CHAPTER 3

Human Systems Integration Roles in a Systems Acquisition Culture

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3.1 INTRODUCTION

What is a *system acquisition culture?* How does one recognize the system acquisition culture in which a program is operating? What effects do the acquisition cultural differences have upon a program, especially upon the human systems integration (HSI) element of the program? The degree to which answers to these questions are known and accommodated may determine the success of the acquisition program itself.

A system acquisition cannot be viewed as an isolated activity without interaction with its cultural environment or without the resultant ramifications of these interactions on the system being acquired. Nor can the role of the HSI specialist be assessed out of context with the complex environment of system acquisition. The impact of several dominant cultural influences must be considered as interacting with the systems acquisition process into which HSI must be immersed. The role of HSI is determined by these cultural influences. To approach the role of the HSI engineer without consideration of the cultural environment increases the difficulty in applying HSI best practices and in resolving the risks to the system's successful development and implementation. Consequently, this chapter focuses on the HSI practitioner's roles in the system acquisition process in light of the system acquisition culture within which they must work.

3.1.1 Acquisition Culture Defined

Culture has been defined sociologically as "the sum total of ways of living built up by a group of human beings, which is transmitted from one generation to another" (Barnhart and Stein, 1963 p. 327). Applied within the context of the acquisition environment, "culture" implies that there is a pattern in the "way of living" or some communicated and repeated way of conducting acquisition related business from one acquisition workforce generation

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to the next. *Culture pattern* similarly has been defined as "a group of interrelated cultural traits of some continuity" (Barnhart and Stein, 1963 p. 327). *Culture trait* may be referred to as "any fact in human activity acquired in social life and transmitted by communication." Recognizing an absence of precision in the definition, *acquisition culture* refers to the continuity and pattern of activities that reflect a habitual way of doing system acquisition business. The acquisition culture referred to here involves the buyers, sellers, and users of systems. The examples cited here are taken mainly from experience derived from the public sector where various agencies of the federal government are the buyers. The sellers are normally private companies (vendors) that engage in contracts with the government to provide the systems. However, the "sellers" during the development phase of acquisition may also be other government agencies, federally funded research and development centers, and other organizations that may act in the acquisition process in much the same manner as traditional system vendors. The buyers are normally government employees who act as agents for the user. Preferably users are "end users" of systems and equipment but may also be other participating individuals intermediate to the buyer and end user.

Each of these actors in the process has his or her own culture that often has cross-cultural ties. While it may be argued that there is a culture within a buyer's and seller's community that sets them apart from each other, the segments within each community have their own culture. As an example, let us assume that the U.S. Department of the Army is in the process of procuring a new aircraft. The culture within the U.S. Army's set of actors is certainly different from that of the culture within the aircraft vendor's community. However, the army program management staff may have more in common with the vendor's program management staff than with the army aviator in the field. Similarly, the vendor's program management staff may have a greater cultural tie to their army counterparts than to the technical design staff. The HSI practitioners on both sides of the army–vendor cultural divide are constantly called upon to jump the cultural gap and perform as advocates for the needs of the army aviators (the end user) in the field during the acquisition process. To deal with each cultural enclave successfully means that the culture must be identified and understood in terms of its patterns and traits.

3.1.2 Players in the Acquisition Culture

There are a number of players in the acquisition arena with which the HSI practitioner must deal. Each of these players has an influence on the role that HSI plays in the process of acquiring and fielding a system. One of the unique characteristics of the HSI practitioners is that they must straddle a number of different cultures and be comfortable speaking the language of the players in each. The primary player in this realm is the manager of the program that the practitioner supports. The HSI practitioner is normally a supporting member of the cast and often is admitted to the stage reluctantly.

The focus of program management is cost and schedule, with technical performance also a factor. Program management is a continual exercise in conflict resolution and resource allocation. Human systems integration is seen as a means to reduce the risk that cost, schedule, or performance goals are not met. Generally, program managers are "satisfiers," not optimizers. That is, their battle cry is "good enough is good enough." If the system minimally satisfies requirements and meets the cost and schedule goals, even though the system could experience substantial enhancement with a small additional expenditure, it is deemed successful. This success is narrowly defined through interpretations of the requirements documents and operational objectives that are specified in various documents and acquisition milestone directives. There is continual pressure from the operational community to expand the scope of the acquisition and enhance system capabilities.

The role of the HSI practitioner is often to understand the user's functional needs and the operational environment as a method to communicate the human performance component of system performance. The practitioner helps the program management staff realize what program risks might be encountered if the user community takes exception to various characteristics of the system. This role must be carefully orchestrated and performed in conjunction with the formal user representatives that are one of the primary stakeholders on the program manager's team. The practitioner must anticipate human performance issues for the system, define an HSI program to identify and control risk, and verify that the level of risk is acceptable to program management.

The operator and maintainer have their own culture that often clashes with that of program management. A prime directive for the HSI practitioner is to "Know Thy User," which includes the need for sensitivity to the user's culture. There is tremendous variability in these cultures that have an impact on the acceptability of any given system. Military air traffic controllers have a vastly different culture from their counterparts in the Federal Aviation Administration (FAA) who are represented by a union, even though the task demands and operational environment may be similar. This difference may result in the acquisition of a system that functionally meets a narrowly interpreted set of requirements that is acceptable to one user culture and not to the other.

Meister (1997) refers to the gap between HSI practitioners and researchers. Many HSI practitioners have been schooled in the fundamentals of experimental psychology and must deal with psychologists that perform research that the practitioner must alternatively direct, access, interpret, and apply to the system of interest at the moment. The practitioner must be able to influence research efforts so that the results can be transferred to the operational environment through its application in the design of the system. Researchers by their nature are academically oriented and focus on the process of defining a concept for investigation, proposing an investigative mechanism, controlling the experimental environment, and reporting the results. Much of the focus is on the experimental design and publishing a paper in the open literature. Success is often defined by the acceptance of the paper for publication in a refereed journal. The actual experimental result is of secondary importance. For the practitioner, the experimental results help to form what Meister (1997) refers to as "'workplace' knowledge." This is the grist for the HSI mill.

For the most part, researchers are reluctant to deal directly with engineers. Engineers demand quick, unequivocal answers to questions and want quantitative design input that can be directly applied to the design or its specification. Most engineering disciplines are used to dealing with objects that exhibit little variance and function in a predictable manner given a specified environment. If the environment changes, few measurements are needed to quantify the behavior of the object in the new environment. Engineers are generally intolerant of answers to design questions that contain the phrase "it depends." The HSI practitioner must quickly learn that the design of the system will proceed in most cases either with or without the influence of the benefits of the HSI program. The engineering staff is responsible for assuring the technical performance in the acquisition process, and the HSI practitioner must bridge the gaps between research results, user needs and demands, cost and schedule constraints, and his or her own sense of responsibility to all the parties that have a stake in the outcome. All these issues must be captured and communicated not only within the program manager's staff but also to the system vendor that ultimately must offer a product that meets the user's needs and helps to achieve the performance goals of the organization.

3.1.3 Influence of Culture

Just what are the ways that the acquisition culture affects HSI in an acquisition program? It is not within the scope of this chapter to explore the ways in which culture is developed, shaped, and transmitted from one system acquisition generation to the next. One merely needs to acknowledge that acquisition cultural influences do become established. We do know that experience, such as that from past acquisitions, shapes attitudes in ways that establish and develop patterns of doing business (see Fig. 3.1). These patterns create or influence tendencies or biases toward certain approaches which, when analyzed and properly understood, may predict trends for future acquisitions. It is important to recognize that knowledge about the acquisition culture can help not only to determine how a workforce may conduct an acquisition but also to modify the approach selected. Where there are HSI risks associated with certain patterns or trends in the acquisition culture, mitigating strategies can be employed to lessen the risks of these cultural traits.

3.2 COMMON CULTURAL INFLUENCES

What are the dominant cultural influences that interact with the human engineering process in an acquisition program? The key cultural influences that must be considered to determine their impact include the general business approach of the agency, the research and development culture, the influence of operational settings, and the strategic and tactical political environment. Each will be discussed.

3.2.1 Business Environment

For HSI, the cultural impact of the business environment is determined by the difference in responsibilities between the buyer and the seller. The purchaser has three responsibilities: (1) to define system/product requirements, (2) to conduct acquisition program support

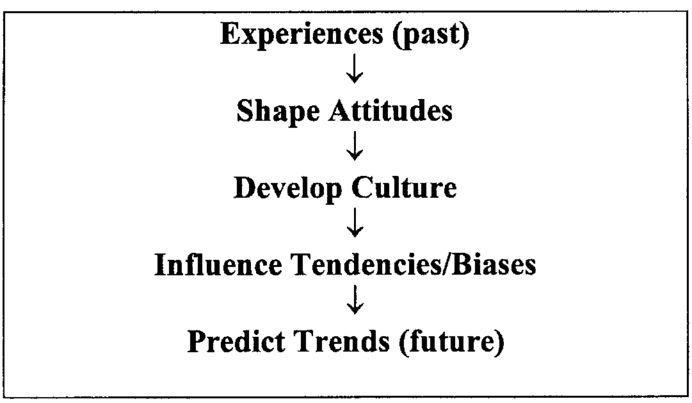

Figure 3.1 Process of cultural development.

