where the Capability Document s specify the "safe limit's." Safety and health hazard requirements often stem from human factor issues and are typically based on lessons learned from comparable or predecessor systems. For example, both physical dimensions and weight are critical safety requirements for the accommodation of pilots in ejection seat designs. Environment, safety and health hazard thresholds are often justified in terms of human performance requirements, because, for example, extreme temperature and humidity can degrade job performance and lead to frequent or critical errors. Another methodology for specifying safety and health requirements is to specify the allowable level of residual risk as defined in MIL-STD-882D, "DoD Standard Practice for System Safety," for example, "There shall be no high or serious residual risks present in the system."

6.3.5.3. Environment, Safety and Occupational Health (ESOH) Planning

6.3.5.3.1. Programmatic Environment, Safety, and Occupational Health (ESOH) Evaluation (PESHE)

The Human Systems Integration Plan should recognize the appropriate timing for the PESHE and define how the program intends to ensure the effective and efficient flow of information to and from the ESOH domain experts to work the integration of environment, safety and health considerations into the systems engineering process and all its required products.

6.3.5.3.2. Health Hazard Analysis (HHA)

Health Hazards Analysis(HHA) should be conducted during each phase of the acquisition process beginning with a review of issues related to predecessor systems. During early stages of the acquisition process, sufficient information may not always be available to develop a complete HHA. As additional information becomes available, the initial analyses are refined and updated to identify health hazards, assess the risks, and determine how to mitigate the risks, formally accept the residual risks, and monitor the effectiveness of the mitigation measures. The health hazard risk information is documented in the PESHE. Health hazard assessments should include cost avoidance figures to support trade-off analysis. There are nine health hazard issues typically addressed in a health hazard analysis (HHA):

- **Acoustical Energy.** The potential energy that transmits through the air and interacts with the body to cause hearing loss or damage to internal organs.
- **Biological Substances.** An infectious substance generally capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans.
- **Chemical Substances.** The hazards from excessive airborne concentrations of toxic

materials contracted through inhalation, ingestion, and skin or eye contract.

- **Oxygen Deficiency.** The displacement of atmospheric oxygen from enclosed spaces or at high altitudes.
- **Radiation Energy.** Ionizing: The radiation causing ionization when interfacing with living or inanimate mater. Non-ionizing: The emissions from the electromagnetic spectrum with insufficient energy to produce ionizing of molecules.
- **Shock.** The mechanical impulse or impact on an individual from the acceleration or deceleration of a medium.
- **Temperature Extremes and Humidity.** The human health effects associated with high or low temperatures, sometimes exacerbated by the use of a materiel system.
- **Trauma.** Physical: The impact to the eyes or body surface by a sharp or blunt object. Musculoskeletal: The effects to the system while lifting heavy objects.
- **Vibration.** The contact of a mechanically oscillating surface with the human body.

6.3.6. Survivability

6.3.6.1. Survivability Overview

Survivability factors consist of those system design features that reduce the risk of fratricide, detection, and the probability of being attacked; and that enable the crew to withstand natural and man-made hostile environments without aborting the mission or suffering acute chronic illness, disability, or death. Survivability attributes, as described in the Joint Military Dictionary (JP 1-02) , are those that contribute to the survivability of manned systems. In the HSI construct, the human is considered integral to the system and personnel survivability should be considered in the encompassing "system" context.

6.3.6.2. Survivability Parameters/Requirements

A Survivability / Force Protection Key Performance Parameter should be considered for any "manned system or system designed to enhance personnel survivability" when the system may be employed in an asymmetric threat environment. The Capability Document s should include applicable survivability parameters. This may include requirements to eliminate significant risks of fratricide or detectability, or to be survivable in adverse weather conditions and the nuclear, biological, and chemical (NBC) battlefield. NBC survivability, by definition, includes the instantaneous, cumulative, and residual effects of NBC weapons upon the system, including its personnel. It may be appropriate to require that the system "permit performance of mission-essential operations, communications, maintenance, re-supply and decontamination tasks by suitably clothed, trained, and acclimatized personnel for the survival periods and NBC environments required by the system."

The consideration of survivability should also include system requirements to ensure the integrity of the crew compartment and rapid egress when the system is damaged or destroyed. It may be appropriate to require that the system provide for adequate emergency systems for contingency management, escape, survival, and rescue.

6.3.6.3. Survivability Planning

The Joint Capabilities Integration and Development System capability documents define the program's combat performance and survivability needs. Consistent with those needs, the program manager should establish a survivability program. This program, overseen by the program manager, should seek to minimize (1) the probability of encountering combat threats, (2) the severity of potential wounds and injury incurred by personnel operating or maintaining the system, and (3) the risk of potential fratricidal incidents. To maximize effectiveness, the program manager should assess survivability in close coordination with systems engineering and test and evaluation activities .