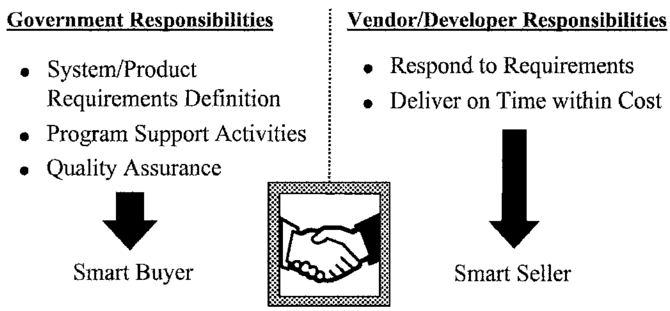

Figure 3.2 HSI business cultural environment.

activities, and (3) to assure quality. From the vendor's viewpoint, there may be many competing influences upon the approach to be taken, but the basic responsibilities are to respond to the requirements and deliver on time and within cost. As for all components of the intended purchase, the HSI roles and responsibilities of the purchaser and developer/vendor reflect the relationships between being a "smart buyer" and a "smart seller." For the HSI component of the purchase, the central issue is how good the buyer and seller are at meeting HSI objectives in system acquisitions (see Fig. 3.2).

It is insufficient in the acquisition environment simply to have HSI expertise available to the acquisition community. The HSI practitioner must be prepared to address both the means needed to accomplish the HSI effort and the ends (resulting products and services) of the HSI endeavors. Many other "means" are essential to facilitate the required culture. That is, the management support, policies, processes, tools, and training must be in place to provide the supportive atmosphere for HSI to succeed. Figure 3.3 depicts some of the major elements of the HSI business measures that assist in the evaluation of the culture. Each of these measures contributes to the culture of the HSI environment. For example, if the vendor's acquisition workforce has HSI expertise that has positively influenced the design and development of past acquisitions, then the strategy of the buyer (and the roles of the HSI practitioner) differ significantly from that in which the vendor's ability or willingness to address human performance considerations is questionable. That is, in the

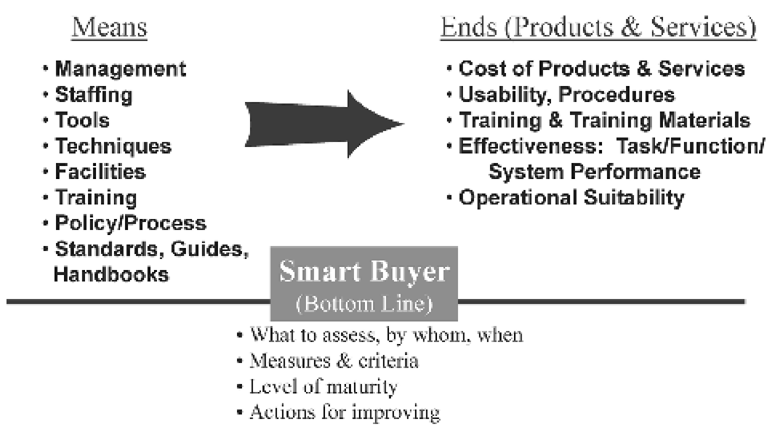

Figure 3.3 HSI business measures.

first instance the purchasers' HSI participation in activities such as the design of user interface may be more limited (e.g., by emphasizing the role of quality assurance during test and evaluation). The HSI practitioner and the program management leadership must be responsive to the implications of the measures of business culture in general and the HSI culture specifically.

3.2.2 Research and Development Environment

A second key cultural influence that must be considered is the research and development (R&D) environment. In all effective system acquisitions, the purchase is made in an environment in which required HSI information is generated or otherwise acquired and then applied to the specific system (Wickens et al., 1997). The process by which this HSI information is acquired is usually referred to as "research" while the HSI activities are referred to as "application."

Research Process Description Different organizations have various ways to describe the type of *research* (e.g., basic, applied). In all cases, there is both general (or *core*) research conducted to understand the fundamentals of the users' operational environment and targeted (or *specific*) research to understand how the fundamentals of operation are affected in certain systems, conditions, or applications. Regardless of the amount of or relationship between the core and specific research, the HSI practitioner's role will be affected by the infrastructure of the research program. For example, where research programs are well funded, expertly directed, and well coordinated with operational needs, the HSI participation is likely to be more influential on requirements definition and less dependent upon design, evaluation, and validation.

Application Process Description Different organizations have various ways to describe the process, phases, or stages of *application* as well. In cases where the application process is mature, the information acquired is applied through a systematic process that includes requirements definition; proposed solutions; and evaluation, validation, and implementation. In the FAA, for example, the acquired information is applied through different processes for system acquisitions, air traffic services and operations, and regulation and certification functions (see Fig. 3.4). Whether these phases and processes are well defined or not, conducted intensely or not, specifically named or not, they are nevertheless sequentially (and often iteratively) implicated in all applications. The degree to which they are defined and institutionalized in the application imposes an influence upon the role of the HSI practitioner. For example, for applications during which a market analysis (conducted during the proposal of solutions) fully analyzes the human component, the HSI role will likely be better defined, funded, and integrated in the subsequent design and development.

Relationship between Research and Application Within the R&D patterns that have been established, the relationship between the research component and the applications component of an acquisition also affects the HSI role and activities. There is a natural tendency for the cultures of research and application to differ. Research activities foster behaviors that are based upon "learning" mental models of the work environment. Assumptions related to this mental model tend to rely on outcomes that are dynamic, include many interdependencies, contain indirect influences, show continuing effects over

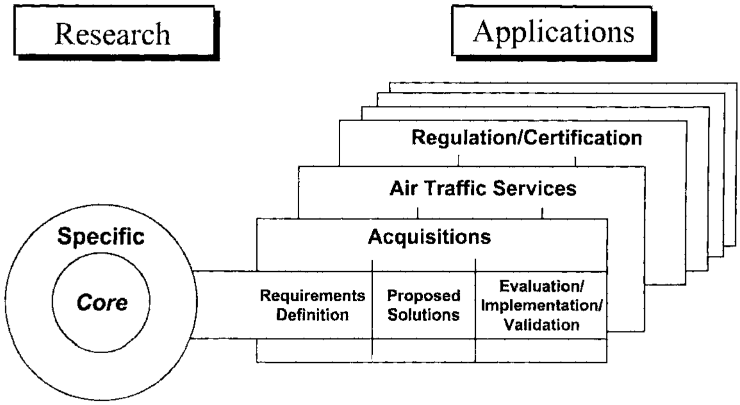

Figure 3.4 HSI research and application cultural environment.

time, and view the human component less mechanically. Application activities motivate behaviors that are based more on "problem solving" mental models. Assumptions related to this mental model rely on outcomes that are decomposed into subproblems, focus on fixing a problem or achieving a goal, search for a root cause, and use mechanistic and physical metaphors for analysis. Table 3.1 provides a list of attributes related to each of these mental models (Carroll and Perin, 1995).

Acquisitions that bridge the gap between the differing mental models and find good connectivity between the research element of the agency and the application elements greatly reduce the risks associated with human performance in complex systems. Contrarily, cultures that fail to foster the direct linkage between research programs and application efforts likely will grow an agency research program that is disconnected with systems being acquired and fielded. Such a research effort will reinvent the required research (at a greater cost, with fewer options) during later phases of the application.

TABLE 3.1 Attributes of Research and Applications Mental Models

Research: Learning Mental Model	Applications: Problem-Solving Model
Nonlinear	Linear
Integration	Decomposition
Dynamic	Cause–effect
Divergent	Convergent
Organic	Mechanistic
Human	Technological
Error expected	Error avoiding
Learning	Fixing
Relationships	Checklist audits
Understanding	Root cause
Collaboration	Specialties

Source: Adapted from Carroll and Perin (1995).

Linkages between Research and Application The HSI linkage between applications and research can take two forms. In one case, the operational community can specify needs that must be met or capabilities that are lacking. The articulation of these needs then provides the spark for the research effort that endeavors to provide the technology or nonmateriel solutions to the specified problem in response to operational demands. An alternative approach is for research to push operational capabilities by offering novel solutions to operational problems or providing operational capabilities that were previously not identified or articulated by the user community. Either approach can provide benefits and the HSI practitioner must be prepared to deal with providing a linkage between the research and acquisition communities in either mode. In the operational demand mode, the user community has already encountered or envisioned a shortcoming and often needs the solution in hand in the short term. The articulation of the need is often stated in the context of current procedures and technology that is deemed insufficient for a new environment, newly discovered threat, or new requirements for system throughput stated in terms of system capacity or safety. This leads to applied research that struggles to understand and define the criteria for success and the ultimate requirements for desired performance levels.

Many acquisition models specify that the acquisition cycle begins with a mission analysis that leads to subsequent activities, including the generation of a statement of operational requirements. These acquisition models often specify that the front-end documentation should specify the problem and not a solution. The models often state that both research and application activities should stem from mission needs. The challenge in this process is that the HSI practitioner is called upon to perform a portion of the mission analysis and must deal with an operational community that has learned to be pragmatic as a matter of training and daily survival. This pragmatism leads these constituents to be solution oriented, which can result in shortsighted requirements documents that are essentially shopping lists based on claims or demonstrations on the part of system vendors. Stating the HSI elements of mission needs and operational requirements is often difficult and requires an intense level of cooperation and communication to develop a visionary statement that directs research or development efforts. The HSI community is well served by the use of traditional mission and function analyses as well as human performance modeling. Such efforts often require the HSI practitioner to structure the analyses while the operational community provides the subject matter. The result can be a joint venture where each part of the community invests its own capital in the form of time and expertise to yield an analytical product. If the product is credible, the sense of ownership on the part of all the participants provides the motivation to form a team and sell the argument to organizational management for funding and development. By serving as a core element in the team, the HSI practitioner can be maximally effective.

In the cases where R&D efforts offer technology to push operational capabilities, the challenges for the HSI discipline are greater. Such offerings tend to be attractive to the management community since it potentially represents an opportunity to reduce risk and provide a system to the field with a shorter development cycle by sending the system to a field site to demonstrate the technology and get user buy-in. Once the user agrees that this technology is needed, the mission analysis and requirements documents reflect a need that can only be satisfied by this technology, and the focus shifts to delivery of technology rather than on the functional needs of the operational community. This leads to dissatisfaction during the test phase when a new group of users is exposed to the system and determines that the mission cannot be performed with the new system.

The role of HSI in a technology-push environment is to participate in the mission analysis and requirements definition process to assure that the critical needs of the user are articulated and the human interface risks associated with adopting the technology are defined. If additional investigations or other HSI activities are needed during the acquisition to assure that the mission needs are met, they must be identified at this point. Research programs that migrate to the acquisition cycle tend to focus on production versions of the research prototype with the assumption that if the system "worked" as a research product in a demonstration setting, it is good enough.

3.2.3 Operational Environment

Another cultural influence is the operational environment. That is, the culture of the operational environment will also bring a set of boundaries that will impact the role of the HSI effort. The considerations reflected in the HSI role by the operational environment include the operational mission approach, operational philosophy, and program operational emphasis. For example, consider the difference for the role of human safety in a business operation versus that of an aviation operation. Similarly, an operational philosophy such as "automation will be used extensively" has a different influence on the HSI role if one is considering the human on the deck of an aircraft carrier versus the human role in the control of the flight of missiles. Also, an acquisition that emphasizes the reduction of military staffing levels and manpower costs—such as a new naval warfare ship—will not present the same HSI role as one that emphasizes technological changes—such as the global positioning system application (Hughes and Dornheim, 1995).

As an illustration within the FAA, consider the operational environment of air traffic services (ATS) and airway facilities (AF) maintenance operations. Within ATS, there is a centralized emphasis on avoiding operational errors. Notwithstanding the importance of personnel safety within AF, decentralized operational effectiveness of the maintenance support function is the essential ingredient. The culture of these operational environments will become reflected in the strategies and approach to the development of procedures, training, system design, staffing guidelines, and other HSI roles within the acquisition programs. In another example, consider the appreciable differences in the HSI practitioner's role for the design and development of a small airport tower versus the design and development of a large, metropolitan tower where the complexities of the crew coordination, communications, interfacing procedures, program integration, and redundancy are paramount.

The operational environment can also levy an influence in terms of levels of technical sophistication in the workforce and the legacy systems with which the workforce must deal. While there is a significant movement in modern society to adopt new technology to resolve problems and advance productivity, not all workplaces can tolerate large changes in the technology base. Some workforces may be represented by powerful unions that will resist the rapid introduction of certain types of technology if it is perceived as a threat. The change may also be perceived by management as a threat if the proposed changes will entail risk to profits or revenue in the short term. This was a hallmark of the railroad industry in the 1970s. There were significant HSI and human factors challenges associated with enhancing safety and increasing the productivity of the rail system. Some of the enhancements were possible by combining advances in railcar braking systems and sensor systems associated with track-train dynamics to achieve enhanced levels of operator performance on long-haul freight trains. The legacy of the large amounts of rolling stock with 1950s-era braking systems coupled with resistance to change from both management and the labor force stymied the efforts of government agencies to apply the products of rail transportation research, including HSI and human factors efforts. The introduction of graphical displays to the locomotive cab at that time was met with skepticism. Thirty years later, the widespread use of computers in the workplace has eventually met with some degree of acceptance, as in the locomotive cab, although they still display the status of the same 1950s type of braking systems.

3.2.4 Political, Management, and Organizational

The last key cultural influence that affects the HSI role is the culture of the political, management, and organizational environment. Consider, for example, the implications upon the HSI acquisition functions that are set in an environment in which the workforce is unionized (such as for the FAA's air traffic control systems) versus one that is not [such as U.S. Department of Defense (DoD) weapon systems]. Consider one that is government (where political influence and oversight are direct) versus one that is nongovernment (such as the automobile industry, where market forces dominate). The context of these organizational forces materially affects the design and implementation of HSI endeavors (Wickens et al., 1998).

3.2.5 Impact of the Cultural Environment

Elements of the HSI role that are affected by the cultural environments include such parameters as the HSI management concept, organizational design, and practitioners' authority. For example, should the HSI effort be managed centrally by an HSI specialized office or should the effort be managed by a decentralized effort closest to the program or product? The answer to that question needs to be found within the cultural context of the business, R&D, operational, and political or organizational environment of the acquisition. One of the fundamental issues related to the management and execution of HSI support concerns the organizational structure of HSI professionals. Are they to be centralized and parceled out to engineering teams as the needs become evident? Or are they to be acquired by and for disparate system engineering applications without regard to centralization of the HSI engineering discipline? When making decisions on these topics, it is important to determine the degree to which domain expertise is needed on the programs. HSI practitioners tend to gain expertise in a particular area and often in specific subareas such as the "oceanic" domain of air traffic control, and the degree to which this expertise transfers to other domains varies. Working with subject matter experts and field personnel tends to be easier if their jargon and tasks are already known. Their confidence in HSI input, judgment, and assessments is heightened if the practitioner is already considered knowledgeable in the domain. Building this expertise and trust takes time that may not always be available. Closely tied to this issue is that of providing continuity among the HSI staff. Maintaining appropriate expertise may be especially difficult for projects that involve long-term studies, the application of domain-specific principles over a period of time, or an acquisition strategy that uses an iterative approach to building the system.

Other factors in defining and conducting the HSI role that are affected by the cultural environments include those in Table 3.2.

TABLE 3.2 HSI Functions and Attributes Affected by Cultural Environment

- *Management and execution concept:* centralized or decentralized HSI management and execution
- *Flexibility:* standardized support or tailored to organization being supported
- *Location:* separate or collocated with teams being supported
- *Organization:* matrixed support or structured under product leader
- *Responsibilities:* consultant/advisor or fully accountable for HSI portions of all program products
- *Authority:* provides suggestions and recommendations or has signature/approval for all HSI in plans, studies, analyses, documentation, reviews, reports, and tests
- *Coordination:* isolated program support component or representative to coordination and integration groups
- *Performance assessment:* independent in determination of performance or jointly appraised in conjunction with other program performance evaluations

3.3 HISTORICAL PERSPECTIVE OF CULTURE

A second perspective for cultural influences upon the HSI role is the traditional or historical role played by HSI practitioners and human factors engineers. It can be easily argued that the origins of human factors engineering have their antecedents in the fundamentals of twentieth-century management thought conceptualized by Henri Fayol in 1916 (Mittler et al., 1990). However, the practice of HSI has only recently seen widespread maturity in its application—and even now that maturity is sporadic. The history of HSI is certainly not long, and the description of the roles of the HSI practitioner continues to evolve. For example, in relation to software development activities for the computer–human interface, the software engineer and HSI practitioner increasingly communicate and work closely together in the process of rapidly developing prototypes. Notwithstanding the short history and dynamic nature of the HSI role, the influence of this historical and still emerging HSI role can be divided into three major categories: (a) the context of the HSI role in system acquisitions, (b) HSI roles in direct support of system acquisition activities, and (c) HSI managerial and oversight roles and responsibilities.

3.3.1 Context of HSI Roles in System Acquisition

The historical role of the HSI practitioner has been established and refined over the past two to four decades and is outlined here as an introduction. First it should be understood that the interfaces associated with the HSI role are many and varied. For example, historically the role of HSI and human factors engineering in the participation of equipment design activities is well documented in the literature of system engineering disciplines. This role is similar and complementary to the traditional role of the ergonomics engineer in which the issues related to knobs and dials, controls and displays, and fit and function are addressed. (A list of the common HSI issues is given in Table 3.3.)

The role of the HSI participant in the design and development of equipment (hardware and software) has also been extended to include other system development interfaces, that is, those interfaces related to safety and health, management and organization, cognition, or cooperation. For example, HSI participation in the system development process should entail consideration of the organizational interfaces. These interfaces go beyond the analysis of tasks and job functions by including the job design (i.e., how the functions

TABLE 3.3 HSI Issues Common to Acquisition Programs

- *Workload:* operator and maintainer task performance and workload
- *Cognitive decision making:* requirements for operator and maintainer tasks and decisions and related performance measures
- *Training:* minimized need for operator and maintainer training
- *Functional design:* equipment design for simplicity, consistency with desired human–system interface functions, and compatibility with expected operation and maintenance concepts
- *Computer–human interface:* standardization of computer–human interface to address common functions and employ similar user dialogues, interfaces, and procedures
- *Staffing:* accommodation of constraints and opportunities on staffing levels and organizational structures
- *Safety and health:* prevention of operator and maintainer exposure to safety and health hazards
- *Special skills and tools:* considerations to minimize the need for special or unique operator or maintainer skills, abilities, tools, or characteristics
- *Work space:* adequacy of workspace for personnel, their tools and equipment, and sufficient space for movements and actions they perform during operational and maintenance tasks under normal, adverse, and emergency conditions
- *Displays and controls:* design and arrangement of displays and controls that are consistent with operator's and maintainer's natural sequence of operational actions
- *Information requirements:* availability of information needed by operator and maintainer for a specific task when it is needed and in appropriate sequence
- *Display presentation:* ability of labels, symbols, colors, terms, acronyms, abbreviations, formats, and data fields to be consistent across display sets so that they enhance operator and maintainer performance
- *Visual/aural alerts:* design of visual and auditory alerts (including error messages) to invoke necessary operator and maintainer response
- *I/O devices:* capability of input and output devices and methods for performing task quickly and accurately, especially critical tasks
- *Communications:* system design considerations to enhance required user communications and teamwork
- *Procedures:* design of operation and maintenance procedures for simplicity and consistency with desired human–system interface functions
- *Anthropometrics and biomechanics:* system design accommodation of personnel (e.g., from 5th through 95th percentile levels of human physical characteristics) represented in user population
- *Documentation:* preparation of user documentation and technical manuals (including any electronic HELP functions) in a suitable format of information presentation, at appropriate reading level, and with required degree of technical sophistication and clarity
- *Environment:* accommodation of environmental factors (including extremes) to which user will be subjected and their effects on human–system performance

are performed), the management structure related to the job (i.e., how the job fits within the surrounding jobs and functions), and the organizational structure (i.e., how the job fits within the structure of other jobs, supervisors, and organizational relationships). Table 3.4 provides a list and brief description of the interfaces that have become elements of the HSI practitioners' role. Also provided are the performance dimensions and objectives that relate to the context of the enumerated human interface classes. These eight interfaces may be regarded as an integral part of the "total" system of equipment design and develop, but they are often and easily overlooked if not explicitly identified. It is this context of the HSI