Survivability assessments assume the warfighter is integral to the system during combat. Damage to the equipment by enemy action, fratricide, or an improperly functioning component of the system can endanger the warfighter. The survivability program should assess these events and their consequences. Once these initial determinations are made, the design of the equipment should be evaluated to determine if there are potential secondary effects on the personnel. Each management decision to accept a potential risk should be formally documented by the appropriate management level as defined in DoD Instruction 5000.02 .

During early stages of the acquisition process, sufficient information may not always be available to develop a complete list of survivability issues. An initial report is prepared listing those identified issues and any findings and conclusions. Classified data and findings are to be appropriately handled according to each DoD Component's guidelines. Survivability issues typically are divided into the following components:

- **Reduce Fratricide.** Fratricide is the unforeseen and unintentional death or injury of "friendly" personnel resulting from friendly forces employment of weapons and munitions. To avoid these types of survivability issues, personnel systems and weapon systems should include anti-fratricide systems, such as Identification of Friend or Foe and Situational Awareness systems.
- **Reduce Detectability.** Reduce detectability considers a number of issues to minimize signatures and reduce the ranges of detection of friendly personnel and equipment by confounding visual, acoustic, electromagnetic, infrared/thermal, and radar signatures and methods that may be utilized by enemy equipment and personnel. Methods of reducing detectability could include camouflage, low-observable technology, smoke, countermeasures, signature distortion, training, and/or doctrine.
- **Reduce Probability of Attack.** Analysts should seek to reduce the probability of attack by avoiding appearing as a high value-target and by actively preventing or deterring attack by warning sensors and use of active countermeasures.
- **Minimize Damage if Attacked.** Analysts should seek to minimize damage, if attacked, by: 1) designing the system to protect the operators and crewmembers from enemy attacks; 2) improving tactics in the field so survivability is increased; 3) designing the system to protect the crew from on-board hazards in the event of an attack (e.g., fuel, munitions, etc.); and, 4) designing the system to minimize the risk to supporting personnel if the system is attacked. Subject matter experts in areas such as nuclear, biological and chemical warfare, ballistics, electronic warfare, directed energy, laser

hardening, medical treatment, physiology, human factors, and Information Operations can add additional issues.

- **Minimize Injury.** Analysts should seek to minimize: 1) combat, enemy weapon-caused injuries; 2) the combat-damaged systems potential sources and types of injury to both its crew and supported troops as it is used and maintained in the field; 3) the system's ability to prevent further injury to the fighter after being attacked; and 4) the system's ability to support treatment and evacuation of injured personnel. Combat-caused injuries or other possible injuries are addressed in this portion of personnel survivability, along with the different perspectives on potential mechanisms for reducing damage. Evacuation capability and personal equipment needs (e.g. uniform straps to pull a crew member through a small evacuation port are addressed here.
- **Minimize Physical and Mental Fatigue.** Analysts should seek to minimize injuries that can be directly traced to physical or mental fatigue. These types of injuries can be traced to complex or repetitive tasks, physically taxing operations, sleep deprivation, or high stress environments.
- **Survive Extreme Environments.** This component addresses issues that will arise once the warfighter evacuates or is forced from a combat-affected system such as an aircraft or watercraft and must immediately survive extreme conditions encountered in the sea or air until rescued or an improved situation on land is reached. Dependent upon requirements, this may also include some extreme environmental conditions found on land, but generally this component is for sea and air where the need is immediate for special consideration to maintain an individual's life. Survival issues for downed pilots behind enemy lines should be considered here.

The program manager should summarize plans for survivability in the Life-Cycle Sustainment Plan and address survivability risks and plans for risk mitigation. If the system or program has been designated by Director, Operational Test & Evaluation, for live fire test and evaluation (LFT&E) oversight, the program manager should integrate T&E to address crew survivability issues into the LFT&E program to support the Secretary of Defense LFT&E Report to Congress (10 USC 2366). The program manager should address special equipment or gear needed to sustain crew operations in the operational environment.

6.3.7. Habitability

6.3.7.1. Habitability Overview

Habitability factors are those living and working conditions that are necessary to sustain the morale, safety, health, and comfort of the user population. They directly contribute to personnel effectiveness and mission accomplishment, and often preclude recruitment and retention problems. Examples include: lighting, space, ventilation, and sanitation; noise and temperature control (i.e., heating and air conditioning); religious, medical, and food services availability; and berthing, bathing, and personal hygiene.