TABLE 3.4 HSI Interfaces in Sytems Acquisition

Human Interface Class	Performance Dimension	Performance Objective
1. *Functional interfaces:* for operations and maintenance, role of human vs. automation; functions and tasks; manning levels; skills and training	Task performance	Ability to perform tasks within time and accuracy constraints
2. *Information interfaces:* information media, electronic or hard copy, information characteristics, and information itself	Information handling/ processing performance	Ability to identify, obtain, integrate, understand, interpret, apply, and disseminate information
3. *Environmental interfaces:* Physical, psychological, and tactical environments	Performance under environmental stress	Ability to perform under adverse environmental stress, including heat/cold, vibration, special clothing, illumination, reduced visibility, weather, constrained time, and psychological stress
4. *Operational interfaces:* procedures, job aids, embedded or organic training, and on-line help	Sustained performance	Ability to maintain performance over time
5. *Organizational interfaces:* job design, policies, lines of authority, management structure, organizational infrastructure	Job performance	Ability to perform jobs, tasks, and functions within management and organizational structure
6. *Cooperational interfaces:* communications, interpersonal relations, team performance	Team performance	Ability to collectively achieve mission objectives
7. *Cognitive interfaces:* cognitive aspects of human–computer interfaces (HCI), situational awareness, decision making, information integration, short-term memory	Cognitive performance	Ability to perform cognitive operations, e.g., problem solving, decision making, information integration, situational awareness
8. *Physical interfaces:* physical aspects of system with which human interacts, e.g., HCI, controls and displays, workstations, and facilities	Operations and maintenance performance	Ability to perform operations and maintenance at workstations, work sites, and facilities using controls, displays, equipment, tools, manuals, etc.

Source: Adapted from Federal Aviation Administration and Carlow International Incorporated.

role and the culture of the HSI and system acquisition effort that determines the extent to which these elements are adequately addressed.

3.3.2 HSI Roles in Direct Support of System Acquisition Activities

The roles of the HSI practitioner are as diverse as the applications they support. These roles and tasks begin early in the program with participation in mission analysis and requirements determination processes that may only serve to identify the major impacts and constraints of the human element upon the new capability being acquired. For example, early HSI activities may be initiated to limit the manpower and staffing requirements of predecessor systems, limit time-consuming and costly training requirements, simplify complex procedures that induce errors and increase task performance times, or all three. The HSI role continues through the verification of test and evaluation programs into the design of monitoring functions and data collection plans that serve to evaluate the degree to which human–system objectives are continuing to be met after system deployment and implementation (i.e., during the in-service management phase of a system). Note that the role of the HSI practitioner may change drastically if the vendor chosen for an acquisition has little or no HSI capability. In some cases, the vendor may reject the buyer's efforts to generate an HSI program that is integral to the design effort. The buyer's HSI practitioner must then determine a strategy that will reduce risk for the program and achieve the objectives without HSI support in the vendor's organization. While each organization may define their acquisition phases differently, Table 3.5 provides a list of the common major HSI roles in direct support of system acquisition activities.

TABLE 3.5 Major HSI Roles in Systems Acquisition Activities

HSI will perform, direct, or assist in conducting the following activities:

- Mission analysis and requirements determination (human impacts, constraints)
- Human–system interface considerations in market surveys/investigations/trade studies
- Generation and update of HSI plans
- HSI input to solicitation package preparation
- Identification and analysis of critical tasks performed by operators and maintainers
- Generation, refinement, and analysis of operational scenarios, human–system modeling, and human in loop simulations
- Development, demonstration, and evaluation of human–computer interface design requirements, prototypes, design, and development efforts
- Review/analysis of human engineering documentation
- Coordination of HSI working group activities
- Conduct of task performance analyses and coordination with training and logistics
- Conduct and coordination of safety and health hazard analyses
- HSI concepts, analyses, and assessments of engineering change proposals (ECPs) and design reviews
- HSI input to test and evaluation (T&E) plans, measures, criteria, and data collection efforts
- Design and evaluation of monitoring and data collection plans for postdeployment human–system performance

3.3.3 HSI Management and Oversight

The roles and responsibilities of the HSI practitioner are defined, in part, by the degree to which the HSI management and oversight responsibilities have been institutionalized (i.e., the "culture" of HSI management). Detailed descriptions of supervision and management of acquisition programs are covered in texts related to acquisition program management and general system engineering. However, four key areas of HSI management responsibility and authority determine the HSI acquisition culture: (a) policy, process, and procedures; (b) organization and infrastructure; (c) tools and training; and (d) integration activities.

Policy, Process, and Procedures The culture surrounding the HSI effort will affect and be affected by the promulgation of policy, the definition of processes, and the practice of procedures related to HSI planning and implementation. That is, in agencies that publish and enforce strong HSI policies, the acquisition culture will be significantly more conducive to identifying and resolving HSI issues than those agencies without such policies. Those organizations that establish and exercise definitive HSI processes have proven to be more successful in the mitigation and resolution of human performance problems than those organizations without such processes. Similarly, in those agencies where the practice of HSI has become institutionalized, repeatable, and common, systems find better and cheaper solutions to HSI considerations. Policies, processes, and procedures that should be developed and institutionalized include those related to

- the importance and objectives of HSI;
- methods to coordinate HSI research with HSI engineering;
- the definition, scope, and role of HSI in the acquisition process;
- the process of conducting HSI activities and its relationship to other engineering disciplines and activities;
- documentation requirements related to the HSI activities; and
- mechanisms for the evaluation of HSI programs across the agency.

Organization and Infrastructure Those charged with some responsibility for the HSI research and engineering functions within an organization should give significant consideration to the organization and staffing of the HSI organizational infrastructure. No element of the HSI program is more important than the number, qualifications, and organizational relationships of the HSI professionals supporting the acquisition efforts. No other indicator is more evident of the culture surrounding the HSI environment. If the status of the HSI personnel and organization reflects a weak investment, it is a probable indication of serious deficiencies in the HSI program at all levels of management and implementation. Establishing the HSI organizational infrastructure should be among the highest priorities for those intending to support HSI within the acquisition community.

Tools and Training Many organizations attempt to develop some of their own HSI tools and training. Having the right set of tools and training readily accessible to the acquisition workforce will result in significant benefits to the acquisition program. However, precious HSI professional expertise can be wasted in the development of tools and training attempting to create capabilities that may already be available. It is necessary to evaluate where, how, and what kind of HSI capabilities should be acquired—whether purchased from outside the organization or grown from within.

Integration Activities An adequate HSI culture is one that is able to promote the planning and execution of the appropriate engineering activities. Such a culture necessitates that the development of policy, process, and procedures; organization and infrastructure; and tools and training becomes integral to the acquisition process itself (Wickens et al., 1997). It may be obvious that development of this infrastructure and culture entails a considerable amount and continuity of effort. A list of HSI managerial and oversight roles and responsibilities is provided in Table 3.6.

Sampling the HSI Culture The culture of the HSI environment will contribute to the definition of the management and oversight HSI responsibilities. The identification of some sample HSI responsibilities may serve to describe this HSI role more fully. Typical tasks assigned to an office with HSI responsibilities that should be considered within the cultural context of the acquisition environment include those in Table 3.7. This provides a list of typical tasks affiliated with the HSI management and oversight role.

3.3.4 Caution: Culture of Computer–Human Interface

More than a small number of HSI programs have suffered from the deleterious effects of failing to define the proper scope to the HSI effort. With the proliferation of management information systems and the predominance of software costs associated with the human–

TABLE 3.6 HSI Managerial and Oversight Roles and Responsibilities

Typical roles and responsibilities of a centralized HSI office include the following:

- Identifying an HSI point of contact for interaction with system product team/integrated product team (IPT)
- Providing guidelines for preparation of HSI plans and development and execution of HSI program
- Participating as member of human system integration working groups (HSIWGs)
- Coordinating and monitoring effectiveness of HSI processes and procedures
- Identifying and/or establishing standards and monitoring their application across IPT/product teams
- Advising IPT HSI coordinator of HSI risks and concerns associated with integration of systems across domains and recommending course(s) of action for their resolution
- Identifying and coordinating HSI and related research needed to address issues that cross products and/or cross IPTs that interact with domain
- Participating in technical interchange meetings with program/product HSI coordinators
- Reviewing acquisition and program-related documentation for proper inclusion of HSI considerations
- Providing HSI inputs to statements of work (SOWs), system specifications, and data item requirements, monitoring contractor activities, and reviewing contractor deliverables
- Providing information and participating in source selection activities, acquisition reviews, resource council briefings, and any other related program reviews
- Monitoring technological advances, marketplace trends, and relevant HSI research and analyses and sharing findings with HSIWG

TABLE 3.7 HSI Management Tasks (Example)

The HSI management and oversight tasks include the following:

- Identifying an HSI coordinator who serves as the focal point for coordinating all HSI activities among other organizational HSI elements and with other integrated product team (IPT) HSI representatives
- Preparing and executing IPT HSI plans that are compatible with organizational acquisition management system policy and guidance
- Identifying product HSI representatives responsible for integrating HSI considerations throughout product development
- Resolving human performance issues that occur during prototype development and testing
- Coordinating with HSI representatives to ensure HSI considerations within and across products are adequately addressed
- Establishing HSI coordinating groups that include HSI representatives from product teams and specialists from HSI areas of concern to serve as technical resources
- Establishing and monitoring effectiveness of HSI processes and procedures
- Establishing means for HSI representative to advise IPT of risks and concerns and recommending course(s) of action for their resolution
- Identifying HSI research needed to address issues common to product teams or that cross IPT boundaries and coordinating those research needs with other organizational elements
- Conducting periodic technical interchange meetings with HSI representatives to present and discuss HSI concerns and methods for mitigating them and to consider trade-offs among HSI technical areas for improving system performance or reducing cost
- Ensuring HSI considerations are addressed in all acquisition and program-related documentation [e.g., requirements documents, cost–benefit analyses, statements of work (SOWs), test plans]
- Ensuring HSI considerations are thoroughly addressed in transition plans for new systems and functions being integrated into environment
- Ensuring that HSI specialists actively monitor activities of prime contractors and subcontractors in all HSI technical areas as specified in SOWs, system specifications, and standards
- Providing HSI information for and participating in source selection activities, acquisition system and program reviews, resource council briefings, and any other related program reviews
- Monitoring technological advances and marketplace trends relevant to products and sharing pertinent findings with other HSI representatives

system interface, the importance of computer–human interface (CHI) or other similar terms such as human–computer interface (HCI) or man–machine interface (MMI) has been widely acknowledged. The interpretation of these various terms is often confused with the full scope of a proper HSI effort. That is, too often the HSI effort is confined to the important but limited considerations of screen design. The acquisition cultures that relegate HSI to this diminutive form are likely to flaw the program seriously.

The mundane and elementary factors associated with screen design can mask more serious concerns that center on the basic functions that can be performed by the system and the capabilities that the system operator can exercise in the performance of the mission or task. In many cases the functions and capabilities are centered on the technology and interests of the designers that coincidentally have an overlap with the needs of the user to perform the required task. A problem, for example, arises when the excess capability that is not needed requires maintenance and lies dormant in a system that is also deficient of needed capabilities. This creates a system mismatched to the user's needs. The unmet needs are often cited as "CHI" problems that then require extensive rework in the basic structure and mechanisms of the system. The "CHI" problems are really traceable to poorly articulated requirements or the inability of the designer to understand the details of the stated requirements and the operational needs. The HSI practitioner may in some cases unwittingly reinforce the concept that CHI relates to screen design by justifying the need for an HSI program that is primarily based on checklists, color guidelines, CHI principles, and CHI style guides. The design and management members of the team then see this as the main thrust of HSI and relegate the activities to the latter stages of development since these attributes can be easily reconfigured in most software intensive systems. Techniques, such as a heavy use of checklists, force a bottom-up approach to HSI where a more holistic approach may better serve the user and garner more support on the part of the acquisition team.

The scope of the HSI program and role of the HSI practitioner must be recognized for the macroergonomic as well as the microergonomic requirements. Table 3.8 provides a sampling of the differences between these two critical roles. For example, in addition to screen design, it is important to understand (and design) the cognitive requirements (e.g., memory requirements, calculations) associated with the screen's presentation of information. Also, while it is important to address the design of knobs and dials for the system, it is equally important to design the mapping of these controls to fit with the operators' and maintainers' tasks. In another example, the task performance of the individual user is paramount to good system design. No less important are the considerations of how these tasks fit into the design of crew performance considerations. In fact, well-designed crew resource management programs usually identify crew tasks or the sharing of tasks among individuals that may go unheeded in programs that solely or sequentially focus on the task of an individual.

3.4 CHANGING ACQUISITION CULTURE

Without regard to any particular effort to modify the general cultural environment within the acquisition community, there have been inescapable forces working to change it. Specific changes that have occurred over the past 10 years within the acquisition culture include (a) the increased intensity of HSI, (b) the elevated stature of usability, (c) the predominance of cognitive factors, (d) social and legal concerns for special accommodations, and (e) growing cross-cultural issues of interface design.

TABLE 3.8 Microergonomic Versus Macroergonomic Dimensions of HSI: Examples of Range of HSI input

Microergonomic	Macroergonomic
Screen design	Cognitive requirements
Knobs and dials	Control/display-to-task mapping
Individual skills	Population attributes
Procedures	Job design and integration
Workload	Staffing and organizational design
Individual performance	Crew/team performance
Product usability	System usability
Training regimen	Skill acquisition and decay

3.4.1 Intensity of HSI

No systems have been devised to operate without a human–system interface. Despite the consistency in the need for HSI support, the nature (intensity) of this interface has changed markedly, especially within the last two decades. Increasingly, more and more devices in the marketplace project an interface that personally and continuously interacts with the user. For example, an increasing number of household appliances contain information systems that provide feedback or instructions to the user and require input or response from the user. As miniaturization continues to create opportunities to embed tiny processors in the workplace equipment and personal possessions, an increasing number of applications contain a human–computer component. As the power of the embedded processors grows, so do the role and complexity of the HCI component. Because systems can be designed to be more responsive to their users (even individually tailored in their response), new systems find an increase in the authority and leverage of the user's interaction with the system. Naturally, this improvement in user authority reenforces one's expectations of systems to be responsive to unique and specialized use, which has resulted in an even greater proportion of the system's software being devoted to the human interface (Nielson, 1993). Thus, the density and intensity of the HSI component of systems necessitate a new (modern) cultural view of systems and their interface with the user. This new view involves one in which the HSI participant has a much larger share of the system's risk assessment, engineering, and budget.

3.4.2 Emphasis on Usability

Usability, in some respects, has become the modern buzzword and synonym for the proliferation of user–interface vernacular. Many authors have found "usability" to be an uncharged substitute for terminology that implies a cultural, organizational, or gender bias (e.g., ergonomics, MMI, CHI). Notwithstanding the natural utility of the term, its use has become more common simply because of increased emphasis on systems' usefulness. Contrary to a time not so many years ago when usability was primarily a concern for the user representatives during test and evaluation (as acceptance criteria), current acquisition programs are replete with concerns for system usability from the beginning of the program acquisition. Consideration of usability pervades the program's response to system stakeholders—from end users to senior management. While not every acquisition community has translated this growing emphasis on usability into a viable HSI organization or program, the increased emphasis does help to create a culture where HSI has a greater opportunity to flourish.

3.4.3 Predominance of Cognitive Factors in Design

Another new and growing impact upon the cultural environment of the acquisition community is the change from physical to cognitive attributes of the HSI effort in design and development. Still slow to receive the full acknowledgment of some members of the acquisition community, the design of systems involves a larger and larger contribution from the tasks related to the user's mental requirements. While the movement to cognitive tasks is clearly evident, the change continues with enough subtlety to cause a struggle in gaining full recognition from the acquisition community. Difficult as it may be to find adequate acknowledgment, system HSI design efforts increasingly reflect a predominance of things people must remember, recall, calculate, estimate, evaluate, analyze, interpret, recognize, or otherwise think about.

3.4.4 Special Needs and Accommodation

Human systems integration and its related disciplines (e.g., human factors, safety, CHI) have always been viewed as engineering for the user. Historically, the user has been described as a statistical proportion (e.g., 5th to 95th percentile of the population), a representative sample, or those who display typical operator or maintainer characteristics. Recently, customers of acquisition programs have grown to expect HSI to include previously disenfranchised portions of the population. New tools and user influences have emboldened HSI practitioners to design for all users including those with special needs. Federal law (e.g., Americans with Disabilities Act of 1990 and the Rehabilitation Act of 1973), protective standards (e.g., Uniform Federal Accessibility Standards), and other guidelines (e.g., Occupational Heath and Safety Act) promote expansion of public access requirements and design accommodations to assist those with special needs. Legal issues aside, public relations considerations (i.e., just plain community good will) cause public and private facilities, equipment, and services to meet wider population standards. Indeed, some commercial activities have found new markets in the accommodation of those with special requirements. In many cases, reaching beyond the traditional disabilities population (such as those in wheelchairs), designers have addressed unique access requirements and tailored workspaces to individual needs. As the public tolerance diminishes for designs that exclude even small portions of the population and as market share expands to meet tailored preferences, HSI has responded with tools and methods to incorporate these needs early in the requirements and development processes.

3.4.5 Cross-Cultural Issues of User–Interface Design

A major influence on the role of the HSI engineer and a determinant of the culture of the acquisition environment is the degree of sensitivity to cross-cultural considerations. There is no doubt that the expanded market to the international arena has imposed new design considerations upon the creators of equipment and systems. No longer can the manufacturing community ignore the economic opportunities inherent in appealing to distant populations. These populations contain cultural differences that must be considered at the earliest stages of development. Simplistically, for example, it is unlikely that American-made toys such as dolls or bicycles will meet with equal enthusiasm in Asia or Africa when made with only Americans in mind. Similarly, even the appearances and anthropomorphic elements of our new systems demand attention to cultural differences.

The well-recognized globalization of the marketplace brings with it a globalization of the user that goes beyond differences in size and shape. When the design and development community (including the HSI representatives) define the operator, past assumptions about the uniformity of the users' characteristics are no longer true. An aviation accident in which a commercial aircraft flew into a mountainside (an accident categorized as controlled flight into terrain, or CFIT) provides a salient example. In this accident, it has been implied that the Chinese pilot may not have understood the blaring aural alert directing the pilot to react. A recorded voice communication from one of the pilots to the other has been interpreted as "What does 'PULL UP' mean?" Some of these cultural differences are more subtle.