Habitability consists of those characteristics of systems, facilities (temporary and permanent), and services necessary to satisfy personnel needs. Habitability factors are those living and working conditions that result in levels of personnel morale, safety, health, and comfort adequate to sustain maximum personnel effectiveness, support mission performance, and avoid personnel retention problems.

6.3.7.2. Habitability Parameters/Requirements

Habitability is one of several important factors included in the overall consideration of unit mission readiness. Per DoD Instruction 5000.02 , the program manager shall work with habitability representatives to establish requirements for the physical environment (e.g., adequate light, space, ventilation, and sanitation, and temperature and noise control) and, if appropriate, requirements for personal services (e.g., religious, medical, and mess) and living conditions (e.g., berthing and personal hygiene) if the habitability factors have a direct impact on meeting or sustaining performance requirements, sustaining mission effectiveness, or that have such an adverse impact on quality of life or morale that recruitment or retention rates could be degraded. Examples include requirements for heating and air-conditioning, noise filters, lavatories, showers, dry-cleaning and laundry.

While a system, facility, and/or service should not be designed solely around optimum habitability factors, habitability factors cannot be systematically traded-off in support of other readiness elements without eventually degrading mission performance.

6.3.7.3. Habitability Planning

The program manager should address habitability planning in the Life-Cycle Sustainment Plan and identify habitability issues that could impact personnel morale, safety health, or comfort or degrade personnel performance, unit readiness, or result in recruitment or retention problems .

6.4. Human Systems Integration (HSI) throughout the System Life Cycle

6.4.1. Research and Development (R&D), Studies, and Analyses in Support of Human Systems Integration (HSI)

6.4.2. Human Systems Integration (HSI) in the Capabilities Documents

6.4.2.1. Refining Required Capabilities

6.4.3. Engineering and Manufacturing Development Phase

6.4.3.1. Solicitations and Source Selection

6.4.3.2. Systems Engineering

6.4.3.2.1. System Design

6.4. Human Systems Integration (HSI) throughout the System Life Cycle

6.4.1. Research and Development (R&D), Studies, and Analyses in Support of Human Systems Integration (HSI)

Continuous application of human-centered research data, methods, and tools will ensure maximum operational and training effectiveness of the system. Continual analysis of system functionality provides data to help determine the best allocation of tasks to personnel, hardware, or software. Results guide human workload predictions, man-machine interface requirements, and procedural, software, and hardware innovations needed to ensure that the human element can fulfill and enhance total system performance. Each military department conducts human centered research. The products of this research form the basis for creating and maintaining military standards, design criteria, methodologies, tools, and data bases used when applying HSI to defense systems acquisition. Within each military department, HSI practitioners support ongoing concepts and studies that identify potential HSI impacts on operational effectiveness and resource needs of alternative solutions. Examples of these activities include field assessments, human performance modeling, simulations, and technology demonstrations.

It is equally important that this research work be rolled into the front end analyses that lead to capability requirements. HSI considerations should be carefully examined during the capabilities-based assessment, and the planning for and execution of the Analyses of Alternatives. Failure to examine the human-centric issues up front may unduly complicate integration in a defined materiel solution.

6.4.2. Human Systems Integration (HSI) in the Capabilities Documents

The Initial Capabilities Document may seek to establish a new capability, improve an existing capability, or exploit an opportunity to reduce costs or enhance performance. The Initial Capabilities Document describes the key boundary conditions and operational environments that impact how the system is employed to satisfy the mission need. Key boundary conditions include critical manpower, personnel, training, environment, safety, occupational health, human factors, habitability, and survivability factors that have a major impact on system performance and life-cycle costs. The Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, or Facilities considerations and implications section of the Initial Capabilities Document should discuss all relevant domains of HSI .

HSI capabilities in the Capability Development Document should be specified in measurable, testable, performance-based language that is specific to the system and mission performance. Analyses and results conducted to determine the HSI requirements should be identified in and governed by other programmatic documentation (e.g., HSI plan, Systems Engineering Plan , Training Systems plan, or Manpower Estimate).

6.4.2.1. Refining Required Capabilities

As plans for the system mature, the capabilities documents should become more specific and reflect the integration of program objectives. The program manager should work with Human Systems Integration (HSI) practitioners and user representatives to translate HSI thresholds and objectives in the capabilities documents into quantifiable and measurable system requirements. The program manager should refine and integrate operational and design requirements so they result in the proper balance between performance and cost, and keep programs affordable. Additionally, system requirements should serve as the basis for developing engineering specifications, and should be reflected in the statement of work, contracts, Test and Evaluation Master Plan , and other program documentation. Over the course of the acquisition process, as trade-offs are made and plans for the system design mature, the capabilities documents should be updated to reflect a more refined and integrated set of parameters.