In another aviation example, the impact of culture has pervaded the philosophy of automation in the world's two largest commercial aircraft companies. It is well documented that Boeing and Airbus represent their cultural views very differently (Hughes and Dornheim, 1995). Where Boeing gives the pilot more degrees of flying freedom, Airbus designs tend to put automated boundaries around the pilot's safe-flying envelope. Pilots must be trained to react very differently for these two environments. Designers and especially HSI practitioners must consider the effects of variations in the technology, availability and impact of design tools, learning modalities, language, and management information methods among different cultures. Accommodating a global economy, the international markets, and intercultural communities of the user will continue to play a major role in HSI considerations.

3.5 TRENDS FOR THE FUTURE OF HSI

Changes and trends within the acquisition culture and HSI culture itself portend new HSI roles and relationships. The culture of HSI is responding to and must continue to respond to changes in (a) the relationship between hardware and software, (2) the use of off-the-shelf products, (3) the availability of HSI tools and technologies, (4) the dependence upon HSI compliance, and (5) approaches to program documentation. For a summary of these cultural trends, see Table 3.9.

3.5.1 Hardware/Software

Prior to the accelerated pace of the developments in the age of information (i.e., at least prior to the last decade or two), the acquisition community and HSI representatives focused upon the new hardware being procured. As operational platforms have become more expensive and opportunistic in capturing the advantages of increased information, software enhancements have become dominant. That is, the ratio of acquisition devoted to

TABLE 3.9 Changes in HSI Trends

Historical	Future
1. Hardware orientation on form and fit	1. Software orientation with increased importance of procedures, cognitive tasks, and training
2. Dependence upon communication to design engineer	2. Greater dependence upon NDI/COTS solutions to human–systems performance requirements
3. Limits of technology to integrate	3. Increased rapid prototyping, modeling, simulation with human-in-the-loop
4. Long lead time and iterative design approach	4. Shorter acquisition time for consideration of human resources, human performance requirements
5. Use of design guides and standards to assure level of quality	5. Decreased use of compliance standards and specifications
6. Larger documentation requirement	6. Less dependence upon documentation

the mechanical and hardware portion is decreasing relative to the software component. Not only are hardware systems embedding more software-intensive systems, but the number and size of the information management systems are increasing as well. Similarly, a greater percentage of the software development is devoted to the HCI component. In one study of several systems, Nielson found that 48% of the software was concerned with HCI, making it one of the most costly items of the product (Nielson, 1993).

As the software and HCI component become larger and more pervasive and intense in systems, the tendency and opportunity to make changes increase. The flexibility of system software promotes an acquisition environment in which systems may be (or at least appear to be) developed and revised more rapidly. This rapid development and software-intensive acquisition culture prescribes a role for the HSI representative that occurs earlier in the acquisition phases and is more intense.

Also, the larger share of software considerations (relative to hardware) implies a greater risk in the maintenance tasks as well as the operational functions. Software systems present more difficulty in the diagnostic capabilities and impose special considerations upon the HSI role for the design of maintenance operations, staffing, procedures, training, and the like. Responses from the HSI community will need to resolve demands for new technical skills in the HSI workforce, new methods and procedures to influence software HCI designs earlier, and new techniques and training to assist in this effort.

3.5.2 Development/Off the Shelf

The expense of long-term development programs and the need for faster acquisitions in order to meet the quick pace of changing technology have accentuated the seduction of buying off the shelf. This tendency to select acquisition strategies for nondevelopmental items (NDIs) or commercial-off-the-shelf (COTS) items changes the nature of the requirements by substituting the vendor's market demands for the purity and uniqueness of the users' needs and desires. While much can be said for the acquisition trend to follow the market, the lack of full control over the design and development modifies the risks of the program as well as the resultant role of the HSI practitioner. For example, instead of participating in each stage of the engineering design, the HSI representative assists in evaluating the vendors' alternatives for the human performance component. Changes in the acquisition "culture" may be realized relative to the HSI tools necessary to support NDI and COTS acquisitions, the HSI policies that acquisitions follow (e.g., the HSI role in source selection), and the processes and training of the acquisition workforce.

With respect to the user and maintainer interface with a system, the difference between COTS and NDI can be substantial. Program management is often tempted to dismiss the need for HSI support if the system is a COTS acquisition. The rationale is that the interface is "standard" and the marketplace has driven the vendors to produce a usable design. In the case of widely used products such as personal computer hardware, word processing software, or personal telecommunications equipment, this is sometimes a good rationale. However, most acquisitions for major systems that are to be used to perform essential missions for government agencies are actually NDI acquisitions using off-the-shelf modules and a customized human interface tailored to the functions contained in the system. These are unique systems that have not had the benefit of market scrutiny and feedback in the area of the human interface. These procurements run the risk of buying what the vendor wishes to sell without regard for user needs or the impact on human-in-the-loop system performance. Just as the engineering staff presses for such concepts as "open architecture" in a COTS/NDI procurement to avoid the pitfalls of proprietary components that create interface problems, the HSI staff needs to press for a "human–system architecture" that supports the user in the performance of various tasks and missions.

3.5.3 HSI Tool Technology

Harnessing the power of technology within the acquisition community has recently led to a new arsenal of tools available to the acquisition community, including the HSI elements. Despite the considerable efforts in past years to develop tools and techniques to support HSI, many of these endeavors provided only limited new capabilities. While the concepts for HSI tools have been sound, the limited computing power, high cost, or dependence upon huge databases often diminished their ability to influence timely acquisition decisions. As technology has enhanced processing power, increased the availability of data, and decreased cost, new opportunities have emerged for a proliferation of tools and technologies.

Powerful applications related to design alternatives (such as rapid prototyping techniques) are giving developers options and testers opportunities for evaluations well in advance of past acquisitions. New capabilities are providing the buyer methods to include visual specifications as government-furnished information, thereby decreasing the risk of poor interface designs. These capabilities are especially important to the HSI practitioner in the acquisition cases where there is little confidence in the ability of the vendor to provide a well-designed human interface for the emerging system.

New techniques (both high fidelity and low) are becoming easier to use and more widely distributed among HSI laboratories. Techniques that were labor intensive and lengthy are becoming more easily manipulated and able to be rerun repeatedly with revised parameters.

These new developments of HSI tools and techniques suggest that the future may lead to greater compatibility of tools across HSI domains (e.g., those devoted to workload and staffing, skill assessment and training, or error management) or even integration among various tools. These tools can potentially reduce program risk and have a positive impact on program budget and schedule by reducing the probability that the HSI aspects of the system will not achieve system objectives. The acquisition culture should be prepared for a future where HSI tools are more available, useful, readily taught to acquisition professionals, and integrated with acquisition processes.

3.5.4 Compliance

Decreased dependence upon government (or even commercial) standards and increased use of functional and performance specifications (replacing detailed specifications) are forcing acquisition programs and their assessments to be less compliance oriented. That is, acquisitions are moving away from reliance on design standards (e.g., military standards such as MIL-STD-1472) toward greater use of commercial standards, nonmandatory guidelines, or no standards at all. At the same time, design and program reviews, analysis, and test and evaluation are reverting from an approach that reviewed hundreds or thousands of specific items to one that assesses system performance. While not all acquisitions have met this new challenge, functional disciplines (especially the efforts related to HSI) are becoming less encumbered by "mind-numbing" tables of compliance requirements. Current trends show that the development of statements of work (SOWs) and associated system requirements are eliminating costly and sometimes misleading laundry lists of compliance requirements. The result of this trend for the HSI culture is to create greater dependence upon developing meaningful human performance specifications, monitoring programs more intensely to assure functional specifications are adequate, and collecting comprehensive performance data to provide exit criteria for operations and maintenance system interface. These exit criteria are to be reflected in the test and evaluation plans to determine if the system meets its HSI-related objectives. Changes in the nature of the HSI effort are evident in an earlier and stronger focus on performance data requirements and in the evolution of human–system performance evaluations.

3.5.5 Documentation

There are those who would argue that HSI professionals should not be overly bothered with preparing reports of engineering studies and analysis because no one reads them. No doubt, there is some truth in the statement because most acquisition programs rely on expeditious decisions once the research work is done. However, the value of documenting the HSI objectives, risks, strategies, plans, analyses, research and engineering studies, guidelines, and standards is well proven over time. Yet the trend in acquisitions is for less dependence upon the great volumes of information. These trends imply greater use of oral reports, shortened time frames for decision, and a shift from volumes of specifications to thin guidance and iterative rapid prototypes. Similarly, in many instances, acquisitions are switching from hard-copy to electronic formats. The HSI community must respond to this environment with an equal aptness to be less dependent upon voluminous, costly, and time-consuming documentation, while keeping in mind the undeniable need for written documentation throughout the acquisition program.

3.6 HSI CULTURAL MYTHS VERSUS REALITIES

The cultural biases about HSI that abound in the acquisition community have not served the HSI discipline or acquisition programs well. In order to dispel some of the injurious myths related to the conduct of HSI activities, 13 HSI program attributes and the related myths and realities are identified below and summarized in Table 3.10. In item 1, for example, unenlightened acquisition program participants contend that because we are human, identifying the HSI risks and constructing mitigation strategies and solutions can be done by anyone. This argument has led more than one program down the path of high risk until operational demonstrations or tests have illuminated serious user performance problems.

1. *HSI Expertise* HSI requires professional expertise. Acquisition experience has repeatedly demonstrated that HSI problems are only obvious in retrospect. Identifying and anticipating HSI issues and devising mitigation strategies and engineering solutions require the professional expertise of the HSI practitioner.

2. *HSI Research and Engineering Cost* Some argue that HSI is free or can be acquired at relatively little cost. There are those who suggest that because the process of applying and integrating human engineering is either negligible or very low in cost (compared to other budget items), budgets are not affected and budget planning is not

TABLE 3.10 HSI Cultural Myths and Realities

HSI Attribute	Cultural Bias (Myth)	HSI Cultural Objectivity (Reality)
1. HSI expertise	Since we are all human, anyone can do HSI.	Identifying HSI issues and devising mitigation strategies and engineering solutions require the professional expertise of the HSI practitioner.
2. HSI research and engineering cost	HSI is free. There are seldom any significant costs to conducting HSI.	HSI is almost never free. However, to become a sustained and institutionalized activity at the individual project level, applying HSI must appear relatively inexpensive and be easy to obtain.
3. HSI definition and scope	HSI success equals user acceptance.	User acceptance without rigorous performance criteria imposes risky criteria of user preferences.
4. HSI research	HSI can be accomplished via quick and easy methods.	HSI research is a critical ingredient in most acquisition programs. But it is important to tailor the HSI effort to the time and resources available. Big benefits can often come from small rigorous studies.
5. HSI requirements	HSI can be added once the requirements are defined.	HSI activities must be integrated at the earliest stages of the program to avoid human–system performance problems.
6. Location of HSI practitioners	HSI professionals may be organized as an adjunct engineering discipline.	HSI people must be collocated with the product teams they serve and integrated as part of the team.
7. Piecemeal participation	HSI should only be conducted as an activity where all the human elements are tied tightly together.	HSI problems are rarely simple enough to resolve all elements of the issue simultaneously.
8. End of development testing	Because HSI tests are qualification and acceptance tests, they should be conducted at the end of the program.	HSI issues should be tested early and often and should contribute to the iteration of design.
9. Use of controlled conditions	HSI facilities should be sterile laboratories where user performance is tightly controlled.	HSI engineering (similar to other engineering disciplines) benefits from the collaboration that occurs when it invites open technical interchange.
10. Use of typical users	HSI studies should employ only the typical user populations to ensure valid results.	Users are important, but including management and other members of the acquisition team in the project may add increased understanding and credibility to the HSI role and function.
11. Compelling HSI evidence	Only rigorous study in a controlled environment provides sufficient documentation for good HSI designs.	Anecdotal information of real problems may provide compelling evidence for the need of an HSI effort.

(*continued*)

TABLE 3.10 (*Continued*)

HSI Attribute	Cultural Bias (Myth)	HSI Cultural Objectivity (Reality)
12. Documenting study results	Like rigorous research, engineering studies and solutions must be followed up with complete documentation.	Results of engineering studies should be kept as short as possible and be integrated directly into guidelines, tables, or standards.
13. Dependence upon upper management support	HSI depends upon upper management support to succeed.	HSI success is at least equally dependent upon the project management leadership and engineering team members who will actually make it happen.

required. In fact, HSI is almost never free but in many instances can be relatively inexpensive (especially compared to the benefits). Human systems integration is rarely without some costs, but the total program costs are greater and almost always decrease the program options when HSI is not done. A viable research and engineering budgeting process should account for the real costs and benefits of conducting HSI. Nevertheless, to become a sustained and institutionalized activity at the individual project level, applying HSI must appear relatively inexpensive and easy to obtain at the program level.

3. *HSI Definition and Scope* Some acquisition program management personnel suggest that HSI success should be equated to user acceptance of the product or system. This is a risky equation. Users provide an essential ingredient in the development and evaluation of HSI solutions. However, user acceptance without rigorous performance criteria relegates the success to the whimsical and risky criteria of user opinion and preferences.

4. *Ease of HSI Application* Some believe that HSI can almost always be accomplished with a quick and easy or "just-in-time" application. In truth, many acquisition programs require HSI studies and activities with tightly controlled and rigorous data collection and analysis. However, because the engineering community cannot tolerate an HSI solution that does not accommodate the realities of the acquisition schedule, prompt solutions are often sought. It is important to be responsive to the program and tailor the HSI effort to the time and resources available. Often, small studies beget big benefits and should not be neglected.

5. *HSI Requirements* Often, HSI has been applied as if it can catch up on the back end of a program or be added once the rest of the team has defined the requirements or solution adequately. In fact, for a successful program, HSI activities must be integrated at the earliest stages of the program. At a minimum, some form of "attention-getting" HSI requirements should be listed at the initiation of requirements. These early requirements add momentum, definition, and value as the program progresses to more mature states of development—usually at great benefit to the identification and mitigation of potential human–system performance problems.

6. *Location of HSI Practitioners* Sometimes HSI professionals are organized in an acquisition program as an adjunct engineering discipline and not fully integrated with the

other mainline engineers. To be effective, HSI people must be colocated with the product teams they serve. Informal questions and quick responses are likely to add value to the program and build HSI credibility. The HSI engineers need to be a part of the team and other team members need to learn to view them that way.

7. *Piecemeal Participation* Human systems integration involves an effort that considers the various complexities of operator and maintainer system interfaces. Because the HSI effort is best described as an integration discipline, some think that it should *only* be conducted as a whole activity in which all the human elements are tied intricately together. In fact, rarely are all the HSI problems simple enough to resolve all elements of the issues simultaneously. Furthermore, significant benefits will often accrue to the HSI program if other members of the engineering team view it as one in which problems are tackled as they emerge. Because projects generally follow an iterative development process, the benefits of working on HSI challenges "piecemeal" far outweigh the risks of solving only part of the problem at a time.

8. *End of Development Testing* Sometimes HSI tests are viewed as qualification and acceptance tests that should be conducted mostly at the end of the program development to avoid unnecessary costs in testing and evaluation. This is an erroneous assumption. No different from other engineering considerations, HSI issues should be tested early and often and should contribute to the iteration of design. Results of these efforts should be regularly reported, identifying the issues and their status.

9. *Use of Controlled Conditions* Because HSI addresses complex and extremely sensitive issues, it is sometimes assumed that HSI facilities should be sterile laboratories where HSI professionals can evaluate user performance in tightly controlled conditions. No doubt, every research program deserves an appropriate amount of control of the conditions. However, HSI engineering does not differ from other engineering disciplines that benefit from the casual collaboration that occurs when facilities are an open and inviting technical interchange among interested and competent participants.

10. *Use of Typical Users* Human systems integration studies must describe and understand all appropriate parameters of the user population. Consequently, it is often believed that these studies should employ *only* the typical user populations during their research, studies, analysis, and tests to ensure valid results. Of course, the user population (operators and maintainers) and their tasks must be properly identified for study. However, some studies do not necessarily require absolute fidelity in the participating population. Also, including management and other members of the acquisition team in the project provides first-hand knowledge of what HSI is and how HSI activities are conducted, thereby adding increased understanding and credibility to the HSI role and function.

11. *Compelling HSI Evidence* Because research of complex HSI issues requires a well-controlled environment, some suggest that *only* rigorous study and analysis will enable collection of the appropriate data for good HSI designs. It is true that carefully controlled experiments have importance in HSI research and in evaluating human performance. However, anecdotal information or short videos of real problems provide compelling evidence for the need of a well-defined and properly funded HSI program. These short vignettes can be powerful accomplices to the development of more comprehensive HSI efforts.

12. *Documenting Study Results* Engineering studies and solutions should be followed up with appropriate documentation to ensure similar programs benefit from past experiences. This documentation can be invaluable in developing guidelines and standards and in

avoiding repetition of earlier problems. Clearly, documenting progress and results is an essential ingredient in a scientific application of HSI. However, seldom are engineering reports read by a wide audience. Reports of engineering studies should be kept as short as possible. The lessons learned should be integrated directly into HSI guidelines, tables, or standards. Except for rigorous research and studies, one should avoid generating as much of the engineering paper trail as possible.

13. *Dependence upon Upper Management Support* Like many other fledgling initiatives, HSI depends upon some upper management support to succeed. The value of an HSI champion in upper management has been documented in several agencies. Despite the value of this support, in many practical applications HSI success is more dependent upon the project management leadership and engineering team members than on upper management. Teaching and demonstrating the value of HSI to the program participants at the middle management level are essential for success. These members of the team will help make it happen.

3.7 ROLES AND RESPONSIBILITIES

The roles of the HSI players for both government and commercial environments may differ significantly depending upon the culture of the organization and environment. However, the prescribed roles, responsibilities, tasks, decisions, and interfaces for HSI practitioners in an acquisition environment that has proven to be healthy for the HSI effort are often quite similar. While specific HSI timelines of decisions, roles, and downstream consequences vary depending upon the size, complexity, sponsorship, mission, cost, schedule, technological reach, and other factors in the system acquisition program, the sequence of the iterative activities is usually quite predictable. The extent to which HSI plays a part in the design decisions is dependent upon the timely accomplishment of the various HSI tasks. The Appendix provides a generic flow of how HSI roles support (and are supported by) the information, organization, and resources of the acquisition environment (U.S. Department of Transportation, 1998).

3.8 SUMMARY AND CONCLUSIONS

The elements that define the acquisition culture include the business approach and processes; research and development methods and structures; mission and operational considerations; and political, management, and organizational environments. The culture in which an acquisition team operates identifies the habitual patterns of how systems are acquired, affects the roles of the HSI practitioner, and influences the way HSI business is conducted. Knowing how to identify and mitigate the cultural aspects that may impose risks to the acquisition program enables the HSI practitioner to overcome some of the obstacles to achieving valued HSI and to bring the acquisition program increased success. Recent changes within the acquisition culture (especially within the HSI discipline) and trends for the future of HSI attest to the growing importance of addressing these acquisition cultural risks and dispelling the traditional HSI cultural myths.