6.4.3. Engineering and Manufacturing Development Phase

The purpose of the Engineering and Manufacturing Development phase is to develop a system or an increment of capability; reduce integration and manufacturing risk (technology risk reduction occurs during Technology Development); ensure operational supportability with particular attention to reducing the logistic footprint; implement Human Systems Integration; design for producibility; ensure affordability and protection of critical program information by implementing appropriate techniques such as anti-tamper; and demonstrate system integration, interoperability, safety and utility.

6.4.3.1. Solicitations and Source Selection

Human Systems Integration considerations should be clearly defined and given proper weight in solicitations and proposal evaluation guidelines provided to the government evaluation team. The record of contractors in Human Systems Integration should be an element of bid selection and contract performance criteria.

6.4.3.2. Systems Engineering

Once parameters are established in the Initial Capabilities Document and Capability Development Document , Requirements Definition Package or Capability Drop, it is the program manager's responsibility to ensure that they are addressed during the systems engineering process , included in the Human Systems Integration (HSI) Plan and the Systems Engineering Plan (SEP) , and properly considered during cost/performance trade-off analyses. Consistent with paragraph E1.1.29 of DoD Directive 5000.01 , the program manager applies HSI to optimize total system performance, operational effectiveness, suitability, survivability, safety, and affordability.

Program managers should consider supportability, life-cycle costs, performance, and schedule comparable in making program decisions. Each program is required to have a comprehensive plan for HSI. It is important that this plan be included in the SEP or as a stand-alone HSI Plan as the program(s) may require. As required by DoD Instruction 5000.02, the program manager should take steps (e.g., contract deliverables and Government/contractor Integrated Product Teams) to ensure human factors engineering /cognitive engineering is employed during systems engineering. These steps should occur from the Materiel Solution Analysis phase through the life of the program to provide for effective human-machine interfaces, meet HSI requirements, and (as appropriate) support a system-of-systems acquisition approach. The program manager should also ensure that HSI requirements are included in performance specifications and test criteria. Manpower, Personnel, and Training functional representatives, as user representatives, participate in the systems engineering process to help produce the proper balance between system performance and cost and to ensure that requirements remain at affordable levels. Manpower, personnel, training, and supportability analyses should be conducted as an integral part of the systems engineering process throughout the acquisition life cycle, beginning with Materiel Solution Analysis and continuing throughout program development.

6.4.3.2.1. System Design

Human Systems Integration (HSI) plays a major role in the design process. Front-end analysis methods, such as those described in MIL-HDBK-46855A , should be pursued to maximize the effectiveness of the new system. Initial emphasis should be placed on "lessons learned" from legacy, predecessor or comparable systems to help identify and eliminate characteristics in the new system that require excessive cognitive, physical, or sensory skills or high aptitudes; involve complex fault location or workload intensive tasks; necessitate excessive training; require proficiency training; or result in frequent or critical errors or safety/health hazards. Placing an emphasis on the "human-in-the-loop" ensures that systems are designed to operate consistent with human performance capabilities and limitations, meet system functional requirements, and fulfill mission goals with the least possible demands on manpower, personnel, and training. Moreover, sound HSI applications can minimize added costs that result when systems have to be modified after they are fielded in order to correct performance and safety issues.

6.4.3.2.2. Allocations

During systems engineering , analyses should be performed iteratively to define successively lower functional and performance requirements, to identify functional interfaces, and to allocate functions to components of the system (e.g., hardware, software, and human). Tasks should be allocated to the human component consistent with human attributes (i.e., capabilities and limitations) of the user population as established in the Target Audience Description. Requirements analysis should be conducted iteratively in conjunction with logical analysis to develop and refine system level performance requirements, identify external interfaces, and provide traceability among user requirements and design requirements. Human-systems interfaces should be identified as an outgrowth of the functional allocation process. Another product of the systems engineering process is a list of job tasks with performance/confidence levels. This information is used to further refine manpower, personnel and training requirements.