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APPENDIX: HSI ROLES AND RESPONSIBILITIES

Action	Roles/Responsibilities	Program/ Project Sponsor	Program Project Team	HSI Expert	User Representatives
	Activities Supporting All Phases of Acquisition Life Cycle				
Develop (HSI) policy	• HSI representative develops the HSI policy. • Agency lines of business (i.e., program/product sponsoring organizations) and integrated product team/product teams (IPT/PTs) review and comment on policy.	X	X	X	
Develop HSI infrastructure	• Agency lines of business, IPT/PTs, and HSI representative coordinate to identify HSI infrastructure requirements (e.g., staffing, laboratory capabilities, equipment) and develop recommended solutions.	X	X	X	
Plan for budget for HSI activities and to support user involvement in HSI	• Agency lines of business and acquisition teams [e.g., IPT/PTs, mission analysis (MA) teams, concept exploration and investment analysis teams, postdeployment teams] identify funding requirements and confer with HSI representative in developing cost projections to support HSI activities and user involvement.	X	X	X	X
Coordinate and integrate research, engineering, procurement, and operations funded agency HSI activities/projects	• Agency lines of business and IPT/PTs develop integrated funding profiles and plans for programs/projects. • HSI representative develops recommendations for coordinated HSI program and identifies potential duplication and/or disconnects in existing or proposed projects.	X	X	X	

Address cross-cutting HSI issues or HSI issues that exceed team empowerment boundaries	• Acquisition teams (e.g., IPT/PTs, MA teams, concept exploration and investment analysis teams, postdeployment teams) ensure that HSI issues are raised at the acquisition executive level, as appropriate, and for coordinating/consulting with the HSI representative. • HSI representative is responsible for ensuring that mechanisms are in place to identify and resolve known and potential HSI risks.		X	X	
Report on status of HSI	• Acquisition teams (e.g., IPT/PTs, MA teams, concept exploration and investment analysis teams) provide the HSI status on specific acquisition programs (e.g., at acquisition reviews, resource council reviews). • HSI representative prepares and delivers status report on agency HSI to acquisition executives, program management team members, and HSI specialists. • Acquisition executive, agency lines of business, IPT/PTs, and user representatives provide information and feedback.	X	X	X	X
	Activities Supporting Mission Analysis (MA) Phase of Acquisition Life Cycle				
Establish MA teams	• The sponsoring agency line of business establishes and leads the MA team. • MA team leader notifies the agency lines of business, user representatives, and HSI representative that MA team is being established. • Agency lines of business and/or IPT/PTs provide domain-specific HSI expertise.	X	X		
Designate HSI coordinator to support MA team	• Agency line of business coordinates with HSI representative to designate the HSI representative to support the MA team.	X		X	

(*continued*)

TABLE (*Continued*)

Action	Roles/Responsibilities	Program/ Project Sponsor	Program Project Team	HSI Expert	User Representatives
Identify and conduct HSI analyses and data collection to support MA	• Team HSI representative leads planning and provides technical direction or assistance. • An HSI working group (HSIWG) may be established by the team HSI representative to coordinate HSI activities and conduct studies or analyses using a variety of HSI resources.			X	
Identify requirements for users to serve as subject matter experts in HSI analyses	• Team HSI representative identifies the requirements for a valid, representative sample in conjunction with MA team leader and user representatives.				X
Develop and submit requests for user involvement in HSI during MA	• MA team prepares request with support from team HSI representative. • The appropriate agency line of business processes requests.	X			
Develop HSI input for mission needs statement (MNS)	• Team HSI representative in conjunction with HSIWG and other members of the MA team draft HSI input. • MA team responds to questions on MNS HSI issues with support from team HSI representative and other team members.		X	X	X
Prepare final MNS and appropriate briefings and submit to decision authority	• MA team prepares and submits all necessary documents. • MA team leader notifies the HSI specialists and user representatives when MNS decision meetings are scheduled.				X

Establish requirements team to develop requirements document (RD)	• The agency line of business sponsoring the MNS establishes a requirements team. • The leader of the requirements effort notifies user representatives, HSI representative, and IPT/PT that the requirements team has been established.	X		X	X
Activities Supporting Concept Exploration (CE) and Investment Analysis (IA) Phase of Acquisition Life Cycle					
Establish investment analysis (IA) teams	• Office responsible for IA establishes IA team. • IA team leader notifies appropriate agency line of business, IPT/PT, user representatives, and HSI representative that team is being established.	X	X	X	X
Designate HSI coordinator(s) to support IA team and integrated requirements team (IRT)	• CE and IA team leader designates an HSI representative to support the concept exploration and IA team. • Requirements team leader designates an HSI representative to support the requirements team.			X	
Identify and conduct HSI analyses and data collection to support IA and requirements development	• Team HSI representative leads planning and provides technical direction or assistance. • A HSIWG may be established by team HSI representative to coordinate HSI activities and conduct studies and analyses using a variety of HSI resources. • Acquisition teams (e.g., IPT/PT) provide domain-specific HSI expertise.		X	X	
Identify requirements for users to serve as subject matter experts in HSI analyses for IA and requirements development	• Team HSI representative identifies the requirements for a valid, representative sample in conjunction with team leaders and user representatives.				X

(*continued*)

TABLE (*Continued*)

Action	Roles/Responsibilities	Program/ Project Sponsor	Program Project Team	HSI Expert	User Representatives
Develop and submit official requests for user involvement in IA and requirements HSI	• IA team prepares and submits IA user request(s) with support from team HSI representative. • Requirements team prepares and submits user request(s) with support from the team HSI representative. • The appropriate agency line of business processes requests.	X			X
Develop HSI input to IA documentation	• Team HSI representative prepares HSI input for the investment analysis reports (IARs), the acquisition program baselines (APBs), RDs, and other acquisition documentation (e.g., market survey, alternative analyses, investment analysis plans) in conjunction with HSIWG and other members of the IA and requirements teams. • IA and requirements teams respond to questions on HSI issues with support from team HSI representative and other team members. • The IA and requirements teams prepare and submit all necessary final documents including appropriate briefings to decision authority. • CE and IA team HSI representative provides input to APB on HSI resource requirements. • The IA team leader notifies the HSI specialists and user representatives when investment decision meetings are scheduled.		X		X

Activities Supporting Engineering and Development (E&D) Phase of Acquisition Life Cycle

Assign acquisition program to IPT after investment decision	• Decision authority makes IPT assignment.		X		
Notify user representatives and HSI representative of new acquisition program	• IPT/PT leader provides the notifications to these representatives. The tentative schedule for preparation of the acquisition strategy paper (ASP) and integrated program plan (IPP) will be provided to the user representatives.		X	X	X
Assign HSI representative to support IPT/PT	• IPT/PT leader designates an HSI representative.		X		
Identify opportunities for HSI analyses and appropriate HSI data to be considered during the E&D phase	• HSI representative is responsible to lead this action.		X		
Identify and conduct HSI analyses and data collection to support the acquisition program, including operability assessments leading to formal test and evaluation activities	• HSI representative leads this action and provides technical direction or assistance. • Analyses may be conducted by internal agency resources or through contractor support to the IPT/PT. • Team HSI representative coordinates the processing of funding documents outlining HSI support needed.		X	X	
Identify requirements for users to serve as subject matter experts in HSI analyses throughout E&D phase, including operability assessments	• HSI representative works in conjunction with other IPT/PT members to identify the requirements for a valid, representative sample.		X		
Develop and submit requests for user involvement in HSI analyses supporting acquisition program	• The IPT/PT prepares and submits request(s) with support from the HSI representative. • The appropriate agency line of business processes requests for user participation.	X	X		X

(*continued*)

TABLE (*Continued*)

Action	Roles/Responsibilities	Program/ Project Sponsor	Program Project Team	HSI Expert	User Representatives
Develop HSI input for E&D documentation	• HSI representative (in conjunction with other members of the team) prepares the HSI input for E&D documentation, including the ASPs, IPPs, requests for proposal (RFP), information requests, statements of work (SOWs), contract documents, etc. • IPT/PT responds to questions on HSI issues with assistance from the HSI representative. • IPT/PT prepares and submits all necessary final E&D documents to the decision authority.		X		
Develop and execute HSI/human performance plans	• HSI representative (with the appropriate IPT/PT members) develops and executes HSI/human performance plans and data collection for studies, analyses, assessments, test and evaluation, and other activities.		X		
Report on status of HSI	• IPT/PT reports on the HSI status on specific acquisition programs.		X		
	Activities Supporting Post Deployment Phase of Acquisition Life Cycle				
Assign HSI representative to support service or product during postdeployment	• The postdeployment team leader designates an HSI representative.		X	X	
Identify and conduct HSI analyses and data collection to support the program, including postdeployment operability assessments	• Postdeployment team HSI representative leads this action and provides technical direction or assistance. • Actual analyses may be conducted by internal agency resources or through contractor support to the postdeployment team.			X	

Identify data and user requirements for analyses throughout the postdeployment phase	• Team HSI representative works in conjunction with other postdeployment team members to identify the data and user requirements. • The appropriate agency line of business organization prepares and processes user study requests.	X			
Develop and execute HSI/human performance studies, analyses, and data collection plans and activities	• Team HSI representative works with the appropriate postdeployment team members to develop and execute the HSI plans and activities.	X		X	X
Develop HSI input for lessons learned and other postdeployment documentation	• Team HSI representative prepares the HSI input in conjunction with other members of the team. • Postdeployment team coordinates with appropriate user representatives for feedback.	X	X	X	X