6.4.3.2.3. Specifications and Standards

It is primarily the responsibility of the program manager, with the assistance of the Integrated Product Teams, to establish performance specifications, design criteria standards, interface standards, and data specifications in the solicitation and resulting contract. Strong consideration should be given to establishing standards when uniform configuration is necessary for ease of operation, safety, or training purposes. For instance, a control panel or avionics suite may need to be standardized to enhance the ability of the user to access information and to respond quickly in an emergency situation. Standard features preclude the need to teach multiple (or conflicting) responses to similar tasks. Standardization is particularly important when a standard performance is required for safety reasons. For instance, rapid ejection from the cockpit should require standard procedures and tasks. If there are unique health hazard or survivability requirements, such as vibration or shock tolerances, extended temperature range, or noise levels, standardization may be the most efficient way to ensure that the system meets those special requirements. Preference should be given to specifications and standards developed under the Defense Standardization Program. Regulatory occupational exposure standards create performance thresholds. However, use of guidance exposure criteria and ergonomic/Human Systems Integration guidelines should be considered to ensure personnel protection, promote efficiency, and anticipate more stringent standards that are likely to be required during the life cycle of the system.

Performance standards for operators, maintainers, both individual and team, are derived from the performance requirements of the total system. For example, human performance requirements (e.g., completion times or success rates) presumes that in order for the total system to achieve specified performance levels, the human will have to complete tasks or achieve performance objectives within specified confidence levels (usually expressed in terms of per cent of actions completed within a specified time-frame and/or error limit). The training/instructional system should be developed to ensure that operators can meet or exceed the personnel performance levels required to operate/maintain the systems. Additionally, manpower should be determined based on these same performance requirements. Operational tests should also be based on the same criteria.

6.4.4. Production and Deployment

The objective of this phase of the acquisition process is to achieve an operational capability that satisfies mission needs. Operational test and evaluation determines the effectiveness and suitability of the system.

6.4.5. Operations and Support (O&S)

The objective of this phase is the execution of a support program that meets operational support performance requirements and sustains the system in the most cost-effective manner over its life cycle. As required by DoD Directive 5000.01, planning for O&S should begin as early as possible in the acquisition process. Efforts during the O&S phase should be directed towards ensuring that the program meets and has the resources to sustain the threshold values of all support performance requirements. Once the system is fielded or deployed, a follow-on operational testing program, to assess performance, quality, compatibility, and interoperability, and identify deficiencies, should be conducted, as appropriate. Post fielding verification of the manpower, and information resulting from training exercises, readiness reports, and audits can also be used to assess the operational capability of the system. During fielding, deployment, and throughout operational support, the need for modifications to the system should be assessed.

6.5. Manpower Estimates

Manpower Estimate s address manpower affordability in terms of military end strength (including force structure and student end strength) and civilian work years beginning at Milestone B. Additionally, the use of contractor work years support should also be documented, where possible. Consistent with DoD Directive 5000.01 , DoD Components should plan programs based on realistic projections of the dollars and manpower likely to be available in future years. When major manpower increases are required to support the program, or major manpower shortfalls exist, they will be identified as risks in the Manpower Estimate, and addressed in the risk assessment section of the Acquisition Strategy . Program risks that result from manpower shortfalls should be addressed in terms of their impact on readiness, operational availability, or reduced combat capability.

6.6. Additional References

6.6.1. DoD Publications

The following DoD Directives and Instructions provide policy and direction:

- DoD Directive 1100.4 , "Guidance for Manpower Programs"
- DoD Directive 1322.18 , "Military Training"
- DoD Instruction 1100.22 , "Guidance for Determining Workforce Mix"
- DoD Instruction 1322.2 6 , " Development, Management, and Delivery of Distributed Learning"
- Training Transformation Implementation Plan
- CJCS Instruction 3170.01 , "Joint Capabilities Integration and Development System"
- The JCIDS Manual , "Operation of the Joint Capabilities Integration and Development System"
- Joint Military Dictionary (JP 1-02) , "Department of Defense Dictionary of Military and Associated Terms"
- AR 602-2 , "Manpower and Personnel Integration (MANPRINT) in the Systems Acquisition Process"

6.6.2. Discretionary Practices

The following military standards (MIL-STD), DoD Handbooks (DOD-HDBK), and Military handbooks (MIL-HDBK) can be used to support Human Systems Integration analysis:

- MIL-STD-882D , "Standard Practice for System Safety"
- MIL-STD-1472 , "DoD Design Criteria Standard: Human Engineering"
- MIL-STD-46855A , "DoD Standard Practice, Human Engineering Requirements for Military Systems, Equipment, and Facilities"
- DOD-HDBK-743 , "Anthropometry of U. S. Military Personnel"
- MIL-HDBK-759 , "Human Engineering Design Guidelines"
- MIL-PRF-29612 , "Performance Specification, Training Data Products"
- "A Guide for Early Embedded Training Decisions," U.S. Army Research Institute for the Behavioral and Social Sciences Research Product 96-06